Executive Summary

1. BACKGROUND TO THE STUDY

1.1 Introduction

The agricultural sector has been identified as the biggest user of groundwater in South Africa (DWA&F, 1992). It is estimated that 78% of all groundwater abstracted is used for irrigation, 7% for rural domestic purposes and 6% for stock watering. Only 4% of groundwater abstracted is used in the urban environment. Traditionally, however, the urban users have received the most groundwater research and investigation attention. As a result, little is known about the status of groundwater used by the agricultural sector in South Africa.

2. PROBLEM STATEMENT AND STUDY OBJECTIVES

It is recognised worldwide that the agricultural sector contributes to diffuse contamination (Foster and Bath, 1986; Gui, 1987; Pionke *et al.*, 1988; Sommerfeldt *et al.*, 1988). Problems include irrigation practices, animal feed lots and the use of fertilizers, pesticides and herbicides. Point sources of pollution which exacerbate the problem include septic tanks and pit latrines and the disposal of household and agricultural waste products.

Research has been undertaken in specific areas where the quality of groundwater has had an impact on agricultural activities. Areas such as the Sprinkbok Flats, Breede River, Fish River (Middelton) and the Hex River Valley are some examples. On the whole, however, little quantified information is available as to the impact of agricultural practices on groundwater resources and the status of such resources.

Further, it was recognised by the Ground Water Quality Task Group that much could be achieved in terms of protecting groundwater from contamination by agricultural activities by education (Braune *et al.*, 1991). The transfer of information from the groundwater community to the agricultural sector is urgently required. In addition to quantifying the extent of the problem in South Africa, the research effort can be used as a means of preparing and transferring this sort of information. Approximately 90% (by volume) of groundwater users will thus benefit directly from this work.

The initial research objectives of the research programme were as follows:

a. To quantify the impact that agricultural practices have on the quality of groundwater resources in South Africa.
b. To identify which practices have the most serious impacts.
c. To identify practical and easy-to-implement strategies and practices which can be used to prevent or reduce contamination.
d. To prepare a non-technical booklet, in four languages, which transfers the information to farmers and members of the public associated with the agricultural sector.

A one year literature study was undertaken in order to provide some general information concerning the impact of agriculture on groundwater and present known cases of such contamination in South Africa. The study showed that little quantified information regarding known cases of groundwater contamination resulting from agriculture exists. It was, however, possible to highlight those agricultural activities which posed the most serious threat to the quality of South African groundwater resources. Based on the results of the literature study, the project Steering Committee proposed that the research objectives be revised.

The revised research objectives were thus as follows:

a. To confirm the contamination impact on groundwater quality resulting from those agricultural activities identified as posing the most serious threat, namely

   i. Intensive animal husbandry (IAH)
   ii. Use of sewage sludge as a fertilizer
   iii. Use of inorganic fertilizers
   iv. Irrigation
   v. Use of pesticides

b. To identify practical and easy-to-implement strategies and practices which can be used to **prevent** or **reduce** contamination resulting from agricultural activities.

c. To prepare a non-technical booklet, which transfers the information to farmers and members of the public associated with the agricultural sector.

Two research products resulted namely:

a. A *non-technical handbook* - which sets out practices that may be used to prevent or reduce groundwater contamination by agricultural activities ("Handbook of Groundwater Quality Protection for Farmers" - available from the WRC); and

b. A *scientific report* - which presents the findings of the literature study as well as the results of the individual investigations into the five most serious threats listed above (this report).

3. METHODOLOGY AND REPORT LAYOUT

Of the top five potentially contaminating activities, three were identified as not having been sufficiently studied in the field. These activities were intensive animal husbandry (IAH), use of inorganic fertilizers and sludge application to land. Three field study sites were chosen across the country for each activity and studied in detail. Several studies have already been conducted on the use of pesticides and the impacts of irrigation on groundwater quality in South Africa. It was not thought necessary to conduct further field research and this information was collated in the form of essays and is presented in this report.

Details of the methods, results and conclusions of the field investigations and summaries of the information collated in essays are presented in this report. The supporting data from the field studies are contained in an Appendices Volume (available from the CSIR). One of the main aims of this study was to inform farmers about contaminating activities and provide guidance on Good Farming Practices (GFPs). Information on GFPs was collated during course of the specialist studies and presented in an accessible format in a handbook. In addition to GFPs relating to the five activities researched in detail, a chapter on pollution at the farmstead (septic tanks, underground fuel tanks, etc.) has been included. Background information on the occurrence and vulnerability of groundwater and nitrate, the most common contaminant, has also been included in the handbook.

4. SUMMARY OF MAJOR RESULTS AND CONCLUSIONS

An impact on groundwater quality was seen at all the field study sites with vulnerable, shallow, unconfined or semi-confined conditions. Nitrate was the most common agricultural contaminant evident in groundwater sampled. Nitrate distribution and isotopic analyses of NO_3-N indicated the most important sources to be sludge, manure and soil biota. Elevated DOC levels were associated with sludge application and IAH. Potassium, ortho-phosphate and microbiological indicators of faecal pollution, contaminated groundwater as a result of IAH practices.

The greatest impact was seen at a site where **sludge** was applied to agricultural land. Nitrate levels were elevated to 268 $mg.l^{-1}$ in the dolomitic aquifer directly beneath the sludge applied area and were persistent to a level of 30 $mg.l^{-1}$ to a distance of greater than 1 km. However it should be noted that sludge was applied at this site primarily as a means of disposal and application rates were not tied to crop requirements. There was therefore a long history (15 years) of over application. At the other sludge sites, where sludge was used to condition sandy soils, limited increases in nitrate levels were seen. At one site, shallow groundwater (< 3mbgl) was contaminated to a maximum of 38 $mg.l^{-1}$ but this was not persistent with depth. This site also had a long history of application. At the other site, only a 2 $mg.l^{-1}$ increase in nitrate levels was noted during the first season of application. Cumulative impacts of sludge application therefore appear to be significant.

Increased DOC levels were seen at 2 of the sludge field sites in shallow groundwater samples: to 30 $mg.l^{-1}$ at site C and to 10 $mg.l^{-1}$ at site A.

Significant impacts on groundwater quality were seen at **IAH** site B, overlying a shallow alluvial aquifer. Pollution was associated with livestock concentration in pasture and irrigation of effluent. The highest nitrate levels seen at this site were 156 $mg.l^{-1}$. Increased levels of DOC, potassium, ortho-phosphate and faecal coliforms were also seen. IAH site A showed some contamination by nitrate and faecal streptococci. Site C showed no contamination as a result of natural aquifer protection and good practices.

Limited impacts on groundwater quality were found to be associated with the application of inorganic **fertilizers**. High nitrate levels (>10 $mg.l^{-1}$) were seen at all the fertilized sites, however, the source of

this nitrate was not exclusively inorganic fertilizers. Fertilizers are believed to contribute to high nitrate levels but other activities, such as the application of organic fertilizers and deep rip ploughing are also thought to play a significant role.

The literature reviewed in the essay on the impact of **irrigation** showed that percolates from the root zone and irrigation return flow can cause the salinisation of groundwater in irrigated aquifer systems. Significant salinisation has been reported in groundwater underlying the irrigated lands of the Great Fish-Sundays River basin (TDS increased from 2 000 to 3 400 $mg.l^{-1}$). At the Vaalharts irrigation scheme it is estimated that between 17 and 63 million cubic metres percolate to the water table annually carrying nearly 30 000 tons of dissolved salts. This has resulted in increased groundwater salinity, a rise in the water table and some water logging of soils.

The review of **pesticide** contamination of groundwater showed that limited, scattered information is available. In the early 1990s, a study showed that the herbicide atrazine was present in most rivers and dams in the maize producing areas of South Africa. These included the Olifants, Vals, Vaal, and Renoster rivers. This river water is used in many areas for irrigation and therefore where aquifers are recharged, acts as a source of pesticide contamination. Tests of the herbicides methochlor and terbuthylazine have shown that they leach beneath the root zone in a wide variety of South African soils.

5. RECOMMENDATIONS FOR FURTHER RESEARCH

Details of further scientific work related to the specialist studies are given in those chapters. It is recommended that longer term monitoring of groundwater quality and agricultural activities at the study sites listed below would improve the understanding of the processes at work.

- Sludge site B.
- IAH site B
- Fertilizer sites B and C.

As nitrate is the main contaminant of concern, it is recommended that further investigations into the impact of elevated nitrate levels on the environment and human health should be conducted. More detailed studies are required on the processes of nitrate accumulation in groundwater from anthropogenic and natural sources.

New areas of study warranting further research are:

- The impact on groundwater quality of deep 'rip' ploughing new areas for cultivation. This is thought to release nitrates derived from soil biomass decaying as a result of exposure, but the level or persistence of contamination is not well documented.

- Methods to determine the rate of bioavailable nitrogen release from organic sources such as sludge, different soil types and manures.

- The mobility and persistence of hormones and steroids used in IAH is a new area of research that has not received attention in South Africa. If effective, analytical techniques are available, this area should be investigated.

At the moment knowledge and expertise of pesticide impact on the environment and groundwater in particular is widely scattered in South Africa. Contact between the various persons is informal and occasional. It is strongly recommended that a vehicle be established that will encourage focussing of this expertise. This will enable increased public and/or government interaction with more effective results. The ideal vehicle would be electronic interlinking of the expertise and opening the group to interested parties. The first step would be to identify the role players and establish a working group.