Monitoring groundwater quality in South Africa: Development of a national strategy#

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Abstract

Little is known about the temporal distribution of groundwater quality on a national scale in South Africa. The effective management of the country's groundwater resources is thus difficult and a need exists for a national network for monitoring groundwater. A literature-based project was initiated with the aim of identifying practical strategies to be used in the establishment of the desired network. Prior to identifying possible strategies, a statement on monitoring network objectives was developed. Cognisance of special constraints and considerations such as responsibility and funding was also taken. Various approaches and strategies for establishing national or regional monitoring networks were evaluated, the most appropriate of which were proposed for use in the establishment of a South African network. The strategies considered aspects such as information needs, available resources, monitoring frequencies, funding and the use of a pilot-scale study to initiate the network. A network manager and a Review Committee should be appointed and be responsible for the establishment of the network. Some technical issues had to be considered owing to their impact on the strategies to be adopted. Empirical and hierarchical approaches to the development of the network were considered essential. Work on the network has subsequently started and many of the proposed strategies have been adopted.

Introduction

Knowledge concerning the spatial distribution of groundwater quality in South Africa on a national scale is still limited, with Bond (1946) remaining the major reference source. Although some progress has been made in this regard during the last five years (Cogho et al., 1992; Fleisher, 1990; Levin et al., 1989), much still remains to be done. The present initiatives of the Department of Water Affairs and Forestry (DWAF) will further enhance regional groundwater quality characterisation and improve our knowledge. However, almost no information is available concerning temporal changes in groundwater quality. This lack of information makes it difficult to effectively manage the country's groundwater resources. A need therefore exists for the establishment of a national program of groundwater quality monitoring.

The Water Research Commission (WRC) was approached to fund a one-year literature study in order to provide impetus to the establishment of a national network for groundwater quality monitoring. The objective of the research was to develop a practical strategy for monitoring groundwater quality on a national scale. The following were identified as important considerations:

- the purpose of a national monitoring program
- the cost and manpower available for the monitoring program
- the most important areas to be covered (major pollution sources, sole-source aquifers)
- the variable nature of groundwater over short distances (representativeness)
- methods of sampling and frequency, analysis, data storage and information reporting
- possible linkage to national networks for surface-water quality monitoring.

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At the outset it was recognised that practical strategies would be required if a national network is ever to be established in South Africa. Such strategies need to be aimed at conquering the many challenges and problems which will have to be overcome. These include the large areas involved, the high degree of spatial variability and the resources required to establish the network. Further, it was noted that no national effort will ever be perfect. An integrative, building approach and the adoption of positive philosophies are seen as ways of ensuring that a national monitoring network can become a reality.

Research approach

The approach to the design of monitoring networks has rapidly evolved over the last few years (Sanders et al., 1987). Networks are now designed on a systems approach, which provides a framework for a logical flow of information. The development of an objective statement is central in the whole process of network establishment and operation. Objective statements must be flexible and dynamic so that the statement can be modified or be allowed to evolve as circumstances and knowledge change. The following objective statement was proposed for the national network:

> **The objective of a national groundwater quality monitoring network is to provide ambient groundwater quality information on a national scale over the long term so that national water managers and planners have available to them general information pertaining to quality trends and status in both space and time for resource planning and management purposes.**

Prior to addressing possible strategies, some special constraints and considerations were appraised. Although the responsibility for establishing and funding a national network rested with DWAF (DWAF, 1992), the state could delegate some of the responsibility for data collection to other organisations, such as Regional Services Councils and Municipalities. These major water users could also provide assistance and financial support to

establish the network. Current trends in groundwater management in South Africa (DWAF, 1992) support the need for groundwater quality information. The need to integrate groundwater quality information with surface-water quality information was also recognised. The lack of geohydrological knowledge on a national scale was identified as a limiting factor. In some areas, regional and local information is available to facilitate the establishment of a network. In areas with little or no information, strategies are required to overcome this shortcoming.

Identified strategies

Strategies that were used in the United States of America and Europe to establish large-scale groundwater monitoring networks and groundwater protection programs were studied (Vrba and Pekny, 1991; Engelbrecht, 1990; Kozlovsky, 1988; Ackerman, 1987). In some cases, literature covering surface-water programs was also evaluated. Strategies and approaches employed in the establishment of the South African networks for monitoring surface-water quality (Harris et al., 1992) were considered in depth. Conclusions were that numerous different approaches could be used and that a set of strategies, rather than a single strategy, was appropriate.

Information

The definition of groundwater quality information is a complex task. The inherent differences between surface water and groundwater contribute to the complexity. The determinands to be included in the monitoring list are subject to a trade-off between groundwater quality information needs and available financial resources. The general but short list of chemical determinands presented in Table 1 should be used to define trends and water quality for domestic, agricultural and industrial use. Furthermore, special surveys, carried out in conjunction with national monitoring, can be used to collect information about constituents that are excluded from the national monitoring list.

TABLE 1
THE GENERAL LIST OF CHEMICAL DETERMINANDS TO BE USED TO DEFINE TRENDS AND WATER QUALITY FOR DOMESTIC, AGRICULTURAL AND INDUSTRIAL USE

Field measurement (where possible)	Laboratory analysis
Temp	EC
EC	pH
pH	Na
T.Alk	K
	Mg
	Ca
	Cl
	SO_4
	T.Alk
	NH_4
	NO_x
	DOC
	TDS (calc.)

Resources

From a practical point of view, a full national monitoring program cannot be put in place immediately. A strategy of initiating monitoring in priority areas was, therefore, deemed essential. As resources allow, the areas being monitored can be extended. Various information tools were identified that would facilitate the definition of priority areas to be monitored. These included a groundwater-users map (DWAF, 1993), the national aquifer vulnerability map (Reynders and Lynch, 1993), the geohydrological regions and subregions map (Vegter, 1990), the national electrical conductivity map (Levin et al., 1989) and, as they become available, regional hydrogeological maps. The spatial representativeness of the water-quality data collected from the priority areas, however, needs to be addressed. It was beyond the scope of the research project to tackle such a complex and demanding issue. The issue was referred to the National Monitoring Review Committee for consideration at an appropriate time. As a practical strategy to overcome the problem of defining priority areas, towns currently using groundwater should be considered to have the highest immediate priority and be used to initiate the network. Such an approach offers several advantages, particularly financial advantages, and will allow a network consisting of approximately 300 stations to be established relatively quickly and cheaply. The water-supply managers can also be used to collect the water samples on behalf of DWAF.

Time

A long-term commitment must be made towards implementing a national program for monitoring groundwater quality. This commitment is on the understanding that it may be years before the tangible benefits of the initiative become evident. Even though annual or biennial monitoring is the most common monitoring frequency for national networks, a 6-month interval for approximately 5 years was selected. This strategy is aimed at removing network teething problems relatively quickly and obtaining usable data sooner than if a less frequent sampling interval were used.

Funding

Funding and logistical support are critical. Most of the strategies that were examined were geared to making full use of available resources and keeping costs to an absolute minimum. During the study, the financial requirements for the establishment of the South African national monitoring network were not determined. However, DWAF needs to make adequate financial and logistical provision for this effort. Additional financial and logistical support from other sectors and lower levels of government, which could either make use of the information or are groundwater users, also needs to be secured. In line with this strategy, all hydrological monitoring networks should be integrated. The structures within DWAF need to be re-evaluated to promote efficient and effective network establishment, operation and integration. The Directorate of Geohydrology's role and participation also need to be addressed. Nonetheless, an experienced geohydrologist must be used in the process of developing and managing the groundwater network.

Review committee

As a means of overcoming the size of the task and ensuring momentum in the initiative, a network manager and a Review Committee need to be appointed. The network manager would be dedicated to the task and would manage the design, implementation and on-going operation of the network. A master plan would have to be compiled to guide the process. The network manager would

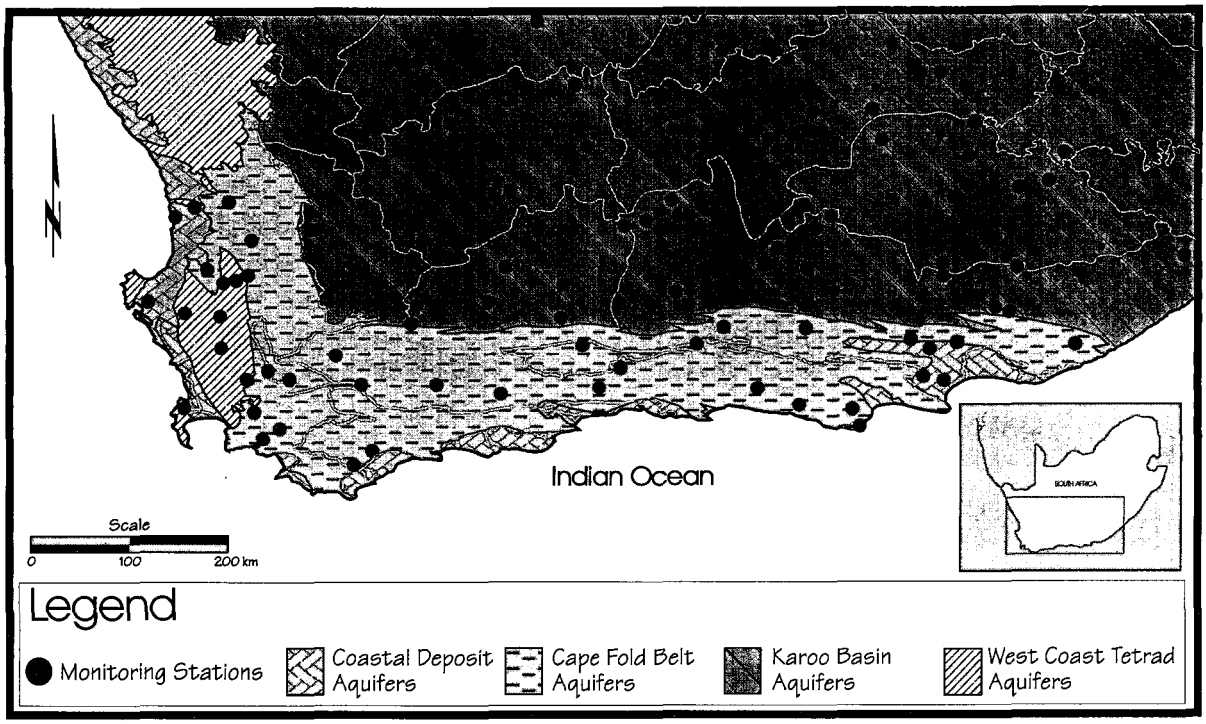

Figure 1
The Western Cape pilot-scale network of monitoring stations (After Vegter, 1990)

be responsible to the Review Committee. This committee could consist of the Groundwater Quality Task Group convened by DWAF (Braune et al., 1991). The group will have various functions to fulfil, including final decision-making, checking that the master plan and target dates are being adhered to and lobbying in various quarters for additional financial support.

Pilot study

Based primarily on experiences in the United States of America (Engelbrecht, 1990; Hirsch et al., 1988; Youngman, 1981), a pilot-scale study area will be used in the initial implementation of the network. Such a strategy will allow logistical problems to be addressed and teething problems to be solved before embarking on the establishment of a national network. The Western Cape can be used for this purpose as it is particularly vulnerable to pollution and a number of smaller towns and villages rely on aquifers as either sole or partial sources of water.

Technical

The literature study did not address all technical aspects that need consideration in the design of a monitoring network. Technical aspects are not usually addressed at a strategic level, but rather during the network design stage. Four components are nonetheless important strategic issues as they play an important role in defining network-resource requirements. Between 400 and 1 000 monitoring stations will be appropriate for the South African monitoring network. Existing boreholes should initially be used, but specially constructed, dedicated boreholes will ultimately be required. A sampling-protocol document will be required to define sampling procedures. This document should be based on Weaver (1992). The selection of laboratories to do the chemical analyses, as well as network quality assurance and quality-control mechanisms, are also necessary. Where possible, existing structures should be used.

Network

Two global strategies were continually promoted throughout the study. An **empirical approach** and a **hierarchical approach** are means of initiating the installation of a national monitoring network. The network should start at an unsophisticated level and work toward the ideal. Future improvement and modifications could then be knowledge-based. The acceptance of these two approaches has many benefits, particularly during the early stages of network design and implementation. These include easy station selection, simple sampling protocol definition and integration into other networks. The establishment of a representative monitoring network will not occur overnight. This major undertaking will require hard work, continual learning and dedication. The desire to achieve and the commitment to succeed by the organisations and people responsible for the network establishment are vital. Support for the team members will be required from all quarters. The proposed Review Committee will have a major responsibility in this regard. Starting the South African monitoring program with simple building strategies while working toward feasible and attainable goals is considered essential.

Implementation of research findings

Since the completion of the literature study and the publication of the research report (Parsons and Tredoux, 1993), DWAF have started to implement some of the identified strategies (Simonic, 1994). A network manager has been appointed. The Western Cape was selected for the pilot-scale monitoring network (Fig. 1) and a national monitoring network sampling protocol document, based

on Weaver (1992), is currently being prepared. Approximately 100 monitoring stations have been included in the pilot-scale network. As a starting point, between 4 and 6 stations were selected from each geohydrological region or subregion (Fig. 1). The demarcation of the regions is governed by lithology and based on the work of Vegter (1990). Only existing stations were considered and these include springs, open boreholes and equipped boreholes. Stations which reflected point-source contamination were specifically excluded from consideration as the national network aims to monitor ambient conditions.

The specific stations in each region or subregion were selected by a hydrogeologist familiar with the area. Only viable aquifers were considered for monitoring. No attention was paid to vertical stratification. As both private and DWAF-owned boreholes are included, varying degrees of information exist for each station. Attention is currently being focused on gaining more information from each station and determining the representativeness of each monitoring point for the geohydrological region and subregion in which it is located.

Two sampling runs were carried out in November 1993 and May 1994. A third sampling run is planned for November 1994. Much of the infrastructure required to establish and manage the national monitoring is now in place. Preliminary working procedures, including data handling and analysis procedures, have also been developed. Once the Western Cape network for monitoring groundwater quality is running smoothly, attention can be paid to expanding the network to cover the remaining three-quarters of the country.

Conclusions

The key factors to the successful establishment of a national network for monitoring groundwater quality are:

- obtaining adequate financial resources
- appointing a Review Committee to guide the process, and
- appointing a network manager to administer the process.

Initiating the national network using a pilot program was considered fundamental to the attainment of a national monitoring network for groundwater quality. The network design and implementation should be activated immediately. Further, the strategies identified during the study should be considered in all further deliberations regarding the national monitoring network for groundwater quality.

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