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OPSOMMINGS
ABSTRACTS

DEEL 2 GRONDWATER
PART 2 GROUND WATER

GROUND WATER RESOURCES OF THE KALAHARI IN GORDONIA

by
M Levin
Nuclear Development Corporation of South Africa (Pty) Ltd

Z M Dziembowski and D Kraemer
Division of Geohydrology, Directorate Water Affairs

Since the first water boreholes were drilled in the dry Kuruman River in 1914 for military purposes, the Kalahari Desert in Gordonia has only very recently received considerable attention as far as ground water resources are concerned. Since then the search for underground water for stock watering had only been carried out by private landowners. Numerous boreholes were drilled in the hope of striking a supply of acceptable quality for stock watering. As this activity met with very limited success the farming community called on the state for help and some investigations were undertaken, especially since the early 1950's, reported by Meyer (1953), Vogel and Bredenkamp (1969).

During the late 1970's a detailed study of ground water occurrence and its quality commenced involving two organisations which utilized geohydrological investigations: 1. The Nuclear Development Corporation to study the uranium potential of the area and 2. The Division of Geohydrology of the Directorate of Water Affairs in order to find and delineate possible freshwater bodies which could be utilized for regional water supply.

The latter contracted the Geophysics Division of the National Physical Research Laboratory of the CSIR, to study in more detail freshwater occurrences found to underlie the lower Kuruman River. The Nuclear Physics Research Unit of the University of the Witwatersrand was also involved in a detailed study of the environmental isotope concentrations in order to establish ground water recharge. Although this multidisciplinary investigation has not yet been completed, a general assessment of the geohydrology of the area is now possible and will be presented.

REFERENCES

Meyer, E I (1953). 'n Geologiese en geofisiese opname van die Kalahari langs die Molopo- en Kurumanriviere in die Gordonia- en Kurumandistrikte, met spesiale verwysing na ondergrondse water. S. Afr. Geol. Surv. (unpublished) report GSO 15/2/203.

Vogel, J C and Bredenkamp, D B (1969). A study of subterranean water in the Southern Kalahari with the aid of Carbon-14 Dating and Isotope Analysis. CSIR, confidential report of the NPRL.

Levin, M (1980). A geological and hydrogeochemical investigation of the uranium potential of an area between the Orange and Kuruman Rivers, Northwestern Cape Province. NUCOR, PEL 272, April 1980.

Dziembowski, Z M and Wessels, M J (1980). Grondwater Geberg in die Kalahari-lae, Kalahari-Wesgebied, Distrikte Gordonia en Kuruman. Int. Techn. Rep. GH3149. Direct. Water Affairs.

De Beer, J H, Duvenhage, A W A, Meyer, R, Huyssen, R M J and Barlow D T (1981, 1982 and 1983). Geophysical and Geohydrological Investigation of the Ground Water Potential of the Kalahari Group along the Lower Kuruman River, Gordonia and Kuruman districts. Rep. Geoph. Div. NPRL, CSIR (Three reports).

Verhagen, B.Th (1984). Environmental Isotope Study of a Ground Water Supply Project in the Kalahari of Gordonia - Int. Symp. on Isotope Hydrology in Water Resources Development. I.A.E.A. Vienna.

GROUND WATER IN MINING EXPLORATION

by R J Connelly
Steffen, Robertson and Kirsten Inc

In any mining environment, ground water is an important consideration. Despite the overall impact of ground water on mining, it is rarely given the consideration it deserves until a problem has developed.

Recent legislation, public awareness and social responsibility on the part of the mining companies, as well as the current drought, have made mining people more aware of the impact of ground water on mining operations.

It is the purpose of this paper to briefly illustrate how ground water impacts on mining but more importantly to show how much of these impacts can be assessed during exploration.

Three major considerations which are:

- ground water for water supply
- dewatering
- impact of mining on the ground water environment

On many proposed existing mines it is evident there is a lack of communication between various parties concerned and ground water can be easily ignored. A typical example is the situation where a mine builds expensive storages for surface water and has an active programme of dewatering. Conjunctive use of ground water and surface water offers large financial benefits.

Dewatering a mine is done for many reasons. For example:

- removal of the danger of sudden inflows, particularly in underground mines.
- improvement of working conditions

- reduction of water pressures in the country rock which could induce instability
- reduction in operating and processing costs.

Mining activity will have some impact on the ground water environment. Some aspects include:

- lowering of regional ground water levels, necessitating compensation to existing ground water users.

- changing water quality either by direct contact with the active mining area or by inducing a flow of different quality water due to increased hydraulic gradients towards the mine.

- changing the regional water balance and ground water flow regime

To evaluate any of the above aspects, it is essential to have an understanding of the hydrogeologic regime. This includes aquifer definition, mode of ground water flow, aquifer type, water levels and water quality.

One of the initial activities in a hydrogeologic investigation is a borehole census. This entails recording all possible information about all boreholes in and around the area in question. This is to build up a data base of water quality, water levels and approximate yields.

This information is then used to compile piezometric or phreatic contour plans, water quality distribution and possibly ground water hazard plans. The latter can provide target areas for potential dewatering needs or water supply wells. If sufficient information is available for statistical analysis, then the amount of subsequent drilling specifically for hydrogeologic analysis can be very significantly reduced.

Drilling carried out for exploration at prefeasibility and feasibility stage is ideal for collecting this information. It is however very infrequently considered, generally because there is a communication gap between geologists doing exploration and the civil and mining engineers who may be ultimately responsible for water supply and dewatering.

It is the premise of this paper that data essential to many costly aspects of mine planning, can be collected extremely cheaply during exploration. Much of the data can be recorded by the driller with no interruption to his production.

The greater the amount of information available, the greater the amount of confidence that can be placed in results. Understanding the degree of confidence in a set of results is very important to the mine manager, planning capital expenditure on a new mine.

ENVIRONMENTAL ISOTOPES AND HYDROCHEMISTRY IN GROUND WATER STUDIES

by B Th Verhagen
Nuclear Physics Research Unit
University of the Witwatersrand, Johannesburg

EXTENDED ABSTRACT

In the study of ground water it may be instructive to enquire about the condition of the water itself, ie those signals which the water carries and which may provide information about its history, origins and environment. These are contained in the substances dissolved in water (its hydrochemistry) and the isotopic composition of both the water molecule and the dissolved substances.

The hydrochemistry is first established on infiltration: dissolved biogenic CO_2 reacts with lime or decomposing feldspaths in the unsaturated zone to produce dissolved bicarbonates. Further chemical development can now take place involving mineral decomposition in the aquifer, the dissolution of evaporites and chemical exchange. With increasing concentrations, saturation conditions can occur, enhanced by evaporative losses when ground water approaches the surface.

Similarly, the isotopic ratios of the different elements which make up this (usually very dilute) solution, is first established during recharge. The elements O and H retain the signal of the previous history of the molecule itself, ie geographical position, temperature, air moisture content etc. There are also the elements of the dissolved constituents which may cover the entire periodic table and may be of natural or anthropogene origin. The isotopic ratios of these elements can be altered by fractionation processes, such as changes of phase, chemical exchange and radioactive decay. These constitute what are termed environmental isotopes.

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Information can be obtained by sampling the water at a particular point in time or space, or a series of samplings. The results, usually of several different parameters, can then be interpreted in terms of a model of the behaviour of the ground water system, or might even suggest a model. The following topics are briefly discussed:

(a) oxygen - 18 and deuterium in the identification of origins of ground water, the relationship between different water bodies and correlations with ground water chemistry.

(b) environmental tritium in the assessment of ground water turnover times up to about 50 years, the bomb fallout peak and unsaturated zone movement.

(c) the hydrochemistry of carbon, the role of carbon-13 in the identification of the origins of dissolved inorganic carbon and the application and difficulties in interpretation of radiocarbon(^{14}C) in the long-term (up to 40 000 years) dating of ground water.

(d) Chlorine-36 as a promising tool for ground water dating, using tandem accelerator mass spectrometry.

(e) dissolved gases as indicators of conditions under which ground waters were recharged.

The different techniques are discussed and illustrated in terms of hydrological studies conducted in Southern Africa and elsewhere. The emphasis is placed on the extent to which the combination of hydrochemistry and isotopic ratios - so-called multi-tracing - can be used in solving practical hydrological problems and how some methods have become routine in geohydrological investigations.

B Th Verhagen

GEOPHYSICS AND GROUND WATER

by R Meyer and J H de Beer
Geophysics Division, NPRL, CSIR

The recent drought in Southern Africa has again stressed the important contribution ground water can and must make to the water budget in large parts of the subcontinent. In the search for and evaluation of aquifers a variety of geophysical techniques are available to the geophysicist and geohydrologist. Geophysical methods have been employed successfully for several decades as an aid in the mapping of geological structures from which the likelihood for the presence or absence of ground water can be inferred. Over the years it has been established that their relative success depends largely on the geological environment and the experience and skill with which they are applied. Thus, apart from knowing the geological conditions of the area, the correct choice of a suitable technique requires an intimate knowledge of the basic principles, application possibilities, interpretation techniques as well as advantages and limitations of each method.

Hydrogeology involves a wide variety of disciplines that are available to the hydrogeologist of which geophysics is only one, to investigate the hydrodynamic features of the subsurface waterbearing formations. These disciplines include surface geology and hydrology, surface and down-the-hole geophysics, drilling, borehole development, pump testing and finally processing and integration of all available data which should ideally include mathematical aquifer modelling.

From this it is evident that a ground water survey is a team effort and all these techniques are complementary. The main advantage in employing geophysical techniques to ground water exploration, lies in the cost benefit. As the depth increases, the relative cost of a geophysical survey becomes more favourable. In a large ground water survey it should be common practice to drill a few boreholes (unless some already exist in the area) to calibrate the geophysical interpretations. Therefore geophysics will never entirely replace exploratory drilling nor the pump and this should never be the object of a geophysical survey.

Geophysical methods employed in ground water exploration and studies can be divided into two groups; those that utilize artificial fields (eg resistivity, seismic) and those utilizing natural fields (eg gravity, magnetics). When using artificial fields, it is possible to vary for instance the depth of investigation and in addition more quantitative determinations of depth, thicknesses and dips can be made. The methods utilizing natural fields often have the disadvantage of combining the effects caused by shallow and deeper features into one anomaly which makes it difficult to separate these effects during interpretation and complicates quantitative predictions of geological/geohydrological phenomena. For this reason these methods are often used only for reconnaissance.

A brief description of the different surface geophysical techniques used in ground water exploration will be given and their application will be discussed.

Electrical resistivity methods

Because formation resistivity depends largely on the amount of pore fluid present, on the percentage of dissolved salts in the pore fluid and on the clay content of the aquifer, this is the only geophysical method that can give some information on the quality of the ground water, apart from supplying information regarding parameters such as the thickness of the aquifer and the state of weathering. For this reason it is often used to trace the extent of sea water intrusion in coastal aquifers. Under favourable geological conditions estimates can also be made of parameters such as porosity and permeability.

Seismic methods

Of the two seismic methods, refraction and reflection, the former has for many years been the only seismic method employed in ground water surveys. However, with rapid advances in modern technology, shallow reflection techniques have become a feasible proposition even to depths of less than 50 m. Seismic methods are mainly used for an assessment of the state and depth of weathering, thickness of the overburden and rock quality. The prime energy source is explosives although with modern electronic equipment stacking of seismic traces to enhance the signal-to-noise ratio combined with mechanical energy sources are well advanced and are widely used. A big disadvantage in the refraction technique is its inability to resolve layers with low velocity sandwiched between layers with higher seismic velocities.

Magnetics

This method, which is easy to apply, inexpensive and fast, has proved to be extremely valuable in tracing dykes and margins of intrusive sheets. Airborne magnetic surveys can cover large areas quickly and can be used for regional surveys.

Gravity

In geohydrological investigations gravity prospecting is used mainly to determine the bedrock profile below a cover of unconsolidated sediments and to determine karstic conditions in dolomitic terrain. It is, however, slow and data reduction is a tedious operation.

Electromagnetic methods

These methods are used mainly for locating fracture zones under a soil cover. The effectiveness of airborne electromagnetic methods, which have the advantage of rapidly covering large areas, however, is severely hampered by the presence of conductive overburden. Ground EM surveys which can use lower frequencies are also adversely affected by low resistivity surface layers, but not as severely as airborne techniques.

Infrared thermometry

This remote sensing method is widely used in geohydrology to measure the earth's surface temperature through the detection of infrared radiation. By this method it is possible to detect small and shallow aquifers under arid conditions and to detect points of discharge of ground water to, for instance, the sea or from karst channels.

Borehole logging

Geophysical borehole logging consists of the measurement and interpretation of the following properties of the subsurface and its contained fluid: resistivity, water conductivity and temperature, natural radioactive radiation, density, porosity, seismic velocity and borehole diameter. From these measurements geological correlations between boreholes can be made, total porosities determined, and high and low water yielding zones identified.

The methods mentioned above will be illustrated with case histories. The tracing of contaminant movement in aquifers with geophysical techniques as well as new developments in the field of geophysical methods as applied to ground water exploration will also be touched on briefly.

R Meyer and J H de Beer

DOLOMITIC AQUIFERS : A REVIEW WITH PARTICULAR REFERENCE TO THE SOUTHERN AND WESTERN TRANSVAAL

by J R Vegter
Geohydrology, Directorate of Water Affairs

Some of the most important aquifers of South Africa are found in Proterozoic dolomitic strata which outcrop over an area of more than 30 000 km^2 in the Transvaal and Northern Cape. The most extensive dissolution of dolomitic strata is found in southern and western Transvaal. Here, the Malmani Subgroup which consists of alternations of dolomite, chert and thin lenses of shale and limestone and capped by chert breccia, is concealed over wide areas by a mantle of red sandy soil and residual debris, which in places reaches thicknesses of up to 150 metres. This mantle, together with the underlying karstified dolomite, constitutes the ground water reservoir. At the same time it is a formidable drilling obstacle.

The Malmani Subgroup has been intruded by at least four groups of dykes, which compartmentalize the dolomitic formation into more or less independent hydrologic units ranging in area from less than one to several hundred square kilometres. Most of the springs issue on, or near to the contacts of dykes, of the underlying Black Reef quartzite, or of the overlying clastic sediments of the Pretoria Group. The flows of the major springs range from 0,1 to 1,0 m^3/s and give rise to streams such as Schoonspruit, the Klip, the Mooi and others.

The availability of copious supplies from springs or perennial streams rising from the dolomite determined in the previous century the location of towns such as Potchefstroom, Pretoria and Lichtenburg. Likewise, from the inception of gold mining in 1886 up to 1923, Johannesburg and other towns on the Witwatersrand were practically solely dependent on dolomitic ground water supplies.

Further development of dolomitic ground water in the Klip River valley for urban and mining use by the Rand Water Board was however precluded by the Government's attitude that the spring flow should be maintained for downstream riparian land owners.

After World War II the problems of coping with large inflows of water in gold mines on the Far West Rand, originating from the overlying Malmani dolomite, led to the adoption of a policy of dewatering with the unavoidable result of sinkhole formation and subsidence on a large scale. These developments necessitated intensive geophysical, hydrogeological and engineering geological investigations and much exploratory drilling, with the result that a mass of data on the dolomitic aquifers has been acquired. The most important results are given in the text.

The severe drought of the last few years has renewed interest in the dolomitic ground water within the distribution area of the Rand Water Board, as a source for emergency supply. About 1 000 million m^3 of ground water could be abstracted over an area of about 3 000 km^2 without running serious risks of sinkhole formation and land subsidence. If the dolomite aquifers were to be exploited on the basis of assured yield and their storage integrated with that of Vaal Dam a supply in the order of 500 million m^3 per annum could be obtained, which would be additional to the current assured yield of the dam. The economic feasibility of such an integrated system and the various ways in which this could be accomplished, has still to be studied.

J R Vegter

GROUND WATER MODELS AND THEIR APPLICATION TO GEOLOGICAL PROBLEMS

by F D I Hodgson
Institute of Ground-water Studies, UOFS, Bloemfontein

1 INTRODUCTION

Geohydrology, as a science, started during the late nineteen hundreds with the formulation of Darcy's law. During the next eighty years several new equations were formulated and up to 1968, geohydrological investigations were normally performed by geologists. In 1968, the first computer models which describe the flow of ground water through an aquifer, were developed. Thereafter, mathematical modelling developed rapidly and is presently a highly specialised field.

Advanced numerical computer techniques are presently utilized to simulate the movement of ground water. Finite difference, finite element or global element techniques are commonly applied to predict the response of an aquifer to specific external influences. The types of problems which are investigated in this way, range from water-supply to dewatering problems, including the study of mineralization of contaminant movement.

Several examples of ground water models which have recently been applied to South African situations, will be discussed. Some of these apply directly to mining problems, while other relate to water-supply and mineralization movement. The following case histories of ground water modelling will be presented:

(i) dewatering of an open-cast mine,
(ii) ground water in coal mines, and
(iii) exploring coastal aquifers

The problems associated with each of these situations will be discussed in general in this abstract, while actual case histories will be given in the presentation. This will enable the geologist, engineer and manager to evaluate the merit of ground water modelling according to individual circumstances.

2 DEWATERING OF AN OPEN-CAST MINE

Ground water influx into open-cast mines could cause problems in a variety of ways. The following problem areas can be identified:

(i) dewatering of mines costs money,

(ii) if the ground water becomes polluted or if it contains dissolved solids higher than that specified by legislation, it cannot be disposed of in public streams,

(iii) dewatering the mining area will have an effect on the water reserves in surrounding areas,

(iv) long-term influx into the mine will depend on the amount of recharge from rainfall, as well as the geometry and proximity of barriers,

(v) excessive ground water abstraction is to be avoided, because the water could be needed for water-supply in the future, and

(vi) under specific circumstances, slope instability could be caused by ground water movement.

The type of ground water model which is required, should therefore be capable of predicting the following:

(i) pumping rates to lower the water-table to specific levels in point and time,

(ii) the areal response of the aquifer to guard against unwanted effects,

(iii) optimal spacing of dewatering points, and

(iv) the effect of disposal of the mine water into nearby systems.

3 GROUND WATER IN COAL MINES

Until recently, ground water has not been a serious problem in any of the South African coal mines. However, with the introduction of increased underground extraction by longwall and stoping methods, the overlying strata is collapsed. As a result of this, ground water within these rocks drains into the mine workings. Flooding of portions of the mine, contamination of the water in these areas and the dewatering effect which this has on the surrounding areas, are the immediate concerns.

The situation is generally so complex that individual components which act upon the system can only be evaluated by means of a ground water model. Models of this kind should predict the rate of ground water influx and extent of the dewatering cone. Pollution aspects can also be studied with the aid of the model, but to date this has not been done in any of the mines which have been investigated.

4 WATER-SUPPLY FROM COASTAL AQUIFERS

Coastal aquifers have the serious drawback that sea-water would flow into them, as soon as extensive ground water abstraction commences.

This salination is to be avoided, since aquifers which are contaminated in this way, are rendered useless for many years, until the natural movement of ground water towards the sea has again displaced the salt water. The latter process could take tens or hundreds of years, depending on the permeability of the aquifer and the natural gradient of the water-table. Apart from rendering an aquifer useless from a water-supply point of view, the salt water will also attack foundations of buildings and affect vegetation.

However, if ground water in coastal aquifers is not utilized, vast quantities of ground water will be lost to the sea. A system is therefore to be designed whereby ground water abstraction can be optimized. This is where a ground water model is invaluable.

A ground water model for coastal aquifer abstraction is considerably more advanced than the models discussed until now. The fresh water/salt water interface, which is moving all the time, is one of the main complicating factors. Ground water models of coastal aquifers should be able to site abstraction points, specify quantities of water to be abstracted at each of these localities, predict the movement of the interface and consider recharge from rainfall.