Jal Vigyan Sameeksha—a publication of
High Level Technical Committee on Hydrology
Vol. II, No. 1, June 1987

Ground Water Management in Hard Rocks

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Abstract : *Nearly two thirds of the Indian sub-continent is occupied by the hard rocks. These hard rocks have no primary porosity and occurrence and movement of ground water is mainly confined to the weathered mantle, fractures and joints underlying it. Greater portion of the hard rock area comes under the semi-arid region where droughts are a common feature. Management of ground water resources in such a situation, requires a good knowledge of the hydrogeological setting and knowledge of the water bearing capacities of rocks occurring in the area. The paper presents the descriptive aspects of various rock types in relation to occurrence of ground water, potential available and status of development in the four southern states and suggests management strategy required to be adopted for the optimal development of the ground water resource for the socio-economic development of the area.*

1. Introduction

Hard rocks consisting of igneous and metamorphous rocks occupy greater part of the earth's crust. Nearly two thirds of the Indian sub-continent consists of hard rock formations comprising crystalline rocks, granites, gneisses and schists of Archaean Crystalline complex, basaltic formation of Upper Cretaceous to Oligocene period and compact sedimentary formations-Cuddapah, Kurnool, Delhi and Vindhyan systems of Precambrian period. Due to lack of primary porosity in them, the capability of storing and transmitting ground water in them mainly depends on the weathered mantle and the fracture systems developed due to stresses that have prevailed in the crust during the tectonic activity, cooling of the magma, change of temperature and release of load. Many of the fracture systems are related to and controlled by the tectonic structure of the rocks like schistosity, lineation, folding, pinch and swell, developed during plastioelastics flowage under dynamothermal metamorphic conditions. The openings thus developed are known as fissured porosity or secondary porosity. During the long span of geological history, these rocks have been deformed in many ways including deep erosion. Besides, weathering process which is active continously, has either increased or decreased the fissured porosity depending on rock type and climatic conditions. The hard rocks to become an aquifer not only should posses fracture system capable of receiving the infiltered surface water but also the individual fracture should be interconnected to a common hydraulic system. The important fracture system from the ground water point of view are tensile fractures which function as big sub-surface drain pipes, fed by auxillary system of minor ones, resembling a river with tributaries.

The techniques of ground water prospecting and development in hard rocks are of special nature requiring the skill and experience of multi-scientific and engineering disciplines. Hitherto, it was believed that a dug well is the only possible solution for ground water in hard rock. Due to the advancement of technology like remote sensing for search for water and also due to advantage of fast drilling DOWN THE HOLE HAMMER, Air Rotary and Combination rigs during the last two decades, the ground water development activities have gained momentum and established that if proper siting is done scientifically, a borewell is better suited than a shallow dug well in fractured hard rocks as it could maintain sustained yields even during periods of droughts.

2. Hard Rock Hydrogeology of Southern States

The area of Southern Peninsula having an aerial extent of 638,000 sq. km. is underlain by various types of rocks of which 541,895 sq. km. is occupied by hard rocks as detailed in Table 1 :

Geologically Southern India presents a broad spectrum of rock types belonging to various formations ranging in age from Archaean to Recent.

However, the Southern States are predominantly underlian by the Archaean crystalline complex with wide range of rock types of different metamorphic grade.

Granite and gneisses are the most common rock types encountered. Gneissic rocks are banded and wide spread while granites stand out as prominent hills and mounds and are highly jointed. The gneisses are well foliated with the major foliation directions varying from NW–SE to NE–SW and E–W. These have been traversed by basic and acid intrusives.

The Charnockites have been confined mostly to the Eastern Ghats and Western Ghat terrains and adjacent areas. The Khondalites are well foliated with N–S or NNE–SSW trend with steep dips and are intensely weathered

The Dharwarian schists and the associated formations occur as patches and bands within gneissic complex in parts of Karnataka, Tamil Nadu, Kerala and Andhra Pradesh. They are high grade metamorphic rocks with folitation trends ranging from NNW–SSE to N–S with steep dips. The crystalline limestones are seen associated with the Khondalites and sillimanite gneisses in the Eastern and Western Ghats area (Walayar Limestones) and in parts of Karnataka. They are fractured and have developed solution channels.

The Precambrian sediments namely kurnools Kaladgis, Bhimas and Cuddapahs comprising quartzites, sandstones, shales and limestones occur in parts of Andhra Pradesh and Karnataka. Whereas the Cuddapahs show some distortion and displacement, the Bhimas are practically undisturbed and do not posses any large scale solution channels, fractures as seen in Cuddapah limestones. The Badami sandstone is confined to a small area around Badami town in Karnataka.

Table 1 : Distribution of rock types in Southern India

	Andhra Pradesh	Karnataka	Kerala	Tamil Nadu	Pondicherry
Geographical area in sq. km.	276,814	191,773	38,864	130,069	480
Unconsolidated rocks	25,500	3,000	3,672	21,908	480
Semi-consolidated rocks	19,200	—	9,573	12,772	—
Hard rocks	232,114	188,773	25,619	95,389	—

Ground Water in these hard rocks occur in the weathered and fractured zones. Water levels in the wells vary from about 1.5 m to more than 20 m. The annual fluctuation of the water levels varies from about 2 m to 10 m. The exploration carried out by the CGWB has indicated that water bearing fractures occur down to 200 m at favourable locations. The yield of the wells ranges from 0.5 lps to 15 lps. There are instances when borewells have given more than 30 lps. Generally the depth of the open dug wells varies from 10-20 m and occasionally more as could be seen in Combatore area. Though generally the ground water in hard rock aquifers are good, there are problems of high sulphate, high nitrate and high fluoride in certain districts of each State.

3. Recharge

Precipitation is the main source of recharge to the Ground Water. The precipitation is controlled by the physiographic features. Geographically the Southern Peninsula is divided into four distinct physiographic units, namely, the Coastal Plains, Eastern Ghats, Western Ghats and Central Plateau. Between the Western Ghats and the Arabian sea lies a narrow coastal strip, while between Eastern Ghats and the Bay of Bengal there is a broader coastal belt. The area is drained by four major rivers namely, Godavari, Krishna, Pennar and Cauveri. It receives rainfall both from south-west and north-east monsoons. The presence of Western Ghats directly in the path of south-west monsoon has a significant effect on the rainfall distribution over the area. The Western Ghats and the region west of it are humid with heavy rainfall ranging from 1000–3000 mm with highest annual rainfall of more than 8000 mm at Agumbe in Karnataka whereas the area east of it is comparatively dry and semi-arid with rainfall of 450 to 1000 mm except the east coastal regions which receive rainfall from the north-east monsoon and the depressions and cyclones during April–May and October–December. The rain shadow effect of the Western Ghats extend inland to a distance of more than 200 km and this belt has a length or more than 1000 km wherein lies the areas having annual rainfall less than 600 mm.

Ground Water in hard rocks is being developed mostly through open dug wells since centuries. The total number of dug wells till 1985 is about 3 million. The ultimate target is about 4.5 million. The Statewise distribution of dug wells is given in Table 2.

Most of these wells are fitted with electric motors or diesel engines and a few are still manually operated. The dug wells which were easy and cheap to construct, have now become very costly due to the increase in cost of labour and also as the depth of excavation has gone as deep as 30 m in certain places. Development of ground water in these hard rock areas is mainly through open dug wells. Due to advent of high yielding variety of seeds which require adequate quantity of water at the right time and increase in the energisation of wells to meet their requirement with the help of financing agencies like NABARD and REC, the ground water development has been accelerated. Consequent to this and coupled with recurring droughts in some areas, water levels have shown declining trends necessitating deepening of wells. In some areas the decline of water levels has resulted in drying of shallow wells.

4. Ground Water Resource Evaluation

The Central Ground Water Board and the State Ground Water Departments of the four Southern States, are assessing the ground water resources based on the recommendations of the Ground Water Estimation Committee (1984). As per the estimates the annual utilisable resource in the four Southern States (Andhra Pradesh, Kerala, Karnataka and Tamil Nadu) has been worked out to be in the order of 83, 502.2 MCM whereas the net annual ground water draft is of the order of 20,068 MCM. Approximately 63,434 MCM of ground water potential is still available for further ground water development in these four States. The details are given in the Table 3.

Table 2 : Statewise distribution of dug wells

Name of the State	Ultimate Target (Nos.)	Upto 1985 (Nos.)
Andhra Pradesh	1,500,000	982,000
Karnataka	800,000	467,000
Kera'a	700,000	150,000
Tamil Nadu	1,500,000	1,411,000

Table 3 : Ground Water Potential of Southern States of India

State	Utilisable resource (MCM/Yr.)	Net Draft (MCM/Yr)	Balance available (MCM/Yr)
Andhra Pradesh	36,580	7,410	29,170
Karnataka	13,038	1,861	11,177
Kerala	6,919	903	6,016
Tamil Nadu	26,965	9,894	17,071
	83,502	20,068	63,434

The level of the ground water development with state as a unit, in the Southern States varies from 29% in Andhra Pradesh, 13% in Kerala, 14% in Karnataka and 37% in Tamil Nadu. However, the development has reached its optimum stage in about 51 blocks of Tamil Nadu and about 11 taluks in Andhra Pradesh.

5. Management Strategy

Having known the resources and the problems associated with the development, the resources should be managed in a more scientific way to avoid any deletereous effects due to bad management which may not only affect agricultural economy of the area but also the drinking water supply. This is more so due to recurring droughts in the hard rock areas of Southern States.

The main source of extraction of ground water in the hard rock is through open dug wells. Due to low transmissivities except locally, the open wells in hard rock generally serve as storage reservoirs from which water can be pumped after the well has recouped. Periodic deepening of the wells is being resorted to when water levels register a fall. However, in areas where the water level is deep or hard rock is encountered at shallow depths, the cost of excavation becomes prohibitive and drilling of borewells or in well bores will be more economical. But due to highly variable nature of the hard rock areas uncertainity of encountering a productive fracture in the borehole is still high. The prospective and well siting in such a condition becomes a highly specialised job calling for special techniques and methods for locating a productive borehole, the methodology suggested in such a situation is :

(a) Study the geology, tectonic. structure and ground water conditions of the area by systematic hydrogeological surveys.

(b) Study the aerial photos and satellite imageries to find out the regional tectonic and drainage pattern and locate all possible fracture zones depicted as lineaments.

(c) Ground checking of lineaments and eliminating the doubtful areas from the local geological and hydrogeological conditions and demarcating them accurately in the field.

(d) Employing suitable surface geophysical methods at a few transverse lines across each of the zones to determine their width and probable depth and pinpoint the most suitable site for drilling.

In case of dug wells which have gone dry or contain inadequate quantities of water due to recurring droughts or due to the intensity of development in the area, it is suggested to go in for boreholes within the dug well (dug-cum-borewell) and wells where some water is there even during driest month, horizontal bores may be put down to the effective radius of the well.

In some areas it is seen, that though major portion of the area is realing under drought, there are a few farmers who are lucky enough to have a good supply in their dug-cum-bore wells and withdraw water continuously for irrigation sugarcane or rice in their fields. This adversely affects neighbouring shallow wells which go dry and poor farmers suffer heavily. In such a situation, a good deal of extension service by the concerned agencies may change the farmer to adopt the water use and conserving techniques like sprinkler or drip irrigation so that more benefit could be acrue to many from the little source available. Adopting soil conservation techniques like contour bunds, graded bunds, broad ridges and furrows, basins and random tie ridging will increase infiltration of ground water.

The remedial measures to arrest the decline of water levels are through artificial recharge. Fractured aquifers are generally recharged artificially through traditional methods like contour bunding, nalla bunding or gully control, afforestration, water spreading and percolation tanks.

In order to overcome shortages in areas where there is sufficient rainfall but no provision exists to store the same in the surface reservoirs and to arrest the sub-surface flows in the valley fills, impervious barriers or sub-surface dykes may be constructed so that the water stored in these valley fills could be pumped out during the non-rainy seasons to suppliment the irrigation for second and third crop depending on the availability. Since the pumped water is spread on the upstream of the sub-surface dam, part of the applied irrigation water returns to the storage thus allowing for recycling. Thus sub-surface dyke also helps to build up levels in the wells in the upstream.

In areas served by the canal command and where the chemical quality of ground water is beyond permissible limits, the ground water table may be depressed by pumping out ground water into canals so that the salts accumulated in the phreatic aquifers are flushed out so that the ground water quality improves with the recharge during the monsoon.

In good part of the areas in the semi-arid tract of the south, paddy is cultivated under tanks, wells and canal ayacuts. While it may perhaps be possible to cultivate paddy under the tank and canal ayacuts, in requires to be discouraged under well irrigation. Even it should be discouraged under tank and canal irrigation under second crop, since the first crop is partly cultivated with rainfall during the southwest monsoon period. A judicious cultivation perhaps of dry crops like groundnut, grams, oilseeds, mulberry or some other crops which require minimum water can be cultivated under well irrigation and by adopting conjunctive use of surface and ground waters in the tank and canal command areas. There is scope for such adoption under Lower Bhavani, Ghataprabha, Nagarjunsagar and Tungabhadra canal command areas which are all located in the semi-arid areas of the south. Infact, by adopting the conjunctive use methods, much more areas can be brought under irrigation.

This will not only avoid water-logging conditions seen in some canal commands but on the other hand will stabilise ground water levels in the non-command areas where declining trends in water levels are observed in some areas due to reduced recharge (during drought years) and increasing water demands.

Similarly in areas where water-logging is anticipated, conjunctive use should be adopted by developing ground water in such areas and also pumping ground water into canals to extend the command.

Some of the other important methods or management techniques which will have significant influence on the environmental aspects and the water resources in particular are the intensification of afforesation programmes, the social forestry schemes and extension of DRDA programmes which will indirectly help induce ground water recharge and stablise ground water levels. Perhaps these can be combined under watershed management programmes for better and quicker results. The aerial seeding of dry and bare hills can be taken up on a large scale in parts of Andhra Pradesh, Karnataka and Tamil Nadu so that hills will have a good vegetative cover which will reduce runoff and soil erosion during peak monsoons. This will also reduce the silting up of reservoirs, tanks, percolation ponds in these areas.

The most important is the forecasting the resources available each year for the agricultural purposes. This will be possible, if there is a good network of raingauging station to evaluate the distribution of the rainfall which is the main source of recharge to ground water reservoir. Study of long rainfall data to predict the periodicity of droughts to fore warn the farmers is desirable so that they can adopt suitable crop pattern for that year.

Since the satellite data is available for weather conditions daily, a good forecast will help a great deal to avoid drop failures so that the farmers utilise the ground water judiciously by adopting water conserving techniques.

The other important aspects for better management is keeping a watch on the water level fluctuation vis-a-vis ground water recharge and draft. Water level fluctuation trend can be monitored through network of observation wells. There are more than 1200 network stations which are being monitored by the CGWB in these four States. Besides, each state is maintaining another few thousand wells are monitoring stations. The network data should be processed monthly and reports issued as bulletins which will be of immense help to farmers and other developmental agencies. This requires establishing a proper data base. Once this is done, with the computer technology available, it will be easier to process the data and issue reports. Till date no ground water legislation has been introduced anywhere in the country. It is hightime a serious thought is given to this. Since water is a state subject, the states like Tamil Nadu where ground water development is maximum and Andhra Pradesh where some of the taluks have reached the critical stage of ground water development should come forward with Ground Water Legislation.

At present there is no agency at the state level who are able to give authentic data of on going developmental activities i.e. the number of wells, tubewells and borewells constructed monthly or annually and total monthly and annually withdrawal except for the governmental departments and cooperatives. Since the wells constructed by private agencies are much more than the governmental agencies, suitable way has to found out to obtain information on the number of structures constructed by such agencies. Till a comprehensive ground water legislation is brought out a simple bill for getting the data may be proclaimed which will go in a long way to project relative ground water potential exploited and the irrigation potential created. This is very essential for planning the development management of this vital renewable natural resource which accounts for over 40% of the total irrigation in the country today and its development has been accelerated for catering to a much higher percentages in the years to come.

All these management practices can be considered as long term measures and will help mitigate the hardships of the population and improve their socio-economic conditions and living standards.

6. Conclusions

Ground Water, the earth's most widely occu r ng renewable resource is not distributed uniformly through out the country due to wide variation in climatic conditions, physiographic features and hydrogeological environ. The frame-work in which ground water occurs in hard rocks is as varied as rocks and as intricate as their deformation undergone through the long span of geological history. Major portion of the area of hard rocks fall in the low rainfall area and droughts are a common feature. The ground water potential in these rocks is limited compared to sedimentary rocks. Being the formation of low transmissivity, except locally, the ground water extraction structures are generally open dug wells which serve as storage reservoirs from which water can be pumped after it has recouped. However, with advent of DTH rigs, borewells ars being constructed in many places. Due the highly variable nature of hard rock aquifers percentage of failure of boreholes drilled without proper investigation is more. With the increase in investments in ground water sector, in certain parts over-development has occurred causing declines in water levels. Due to 3 to 4 continuous drought years in certain districts, some of the shallow wells have dried up due to decline in water levels. Taking the above aspects into consideration, the ground water management strategy in hard rock areas has been suggested which includes adopting proper methodology for selection of borehole sites; adopting soil conservation techniques, artificial recharge methods for stabilising the water levels; using properly the techniques for conserving ground water; conjunctive use of surface and ground water to avoid water-logging and for improving ground water quality; adopting proper cropping pattern establishing monitoring stations to study the water level trends and ground water quality; issuing monthly water level data and advance forecasting of rainfall trend for adopting proper cropping pattern, collection of monthly well statistics and legislation to affect the same; ground water legislation to prevent over-development and other measures like afforesta tion, watershed management to improve the recharge to ground water reservoir.

Acknowledgement

The author is grateful to Dr. D.K. Dutt, Chairman, Central Ground Water Board for the encouragement and guidance given for preparing the paper.