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THE WEST RAND DOLOMITIC AQUIFER

GEMSBOKFONTEIN COMPARTMENT

BY J.N.E. FLEISHER

CONTENTS:

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1. INTRODUCTION:

A dewatering policy which has been applied in certain compartments of the West Rand dolomitic aquifer has changed previous groundwater conditions to a great extent. Hydrological observations were made, but no evaluation has been undertaken, due partly to the priority given to engineering-geology problems like sinkholes and subsidences, and partly to lack of manpower. The purpose of the present investigation is to collect and classify the obtained data and try to find out characteristic hydrologic constants like storage and percentage of natural replenishment in those compartments where calculations seem feasible.

2. PREVIOUS WORK:

Hydrological aspects of the combined Gemsbokfontein and Zuurbekom compartments are described by Enslin and Kriel (1959). A figure of 7,9% of the average annual rainfall was found to percolate into the underground water. The calculation was derived from a water balance based on gauged and estimated surface water flows, compared with outflows at the eyes and pumped amounts abstracted at Zuurbekom.

3. GENERAL:

The Gemsbokfontein compartment (Figure 1) includes a dolomitic area of 85 km^2, covered by soil of varying thickness. The dolomitic bedrock under the soil cover has a highly irregular surface. On this durface Karoo sediments were deposited unconformably. Relics of Karoo strata in depressions escaped erosion and occur as detached remnants under the soil cover and overlying the dolomite.

The dolomite has a thickness of more than 1 000m. It is claimed however that only the upper zone of 150m is water-bearing due to differential karst development. By its nature the aquifer is heterogeneous and anisotropic. Groundwater storage and movement is accomplished in the weathered zones, in solution channels, fissures and faults.

The relatively impervious Black Reef Series and volcanics of the Ventersdorp System form the base of the dolomitic aquifer with the Pretoria Series the roof. The structure dips generally to the south. These formations and also dykes which run in a north-east direction, form the boundaries of the compartment.

It has lately been proved that the southern faulted dolomitic outcrop separated from the main body and surrounded by Pretoria Series, is part of the main aquifer body, the total extention of the compartment being thus 101 km^2. The southern outcrop is estimated to cover some 16 km^2.

Ground surface slopes gently northwestward (to Wonderfontein River) and northeastward (to Kliprivier) with a water divide in between. The Wonderfontein River runs through the northern part of the compartment. The Donaldson Dam in this river is situated across the boundary of the Gemsbokfontein compartment. Before large-scale artificial abstraction commenced, a water-level contour map derived from a few measurement points showed a low gradient towards the spring. This spring has dried up due to the lowering of the watertable. The annual flow used to be about $3 \times 10^6 m^3$.

In the southern part of the Gemsbokfontein compartment Western Areas and Elsburg Gold Mines have areas under lease. Irrigation over the compartment is at present rather limited.

4. DEVELOPMENT:

Up to 1966 groundwater extraction by the mines was around $40 \times 10^3 m^3$ per month, which increased to $200 \times 10^3 m^3$ from 1966 to 1968.

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During 1969 - 1970 the pumped amounts fluctuated between 200 and 380 x $10^3 m^3$. In the beginning of 1971 the amount rose drastically as a result of an inflow into Western Areas underground mine works (figure 2).

Within a period of 31 months, (8/1970 - 2/1973), a total of 25 979 952 m^3 has been pumped out of the compartment. Taking 3 x $10^6 m^3$, the previous outflow at the spring as a rough estimation of annual replenishment, it means that in a period of 31 months the abstraction was equivalent to 8 and 2/3 years of natural recharge. This period of 31 months, included however 2 and 2/3 rainy seasons (1970/71 - 1971/72 - 1972/73). The negative balance is thus reduced to 18 x $10^6 m^3$ or six years of natural recharge.

The results were two fold:

(a) a large drop in water table over the whole compartment in some places up to 7m, (figures 3 - 27).

(b) the development of sinkholes and subsidences in areas which previously had a shallow water table.

Unfortunately, only 5 observation holes were available during this period, with a poor distribution pattern.

The danger of collapse of the highway and railway line from Johannesburg to Potchefstroom crossing the compartment called for urgent measures. The policy adopted was to recirculate the pumped water back into the aquifer through recharging boreholes. At first water was also pumped from the Venterspost compartment, and from Donaldson Dam to the Gemsbokfontein compartment to overcome the deficit. Later recirculation combined with natural recharge succeeded in raising the water table to "normal" levels.

Simultaneously, a detailed gravity survey was undertaken by the Geological Survey to delineate the weak zones where subsidence might be expected. In the course of that survey 76 boreholes were drilled in order to verify geophysical interpretations. In some of these boreholes casings were inserted so as to be used for water level observations. In a few of the observation wells, automatic recorders were installed. All in all 39 observation holes are still operating.

5. DISCUSSION OF THE RESULTS:

There are no complete water-level records for the period preceding the overpumpage. A comparison of annual rainfall data (figure 28) with the incomplete hydrographs, figures 17 and 20, shows:

(a) The average water level varies by more than 2m over a period of 15 years.

(b) The effects of groundwater withdrawal can be noticed as early as 1969.

The water-level contour map for November 1975, figure 30, represents the groundwater pattern which has prevailed since overpumpage changed the previous natural regime and dried up the eye. It is based on a rather small number of observation points. Water-level elevations are even not related to a common datum plane, yet the map reflects the major features. It is worthwhile noting that all through this period a distinct gradient exists from the vicinity of Donaldson Dam to the south. Boreholes G 1163 (figure 3) and G 1142 did not show a lowering of the water table as a result of the overpumpage early in 1973. It seems that these boreholes are located on the other side of a groundwater barrier. Some uncertainity remains about flow direction in the western part of the compartment. Water level observations do not exclude a possible westward flow.

Boreholes MD 34 and WP 7 deserve some explanation:
The water table in these boreholes is about 7 meters higher than in borehole MD 12, which is assumed to reflect the ground water table in the main aquifer. Between 3/1973 - 12/1974 an accumulated amount of $9.5 \times 10^6 m^3$ had been recharged

through a sinkhole near borehole MD 34 with the result of a local rise in water table to about + 1575 m. After recharging stopped, during the period 12/1974 - 2 1976, the water table dropped to + 1567, which is more or less the original water level.

Most protably these boreholes tapped secondary reservoirs. It is assumed that water migrated via limited fissure conduits into the main aquifer. On reaching normal water level, a natural mound due to rainfall could again develop beginning in 2/1976.

A study of the hydrographs (figures 3 - 27) and precipitation (figure 28) for the rainy seasons of 1974/75 and 1975/76 reveals a rapid response of the water table to the rainfall.

In order to investigate, in comparison, the aquifer's reactions to extraction and artificial recharge a graph has been drawn which shows the results of monthly balances as a net intake or outflow (figure 29). The horizontal line designates zero change while amounts shown above or below refer to changes of water volumes into and out of the aquifer respectively. Superimposing that graph on the different hydrographs reveals the correlation between quantitative groundwater changes and the watertable behaviour (figures 4; 7; 10; 20). Effects of renewed extensive pumpage may be traced in boreholes as an abrupt drop (figures 12; 13; 14; 19).

Only in four boreholes was the water table observed during the drawdown period (figures 10; 7; 20; 17), thus only rough calculations could be done, as follows:

The average drop in water table between 1/6/1972 to 30/2/1973 was around 3.8m. The accumulated discharge at the beginning of that period was 10 375 413 m^3 and at its end 43 273 323 m^3, the difference being 32 897 910 m^3. During that period the natural recharge is estimated at 66% of the average annual recharge of $3x10^6 m^3$, therefore $2x10^6 m^3$. The deficit would be around $31x10^6 m^3$.

The volume of the aquifer material involved in the dewatering is estimated to be 100 x 10^6 x 3,8 = 380 x $10^6 m^3$ where 100 is surface area in km^2. This gives a storage coefficient of $\frac{31 \times 100}{380}$ = 8%. this figure however should be considered as an approximation and represents only the order of magnitude. Calculation for the period of water table recovery, that is from 3/1973 to 5/1975 is as follows: The accummulated pumped amount on the 2/1973 was 18 x $10^6 m^3$. 1,5 x $10^6 m^3$ had been recharged back to the compartment from various sources. An amount of 7 x $10^6 m^3$ is estimated to have infiltrated from rainfall. This brings the total recharge for said period to 8,5 x $10^6 m^3$.

This amounts to $\frac{8,5 \times 100}{18}$ = 47% recovery of the original deficit. The rise in water table in the few boreholes however, would suggest a far higher recovery percentage. For example borehole WP 24 5/7 x 100 = 71% borehole RG 461 2/3 x 100 = 66% and borehole GB 1 2,8/4 x 100 = 70%. This discrepancy can be explained by either or a combination of the following reasons:

(a) Incorrect inflow figures into the compartment of water derived from the Donaldson Dam, the Venterspost mine etc.

(b) The figure of 3 x $10^6 m^3$ for the average natural recharge can be far out. There is a wide range in the amount of actual recharge by rainfall. Furthermore the recharge is very much influenced by the dewatering of the aquifer. For example along the river bed and in the vicinity of the spring, the lowering of the water table would enable a considerable higher intake.

In an attempt to arrive at more refined storage figures a period of 6 months (15/5 - 15/11/1975) has been selected. During this period no precipitation took place. The changes in waterlevel are thus related to pumpage only. Fig. 31 shows the difference in water table levels between the end and beginning of the 6 months period (table 1)

The net discharge during the balance period was 1,806 662 x $10^6 m^3$.
The total volume of aquifer material involved amounts to 22,3 x $10^6 m^3$.
The detailed calculation is shown in table 2.

TABLE 2

AREA	SURFACE km^2	Δh m	AQUIFER VOLUME $10^6 m^3$
A	29,40	+0,35	+10,29
B	11,37	$\pm$ 0	-
C	40,77	-0,80	-32,62
		TOTAL	-22,33

Δh Is the arithmetic average change of water table in every case. The storage will therefore be $\frac{1,8}{22,3} \times 100 = 8\%$. The accuracy of the figure is however proportional to available data. Two sources of error may be summarized:

(a) The distribution of observation wells is most unsatisfactory, leaving out large areas.

(b) The southern boundaries of the compartment are inferred, no data is available to calculate any changes in the southern segments D and E

Logically the next step would have been to select a period were infiltration as well as pumpage took place, like the summer, of 1975/76 so as to calculate the natural recharge. Careful analysis of the hydrographs reveals in many boreholes the peculiar phenomenon of a continuous rise in water table as late as 9/1976, far beyond the rainy season. This feature has not been observed in the previous analogueous season of 1974/75 and did not coincide with the rather large deficit developed in the compartment due to pumpage (figure 29).

Leakage from the dam can be excluded, because if it would have been characteristic of the area it should have been noticed before too.

The rise in water table seems to represent a characteristic feature of the dolomitic aquifer. Natural recharge into the aquifer is not confined to the rainy period only. Considerable amounts reach the water table at a much later stage. The exceptionally rainy season of 1975/76 reveals this rather prominently. In the case of the Gemsbokfontein compartment the monthly amounts of these delayed recharge quantities may equal or exceed the net monthly extraction namely $250 \times 10^3 m^3$.

Some additional percolation due to overflow may take place between the spillway of Donaldson Dam and the first dawnstream gauging station. These amounts would be impossible to detect and yet may contribute to the rise of water tables.

A few water samples have been sent for full analysis to furnish a picture of the qualities involved. The poor quality of water overflowing the dam and percolating into the aquifer can be checked from the attached analysis (table 3). The TDS is 2 000 mg/ℓ with a high amount of sulphates. The currently recirculated water is possibly also of poor quality.

The existence in places of Karoo sediments, which are quite impermeable, will also effect the replenishment and movement of groundwater. Figure 32 provides base Karoo elevation AMSL and its thickness as penetrated in each borehole. An isopach map could not be attempted due to inadequate number and distribution of boreholes. Superimposing a groundwater contour map on figure 32 displays the fact that on the whole the aquifer is phreatic, becoming semiconfined in a few cases only.

6. CONCLUSIONS:

A. This compartment seemed to furnish a rather reasonable model unit, on which long term water-table balances could be calculated. However, such calculations become approximations only due to the following shortcommings:

(a) The poor distribution of observation boreholes leaves out large areas for which no water level data are available.

(b) The amount of leakage from the Donaldson Dam overflow is unknown

(c) The southern boundaries are in places only inferred.

B. The use of an average annual natural recharge figure like $3 \times 10^6 m^3$ inevitably introduces errors. In practice natural recharge varies over a wide range. The use of an average is therefore only employed for calculation purposes.

The period of replenishment in the dolomitic aquifer extends beyond the rainfall season. Selection of a balance period limited to the winter does not ensure no-recharge. Storage figures arrived at in this report maybe somewhat higher than the actual.

C. Drilling programs should be drafted after discussion with the representatives of the different Geological Survey sections (Geophysics, engineering) and possibly with the mines managers so as t meet as many requirements as possible.

D. At the present stage no use is made of groundwater for domestic or irrigation purposes. The sole justification of artificial recharging being the prevention of subsidences. In the future, the same aquifer after restoration, might be considered again for groundwater supply or as a regulating underground reservoir for surface water if such a scheme materializes.

In this respect the water quality distribution would be essential. A geochemical survey of the dissolved minerals constituents should therefore be undertaken actually over the whole Western Rand.

D. About 20 additional observation boreholes are required to supply a better picture of the flow pattern and aquifer boundaries.

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TABEL I

GROUNDWATER LEVELS

NO RAINFALL PERIOD 15 MAY TO 15 NOVEMBER 1975

No.		15.5.1975 a.s.m.l.		15.11.1975 a.m.s.l.	Difference
G1142 2627BD292		1562.00		1561.40	-0.60
G1163 BC23		1562.03		1560.28	-1.75
G1169		1563.82		1562.11	-1.11
G1170		1561.46		1560.43	-1.03
G1137 2626AM215		1557.35		1556.49	-0.86
G1127		1559.75		1558.83	-0.92
G1128		1559.72		1558.83	-0.89
G1141 2627BD 84		1559.54		1558.77	-0.77
G1129		1559.54		1558.81	-0.73
GB 1	5/75	1557.40	10/75	1556.70	-0.70
G1133		1559.33		1558.64	-0.69
G1140		1559.24		1558.69	-0.55
G1162 2627DA88		1559.23		1558.64	-0.59
PV 37	5/75	1557.10		1556.90	-0.20
G1111 2627BC10		1558.99		1558.48	-0.51
G1112		1559.10		1558.55	-0.55
G1107		1558.78		1558.32	-0.46
G1108 2329AD248		1558.83		1558.38	-0.45
PV 13		1557.80		1557.40	-0.40
G1109		1557.35		1557.38	+0.03
G1110		1558.76		1559.11	+0.35
G1075		1556.58		1556.77	+0.19
RG 461		1556.98		1556.99	+0.01
DW 7	5/75	1557.20		1557.20	0
DW 5	5/75	1557.10		1557.20	+0.10
DW 6	5/75	1557.20		1557.20	0
CP 16	5/75	1557.30		1557.30	0
G1168		1559.89		1558.57	-1.32
G1103		1558.50		1557.60	-0.90
G1102		1559.60		1558.57	-1.03
G1106		1557.43		1556.39	-1.04
G1333		1557.58		1556.30	-1.28
G1334		1559.18		1557.80	-1.38

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(Table I continued)

G1105		1557.25		1556.92	-0.33
G1189		1559.22		1557.82	-1.40
G1104		1558.85		1557.30	-1.55
WP 26	5/75	1558.20		1558.00	-0.20
G1101		1558.67		1557.05	-1.62
WP 24	5/75	1559.10		1558.70	-0.40
WAW 3		1559.20		1558.88	-0.32
G1186	2627BC101	1560.09		1558.64	-1.45
G1187		1560.50		1560.17	-0.33
WP 13	5/75	1563.70		1564.20	+0.50
G1397	13/6	1564.90	12/11	1564.87	-0.03
G1356		1557.59		1557.91	+0.32
G1357	13/6 2627BC225	1579.80		1580.12	+0.32
G1120	2627BD48	1556.00		1556.48	+0.48
G1233		1556.22		1556.47	+0.25
G1235		1555.49		1556.00	+0.51
G1236	2627BD82	1556.15		1556.38	+0.23
WP 15	5/75	1560.90	10/75	1560.90	0
MD 12		1560.30		1560.60	+0.30
WAW14		1572.78		1570.48	-2.30
WAW10		1557.80		1557.44	-0.36

TABLE 3

Chemical quality of Water from Donaldson Dam: *

DATE	PH mg/L	TDS mg/L	SO4 mg/L
1/75	8.2	1965	670
4/75	7.1	1925	1160
7/75	7.0	1960	1250
9/75	7.4	1975	1160
12/75	7.9	1425	880
3/76	5.2	1530	840
7/76	5.5	1970	1000

* Information obtained from Industrial Water Division, Department of Water Affairs.

LIST OF FIGURES AND TABLES

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