Geohydrological Conditions of the Deccan Trap Flow around Saugor (M.P.), India

K. N. DAS and V. K. DIXIT
Ground Water and Engineering Laboratories
Department of Applied Geology, University of Saugar, Sagar, M. P.

Abstract

The geological formations that occur around Sagar consist of Upper Rewa quartzitic sandstones of Vindhvan age and nine Deccan Trap flows with three main inter-trappean bands. Most of the villages around Sagar depend upon the flow No. 5 for their water supplies. This flow forms valleys which may occur either in between the Vindhyan hills or Vindhyan hills and Trap hills, or Trap hills. To evaluate the geo-hydrological conditions of this flow under different topographic and stratigraphic controls, detailed geologic, water-shed and water table maps were prepared and analysed, after taking into consideration rain fall data for a period of sixty years.

The villages selected for studies include the farm-lands of Richonda which occur in between the Vindhyan hills and Kudari, which occurs in between the Trap and Vindhyan hills. Villages like Patkui and Bhainsa, occurring on either side of the surface water divide of the same flow, are also taken into consideration. Water table maps for these villages were prepared once before the onset of rains and the second time immediately after the rains, on a scale of 16″ to a mile at 1 foot contour intervals.

From such studies made on this flow, the following conclusions have been arrived at:

1) Where a flow occurs in adjacent Deccan Trap valleys separated by a long continuous Vindhyan ridge, the Vindhyan ridge may act as an underground barrier, separating the ground water body of the flow into two distinct units, and the upper unit may give rise to springs on that valley side of the Vindhyan having the lower elevation.

2) Where the Vindhyan ridge loses its height and disappears below the flow, the adjacent separate water bodies of this flow merge into a single water body. The portion of the Vindhyan ridge that occurs below the ground still continues to act as barrier for the water bodies of the lower flows.

3) Where the flow occurs over a large area, but at places is overlaid by younger flows, giving rise to hills with distinct water-shed characteristics, the water body of the flow is generally continuous on either side of the hills,

immediately after the rains. This, however, gets disrupted into separate water bodies during summer months and it is found to recede in the slope direction; nevertheless, the trend of recession is controlled locally by the levels at which the porous zone of a flow occurs.

4) Where the continuity of the flow is disrupted due to denudation, producing valleys, the continuity of the water table of that flow is also interrupted.

5) On either side of a distinct surface water divide of a flow, the ground water bodies occur as separate units in the flow.

Introduction

The town Saugor and its surrounding villages have excellent farm lands which lie between 78°37′ to 78°52′ E Longitudes, and 23°46′ to 23°57′ North Latitudes (covered by Topo sheets Nos. 55 I/9 and 55 I/13). The area enijoys a tropical monsoonic type of climate, and receives an annual average rainfall of about 120 cms. Of this rainfall about 95 % occurs during the four months from June to the end of September, and the remaining 5% is distributed over all the other months. In the rainy season, the distribution of rainfall is so erratic, that often there would be no rainfall during those days when the crops require it most, and excessive rainfall when the crops do not require water. During the winter months, the rainfall distribution is worse than in the rainy months. Though the farm lands have the advantage of rich Trap soils, optimum crop yields from these farms have not been so far realized for want of adequate irrigation facilities. Unfortunately most of the rain-water is lost as run-off due to lack of effective surface storage capacities in the terrain. This necessitates a thorough investigation of the ground water potentials of the area, so that proper exploitation of them may be possible for meeting the irrigation needs.

The geological formations of this area consist of Upper Vindhyan (Rewah) quartzitic sandstones and nine Deccan Trap flows with three main Inter-trappean bands. The Trap formation, the soils of which support the agricultural lands of most of the villages around Saugor, is the fifth flow in this sequence, and the geological map of Fig. 1 shows its distribution.

The Vindhyan formations occur as ridges, spurs and escarpments, while the Trap formations occur as flat-topped hills, knolls and conical hillocks. The Vindhyan plains, as such, are not exposed by erosion. The Trap plains occur within Trap hills or Vindhyan ridges or between Trap hills and Vindhyan ridges. Sandy soils derived from Vindhyans occur on the Vindhyan ridge-tops and on the adjacent topographic bottoms. The clay soils, derived from the weathering of the Traps, occur in the Trap plains and hills. Sandy loams, an intermixture of clays and sands, occur as fringes at the foot of the Vindhyan ridges, and support forest and grass lands.

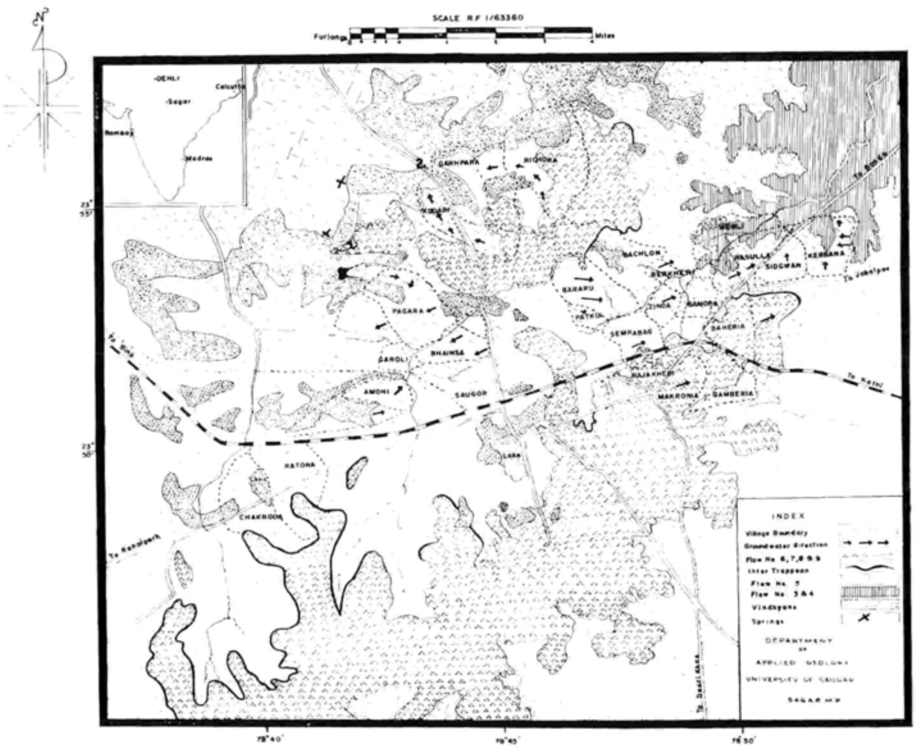

FIG. 1

Correlation Characters of the Fifth Flow

The fifth flow, like other Deccan Trap flows, is basaltic in composition, and is homogeneous in its texture and structure throughout the wide area of its occurrence. It is black in colour, fine-grained and irregularly jointed with an excellent conchoidal fracture. It breaks easily into small sizes. It is the thickest flow (90′) that occurs in the area. The upper part of the flow is characterised either by the presence of a vesicular zone or by an inter-trappean overlying it, both never occurring together. The thickness of these zones varies from about two to fifteen feet. The inter-trappean bed is fossiliferous. It is either argillaceous, calcareous, siliceous or an intermixtures of these. The vesicular zone of this flow mostly contains zeolites and is underlaid by a thin amygdaloidal zone with minerals like quartz, chalcedony etc. Immediately below this zone of the flow occurs the primary near-vertical jointed zone of 5′ to 15′ thickness. This jointed zone, as observed in quite a large number of dug wells, is horizontally fractured, probably due to the crushing and flowing effects of the overlying flows. The middle part of the flow is massive, and nearly free from joints. Its thickness varies from 60′ to 70′. The lower 5′ to 10′ part of the flow has near horizontal fractures at places. This fracturing may be due to the differential cooling and movement of the flow. Tunnel-like openings are not to be seen in this flow. The top of this flow around Saugor occurs at about 1750′ M.S.L. The same flow is to be seen as far as Rahatgarh which is about 24 miles to the S.W. of Saugor on the Saugor-Vidisha road, and as far as Mehr village which is about 14 miles to the North of Saugor, situated on the Saugor-Jhansi road. But the top of this flow attains a height of about 1850′ near Barkoti Kalan, which is at a distance of about 24 miles to the south-east of Saugor, situated on the Saugor-Narasinghpur road. The rise in the height of this flow is more likely to be due to the general tilting of the Trap to the north or north-east which is responsible for the drainage of the rivers towards the Gangetic valley. The characters of the flow are so evident that the correlation of this flow is an insignificant problem.

Infiltration and Recharge Areas

The Trap flow in the area of study occurs mostly in the valley plains except near the village Makroniakurd, where a small outcrop of the same (marked as No. 1 on the Geological Map) forms a hill flat. The plains have gentle slopes. Wherever the plains occur adjacent to Trap hills, they gradually merge with the undulating topography of the hills, and are traversed by gullies. These, on the down slope direction, unite to give rise to streams. The streams, while trying to cross the Vindhyan obstructions, follow the Vindhyan contact till they encounter a Vindhyan gap (shown in the Geological Map as

No. 2). Here they make a crossing through the Vindhyan hills, at first flowing over the Vindhyans, but later, as the Trap weathers more than the Vindhyans, the waters get ponded during winter and summer. The ground-water flowing through the joint planes, bedding planes and cross laminations of the Vindhyans weakens them, and gives rise to springs on the other side of the Vindhyans. The floods of the streams during the rainy seasons break the Vindhyan obstructions and get connected. During this process, the stream loads are deposited in the form of thin covers of alluvium on the ponded area. The weathered complex of this flow has given rise to clay stony soils, stony clay soils, insitu clay soils and transported clay soils. The clay stony soils form the undulating ground, and the stony clay soils occur at the slopes of the ground. The insitu soils occur on the plains of the flow, and the transported clay soils are mostly confined to the banks of the streams. Wherever the erosion is intense as in gully and stream beds, fresh rock outcrops of the flow occur. The entire ground occupied by the flow, excepting the portions covered by the insitu clays, acts as a recharge or infiltration area.

Wherever the flow disappears underneath a cover of younger flows, the recharging conditions of ground-water for this flow depend upon the thickness of cover and the hydrological nature of the flows constituting the cover. If the cover comprises one or two weathered flows, supporting luxuriant vegetation, the entire overlying cover acts as an excellent recharging area to the underlying formation. If root perforations are abundant, the clay soil cover may function even as an aquifer, not only during the rainy season but also during a part of the winter season. The significance of the Vindhyan hills as a recharging ground is limited, for the flow either overlies the Vindhyans or occurs adjacent to them. In addition, the Vindhyans being quartzitic, they are aquifuses, and the only places through which the waters can move are the joint planes, cross laminations and bedding planes.

Hydrological Characters of the Fifth Flow

The vesicular zone and the primary jointed zone, along with its secondary fractured part, constitute the porous parts of the flow. The vesicular zone of this flow generally crops out on the sides of the trap hills, and is rarely to be seen in the plains part of the flow.

The utility of this zone as a water-bearer is limited to the areas of wide areal extensions, where it is capped by thin covers of one or two younger flows, or by their soils or weathered materials. As this zone is normally truncated at the hill sides, most of its water seeps out from its sides during and immediately after the rains, contributing to gully erosion. The weathered part of this zone is more porous than the unweathered part. This zone is the best aquifer part of the flow. The ground-water occurrence, its movement, etc., is just like it is in those formations having pores as their openings. In its place, if an Intertrappean horizon occurs, this part of the zone becomes impervious and acts as a barrier to infiltrating waters.

The primary jointed and secondarily fractured zone, along with the remnants of the vesicular zone, support practically most of the wells in this flow. The joints are nearly vertical, but are mostly interconnected by the secondary fractures in the lower parts of this zone. The water either seeps or trickles through the fractures, or flows like springs through the joints. Wherever this zone is traversed by near horizontal fractures, interconnecting a number of primary joints which, in their turn, are overlaid by the weathered vesicular zone, this zone supplies quantities of water as much as 40,000 gallons per day during the summer months of a normal year of rainfall. This is however reduced to 20,000 gallons if one or two continuous years of drought precede. The water in this zone moves partially under pressure. During the rainy season, that is, immediately after the soil moisture and vadose water zone requirements are met by the infiltrating water, the water levels of wells rise so fast that, at places, the ground-water rises to the ground surface, and even seeps, giving rise to swamps around unfinished wells at low levels. As the summer season advances, the water levels start falling rapidly, the rapidity depending upon the areal extent of interconnections of the jointed zone. A well, piercing through an unconnected primary jointed zone even in the immediate neighbourhood of a good-sized seasonal stream, gets completely dry at the end of a winter season, thereby requiring blasting to interconnect the openings. With the fall of waterlevels, the pressures, as a rule, decrease. If some of the interconnecting joints extend to the other ground water bodies at higher levels or outcrop below the surface water bodies, strong springs from these joints occur even during summer months.

Due to differential erosion, different parts of the flow either outcrop or occur below their weathered materials. If a well ends up in the middle massive part of the flow, it is a failure. Even if it is dug down to the bottom fractured zone, it still remains a failure, for the massive capping layer acts as a barrier, to the downward movement of waters. If the bottom fractured zone forms a stream bed, and occurs below the banks of the streams in the immediately adjacent valleys, or under the weathered materials without an intervening massive zone, a well dug through this zone gives good supplies of water. This zone is underlaid either by an argillaceous fossiliferous intertrappean bed or by an epithermally weathered clay zone of the underlying flow.

Ground Water Level Maps

The movements of ground water in this flow are found to take place both due to water table and confined conditions. Water table conditions are predominant in the vesicular part of the zone and confined conditions occur exclusively in the jointed and fractured zones. Further, water table conditions generally govern the movement of water in the flow during the rainy season and, as the water levels slowly fall in depth below the vesicular zone as the summer advances, the confining conditions begin to govern the movements. Due to such mixed conditions the authors prefer to refer to ground water contour maps as ground water level maps rather than water table or pressure surface maps.

To evaluate the geo-hydrological conditions of the flow under study, ground water level maps, on a scale of 16″ to a mile at one foot contour intervals, for as many as twentyfive villages (which depend on the flow for their water needs), were prepared with the data available from the dug wells in their respective areas. On the basis of the water level maps of these villages, the general ground water movement directions of this flow together with the village boundaries are transfered on to the geological map. The water level maps were analysed and studied to determine not only the various ground water controls but also the behaviour of ground water bodies in this flow. From such studies, it is inferred that, in that part of the flow where the water level contours occur fairly wide apart, the flow zone is more porous, than those parts of the flow where they are closely spaced. These permeable parts generally represent the upper vesicular or jointed and fractured parts of the flow; occasionally even in these parts, tight zones occur. During the rainy season, the water level contours get closer than what they were before the rains. In a horizontal distance of one mile, the average vertical drop of water level is 35′ during the rainy season, whereas during the summer it is 30′. It is due to the availability of more water from the areas of infiltration to flow through, than the open spaces available to permit their movement during the rainy season and there after. It is necessary that the water level maps prepared prior to the commencement of the rains should be taken into consideration to decipher the permeable zones of a flow. At any place, immediately after the rains, the average rise of water level in this flow is 3.0 feet from that of the level before the advent of the rains. Thus, it can be said, apart from the formational control, the rain fall and the infiltration areas have also a bearing on the ground water bodies.

As a result of the study of the water level maps of the villages Patkui and Bainsa, the direction of ground water movement is found to be controlled by the surface water divide of the flow. At Patkui, the ground water movement direction is towards the S.E., and in Bainsa it is towards the S.W. The water levels of the wells situated in the area of surface water divide get nearly dried up during summer months. Then the ground water body of this flow becomes two distinct bodies. During the rainy months these bodies unite to form a ground water divide below the surface water divide. Such ground water divides are to be seen even where there are minor surface divides. Due to denudation, where the continuity of the flow is disrupted, producing valleys, it is seen that the continuity of the water table of that flow, is also interrupted, as noticed in the Mohli area. This clearly reveals that even the minor topographic features of the flow have a distinct control over the movement and occurrence of ground water in this flow.

Where a flow occurs in between Deccan Trap valleys, separated by a long continuos Vindhyan ridge, the Vindhyan ridge is seen to act as an underground barrier, separating the ground water body of the flow into two distinct units. The upper unit may give rise to springs on that valley side of the Vindhyan having the lower elevation. These conditions are seen to prevail in the areas enclosing the villages Kudari and Makronia Kurd on one side of the Vindhyan ridge having higher elevations, and on the other side in the areas enclosed by Sirwai, Barkhera etc., having lower elevations. The natural springs (shown in the map as X) which occur in the lower valley side owe their origin to the ground water body of the higher valley side.

A study of the water level map of the Pagara village brings out the fact that where the Vindhyan ridge loses its height and disappears below the flow, the adjacent, separate ground water bodies of the flow merge into a single water body. The portion of the Vindhyan formation that occurs below the ground still continues to act as a barrier for the water bodies at deeper levels. From this, it is clear, that the Vindhyan formation and pre-Deccan Trap topography have a control over the ground water occurrence in this flow.

Where the flow occurs over a large area, but at places is overlaid by a younger flow or its outliers with distinct watershed charactertics, the water body of the flow is generally continuos on either side of the hill (with a distinct ground water divide below the hill) during and immediately after the rains. This, however, gets disrupted into separate water bodies during summer months, and recedes towards the ground water slope direction. Nevertheless, the trend of recession is controlled locally by the levels at which the porous zones of the flow occur. In this connection, the drainage pattern has a distinct control over the ground water body of this flow, for the recession of the ground water body occurs towadrs the streams during summer months, as observed from the water level maps prepared prior to the commencement of the rainy season.

From the aforesaid, it is concluded that the geo-hydrological conditions of the fifth flow that supports the farm lands around Saugor depend upon the rain fall, topography, drainage conditions of the flow, the infiltration and recharge areas, the hydrological characterstics of the flow and the pre-Deccan Trap topography.

Acknowledgements

This work has been done in cooperation with the Department of Agriculture, Sagar district, Government of Madhya Pradesh, as a drought scheme. The authors express their gratitude to Shri R. N. Singh, the Deputy Director of Agriculture and to Mr. C. R. Ars, the Soil Conservation Officer for their kind help in providing reduced levels of wells of various villages. Grateful thanks are also due to Prof. W. D. West, Sc. D., F. N. I., for critically going through the manuscript.