

LANDUSE IMPACTS ON THE WATER QUALITY OF THE ZWARTKOPS CATCHMENT

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Preface

"Almost every activity which takes place on land affects our water resources in some way.

To control these impacts on the resource, planning must be based on water catchment rather than political borders. Actions that cause or contribute to decreasing resource quality can only be controlled if water- and land-users change their behaviour. They will therefore be encouraged to choose and develop technologies that meet the standards set by Government and develop appropriate codes of practice."

(White Paper on a National Water Policy for South Africa, April 1997)

To achieve sustainable levels of economic development, which are within with the country's carrying capacity, society needs to adopt rigorous and environmentally deterministic approaches in the planning and management of development. This implies long term ecological factors rather than short term economic forces should be the primary determinants of landuse and resource management decisions. The environmental impact assessment process is one such approach, which is used to assess the impact of landuse practices on both the economy and the environment.

Accurate environmental impact predictions are therefore important in day-to-day environmental management, in improving resource planning and allocation, and in demonstrating to the public that government agencies are competent in the control and management of resource development activities both in the public and private sectors. Environmental impact assessments also need to be appropriate to the issues and problems at hand and techniques used should be suited to the level of information needed for management decision-making.

Water quality assessments are but one component of an environmental impact assessment but are necessary for the management of water resources. The process followed in a water quality impact assessment should therefore have the same basic stages as that used in an environmental impact assessment and should make use of the same techniques. This dissertation is such a water quality impact assessment in the Zwartkops Catchment, making use of the environmental impact assessment process and some appropriate techniques. The structure of the dissertation is as follows: Chapter 1 provides the background to and reasons for the study; Chapter 2 discusses the various methodologies and techniques used in the impact assessment; Chapter 3 is an impact assessment of the activities in the

Zwartkops Catchment on its water quality and Chapter 4 contains the conclusions and recommendations.

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Abstract

The process of environmental improvement is one which should begin with an assessment of the current situation. Such an assessment, an environmental impact assessment (EIA), provides a broad picture of the impact of activities on the surrounding environment and furnishes management with the information required for planning of a detailed environmental management strategy for the future. Historically, EIA's have been used to assess the impact of a single planned development project, however, the merits of extending EIA from projects to plan-making have been recognised. Despite this recognition, EIA's in plan-making have not been well tested and an obvious requirement for the further development of the EIA process is through the development of case studies relating to EIA's in plan making. An example of where EIA could be used in this context, is in the making of catchment management plans.

The Zwartkops Catchment has been subject to a deterioration in water quality over recent years. Landuse in the upper reaches is predominantly farming, while in the lower catchment, increasingly intensive urban development occurs. The impacts from these developments on water use in the catchment and on the aquatic ecosystem necessitated an assessment of the impact of landuse activities on the water quality in the catchment to allow for the development of the Zwartkops Catchment Water Resources Management Plan.

This dissertation is an application of the environmental impact assessment process to assess the impact of activities in the Zwartkops Catchment on the quality of its water resources, where an understanding of the impact that catchment characteristics and activities have on the water quality underlies the success of the assessment, as well as the management the water resource. In line with any environmental impact assessment, it is also imperative that the concerns of the interested and affected parties be addressed. The environment impact assessment process and techniques have therefore been made use of where appropriate and assessed according to their usefulness in providing relevant information to the water quality manager.

Opsomming

Die proses om die omgewing te verbeter behoort te begin met 'n beoordeling van die huidige omstandighede. 'n Omgewingsimpakbepaling verskaf 'n wye beeld van die invloed van aktiwiteite op die omgewing en voorsien bestuur met die inligting wat nodig is vir die beplanning van 'n omvattende toekomstige bestuurstrategie. In die verlede is omgewingsimpakbepalings gebruik om die invloed van 'n enkele beplande ontwikkeling te beoordeel, alhoewel die waarde van omgewingsimpakbepalings vir die samestelling van planne reeds erken is. Ten spyte van hierdie erkenning is die waarde van omgewingsimpakbepalings vir die opstelling van planne nog nie behoorlik getoets nie en die opvallende behoefte vir die verdere ontwikkeling van die omgewingsimpakbepalingsproses loop dan ook deur die ontwikkeling van gevallestudies rondom omgewingsimpakstudies en die opstel van planne.

Die watergehalte van die Zwartkopsopvanggebied het oor die afgelope jare verswak. In die bolope word grond hoofsaaklik vir landbou gebruik terwyl toenemende intensiewe stedelike ontwikkeling in die laer opvanggebied voorkom. Die invloed van hierdie ontwikkelinge op die gebruik van water in die opvanggebied en op die akwatiese ekosisteme het dit noodsaaklik gemaak dat die invloed van grondgebruikaktiwiteite op watergehalte vasgestel word om sodoende voorsiening te maak vir die ontwikkeling van die Bestuursplan vir die Zwartkopsopvanggebied.

Hierdie verhandeling is 'n toepassing van die omgewingsimpakbepaling om sodoende die invloed van aktiwiteite op die gehalte van die waterbron in die Zwartkopsopvanggebied te beoordeel, waar 'n insig in die invloed van beide die eienskappe van die opvanggebied en die aktiwiteite op watergehalte die sukses van die beoordeling bepaal en uiteindelik ook die bestuur van die waterbron. Soos met enige omgewingsimpakbepaling is dit noodsaaklik dat die belange van belanghebbende partye aangespreek moet word. Toepaslike aspekte van die omgewingsimpakbepalingsproses en -tegnieke is derhalwe aangewend en beoordeel volgens hulle nuttigheid om toepaslike inligting aan die watergehaltebestuurder te verskaf.

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The process of environmental improvement needs to start through a measure of current situations and performance. This provides a broad picture of the environmental impact of certain activities and provides managers of those activities and the environment with information required for planning and decision making (Welford & Gouldson, 1993:57).

Environmental impact assessments (EIA) are undertaken to identify and predict the impact of development activities on mankind and his surrounding environment. They are however not neatly packaged or rigorously followed techniques which are used to solve all planning problems. As early as the 1950's, EIA's were carried out for major developments in North America, Europe and Japan, with a main objective of protecting public health and safety (Munn *et al*, 1989:635). In the 1960's and early 1970's, a growing awareness of the need to ensure successful economic development, while taking environmental impact into consideration, resulted in the need for EIA's which allowed for input from the public into the decision-making process.

The passing of the National Environmental Policy Act (NEPA) in the United States of America in 1969, which included requirements for environmental impact statements for major developments, influenced the development of EIA methods into becoming an important task. Development of EIA in Europe has been based on the economic Community's EIA Directive which was initiated in 1988. However, EIAs had been widely accepted since the early 1970's, prompted largely by widespread opposition to developments with significant environmental impacts (Welford & Gouldson, 1993:32).

The need to carry out an EIA for those activities which significantly affect the quality of the human environment has thus now been accepted in many jurisdictions, including most U.S. states, Canadian provinces, Japan, Australia and several European countries. Many of the lesser developed countries also have been quick to appreciate the benefits of EIAs and procedures are now established in Colombia, the Philippines, Thailand, Botswana and

many other African, Asian and South American countries (Munn *et al*, 1989:637; Wathem, 1989:3).

Identifying and assessing impacts requires collection and manipulation of large amounts of data and communicating the final results to decision-makers and the public. Considerable attention has been given to developing EIA methods and techniques to overcome these problems. During the 1970's, most of the emphasis in EIAs was placed on measurable physical factors, such as air and water quality. Later, biological and ecological factors were included which were more difficult to quantify. This process has subsequently been further expanded to include socio-economic factors, requiring an evaluation of the trade-offs between environmental and socio-economic factors.

The identification and assessment of environmental impacts from development has, however, become increasingly complex due to the diversity of the impacts which may occur as a result of human interference with environmental and social systems. In impact assessments it is also common to have methods and techniques from many disciplines occurring together. These methods and techniques must provide the planner or decision maker with the necessary information and supporting arguments in an understandable format to lead to a conclusion on the overall significance of selecting a particular management action (Fuggle, 1992:766; Bisset, 1987:3).

Such is the case in the Zwartkops Catchment which drains into Algoa Bay in Port Elizabeth. This catchment, although small relative to adjacent catchments, serves many water user sectors and has been subject to a deterioration in water quality over recent years. Landuse in the upper reaches is predominantly farming, while in the lower catchment, development becomes increasingly intensive and is largely residential, comprising both formal and informal settlements, and industrial. This combination of impacts and water user sectors necessitated an assessment of the water quality in the catchment to provide authorities and local communities with the necessary background information in a format which will enable the selection of alternative management actions.

Historically EIA's have been used to assess the impact of a single planned development project. The merits of extending EIA from projects to plan-making have, nevertheless, been recognised due to the similarities between the EIA and plan-making processes

(Wood, 1989:99). Despite this recognition, EIA's in plan-making have not been well tested and an obvious requirement for the further development of the EIA process is through the development of case studies relating to EIA's in plan making. This dissertation is therefore also important as an example of where EIA could be used in this context, that is, in the making of catchment management plans.

While EIAs cover the impact of activities on all environmental and socio-economic aspects, this dissertation will only address the impact of activities in the Zwartkops Catchment on the quality of the water in the catchment. Also, due to the limitation on the length of this dissertation, only a short description of the public involvement in the EIA process is given in Chapter 2 on the methodologies used.

In addition, while a key factor in the EIA process is the consideration of alternatives, this dissertation, due to its limited scope, will not address this aspect. In the context of this application of the EIA process firstly to water quality management and secondly to plan making or catchment management plans, this would entail the consideration of alternative management actions to address the identified and existing water quality impacts. Such a consideration would require additional information concerning the management structures and legislation available, as well as the funding aspects required for such aspects.

1.2 PROBLEM STATEMENT

Increasing population expansion and development, especially in river valleys, are placing growing demands on the available but limited water resources of South Africa. While the water requirements of industry, urban development, agriculture and recreation need to be met in terms of quality and quantity, these activities also impact on the quality of that water resource. Man-made causes are multiple, with a wide variety of activities being associated with short and long-term increases in salts. Another major water quality problem is eutrophication, which is accentuated wherever there is a concentration of humans or animals, as is faecal contamination. A water quality issue which is receiving increasing attention is that of metal and man-made organic compound pollution in industrialised areas.

While the view in the past has been that environmental disruption is the inevitable price to be paid for economic progress, this position has been increasingly challenged in several forums. There is now growing consensus that, given certain preconditions, both economic development and environmental management can be pursued simultaneously. Although any attempt to develop land or water results in some modification of the environment, that impact may be to a significant extent beneficial, particularly with regards to economic growth and social development. Often, however, the environmental consequences are adverse and vary in the degree of intensity and social acceptability. Recognition of these disadvantages has led to increasing pressure for the inclusion of environmental impacts as a consideration in the planning and decision-making of developments. Today water management agencies almost everywhere are highly conscious of the need to identify and evaluate the impact of development on the water resource (Thanh & Biswas, 1990:34).

Recent developments in water resource management have been to adopt a catchment-based water resource management approach, to enable the integrated and holistic management of water quality, quantity and the ecosystem health. This was identified as a major means of achieving sustainable development of water resources at the United Nations Conference of Environment and Development, which took place in Rio de Janeiro in June 1992 (Edwards, 1995:2). Effective catchment management planning rests upon the water quality assessment, based on data monitored in the catchment and existing information on the catchment, to provide the necessary information for the management of that system. The deterioration of water quality, however, usually results from the cumulative effects of concentrated development in river valleys which is difficult to interpret. Cumulative impacts occur when the impacts from one activity combine with those of another to produce a greater impact or synergistic effects. Most impact assessments are not well adapted to deal with these impacts as they usually only deal with specific development proposals (Fuggle, 1992:766).

Main problem question

- How have landuse activities in the Zwartkops Catchment impacted on its water quality?

Sub-questions

- How can environmental impact assessment methodologies and techniques successfully be applied to provide management information for decision making?
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- How do the catchment characteristics impact on the water quality?
- What is the impact of the catchment's infrastructure on the water quality?
- What are the catchment's landuse activities which are likely to impact on the water quality?
- What water users are likely to be impacted on by activities in the catchment?
- What is the water chemistry in the catchment?
- How does the present state of water quality within the catchment compare against the requirements of identified water users?
- What is the impact of landuse activities on the water quality, with regards to the health of the aquatic ecosystem?

1.3 OBJECTIVES

The main objective of this dissertation is:

- To undertake an environmental impact assessment of landuse activities on the water quality of the surface, ground and coastal waters of the Zwartkops Catchment.

Sub-objectives are:

- To make use of environmental impact assessment methodologies and techniques to provide management information for decision making.
 - To outline the catchment characteristics, with regards to their likely impact on the water quality.
 - To outline the infrastructure within the catchment which is likely to impact on the water quality.
 - To characterise the catchment's landuse activities, with regards to their likely impact on the water quality.
 - To characterise the water users within the catchment.
 - To characterise the water chemistry in the catchment.
 - To assess the present state of water quality within the catchment against the requirements of identified water users.
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- To assess the impact of landuse activities on the water quality through monitoring of the health of the aquatic ecosystem.

1.4 CENTRAL THEORETICAL STATEMENT

The central theoretical statement for this dissertation is that environmental impact assessment methodologies and techniques can be successfully applied to assess the impact of landuse activities on the water quality in the Zwartkops Catchment.

1.5 CONCEPTUALISATION

1.5.1 ENVIRONMENTAL IMPACT ASSESSMENTS

The EIA Process

Environmental Impact assessments (EIA) involve the identification and assessment of environmental consequences from development projects, plans, programmes and policies, in an attempt to ensure that the best development alternative is selected. Environmental impact analysis is a process contained in EIA, which has been defined by Fuggle (1992:764) as a *"process aimed at the recognition of causes and effects, a cause being any action which has an effect upon the environment. These effects are the consequences of an action."*

The EIA procedure consists of four main stages: the proposal generation stage; the proposal assessment stage; the decision stage; and the implementation stage (DEA, 1992:5). These stages are described below:

Stage one: Proposal generation: In this stage, the purpose and need of the proposal are defined. Proposals are generated through consultation with authorities and the public. Alternative proposals are identified, as well as the related issues that need to be addressed. These proposals are checked against the policy, administrative and legal requirements.

Stage two: Assessment: A procedure is followed whereby the effects of the proposals are evaluated for both socio-economic and bio-physical environments. A screening or scoping process is necessary to classify the proposals according to the significance of their impacts. All possible mitigatory measures, alternative actions and management plans are considered.

Stage three: Decision: The action which is in the best overall interest of society is identified and approved at this stage. All relevant information is reviewed, the actions to be taken are decided on and any conditions of approval are determined. A document is produced which reflects this decision. The proposal could also be refused, or further information could be requested if insufficient information is supplied. An appeal procedure can also be initiated.

Stage four: Implementation: The proposal is implemented once approval is granted. Measures should be taken to ensure that the proposal is properly carried out, for example by following a management plan and conducting monitoring programmes and audits.

Specific processes for applying EIA may vary from one development proposal to another, however, the general approach to incorporating the environmental input into the development process should be essentially the same. Essential components of EIA are:

- Scoping is defined as a *“very early exercise in an EIA in which an attempt is made to identify the attributes of components of the environment for which there is public concern and upon which EIA should be focused.”* (Beanlands, 1988:34.)
 - A baseline study, which is usually carried out in the initial stages of an impact assessment and involves the collection of background information, either existing or new information, on the physical and biological environmental characteristics and the socio-economic circumstances surrounding the project proposal which may be affected. The most common problem with baseline studies is that no clear objectives are defined prior to the collection of data, as a result superficial levels of information are obtained for a wide range of aspects, which wastes time and resources (Beanlands, 1988:39).
-

EIA methods and techniques

A satisfactory environmental evaluation method should enable the following four tasks to be performed:

- Collection of data on variables relevant to impact prediction;
- Analysis and interpretation of data;
- Identification of significant environmental impacts; and
- Communication of the analysis results (Fuggle, 1992:766).

Although there is seldom a distinction made between techniques and methods used in EIA in the literature, for the purposes of this dissertation, the following differentiation is made between methods and techniques:

- Methods of environmental analysis are "*structured mechanisms for the identification, collection and organization of environmental data in order to analyze impacts. In addition, methods are means whereby information is presented in a variety of visual formats for interpretation by decision-makers and members of the public.*" (Bisset, 1987:9.) EIA methods have also been termed as methodologies, technologies, approaches, manuals, guidelines and procedures (Bisset, 1988:47).
- EIA techniques are specialised procedures for evaluating the impact within environmental analysis. In any EIA a number of techniques may be used to provide data which is then collated, arranged, presented and even interpreted.

Techniques and methods differ in the type of conclusions that can be gained from them and in the role that they play in decision making. Problems are encountered in using these techniques/methods which range from those of identification and prediction to those of decision making. To address these differences and problems, McCall Skutch & Flowerdew (1976:210), attempted the following classification of the techniques/methods, based on functional considerations:

1. Those designed for the identification of impacts (e.g. simple matrices).
-

2. Those designed to assess and qualify the impacts (e.g. quantification and matrices, where scoring is used).
3. Those designed to compare impacts and select the least harmful alternative (e.g. overlay mapping).

No single method, however, is best for all circumstances, rather each method will have its own strengths and weaknesses, as well as demands on specific resources, and should be used accordingly.

Thus, EIA is an information gathering exercise through which predictions can be made and decisions can be taken objectively. It offers the opportunity to develop environmental awareness in management decision making from an early stage, while offering the potential to incorporate any future needs of an environmental management system into the physical design process. The information collected in an impact assessment should be incorporated into an environmental management system, audited regularly and improved through life cycle assessments. EIAs are therefore the start of a never-ending environmental improvement and management programme (Welford & Gouldson, 1993:50).

1.5.2 WATER QUALITY MANAGEMENT ✕

The Department of Water Affairs and Forestry (DWAF), as custodian of South Africa's water resources, is responsible for managing the quality of water. Until the late 1980's, Uniform Effluent Standards were used to prevent a deterioration in the quality of water resources, while certain regulations such as those related to control of mining activities, were used to control activities likely to cause pollution. This approach, however, only addressed point source discharges and a deterioration in the quality of receiving waters continued. The DWAF, therefore, recently changed its approach to the management of water quality from "end-of-pipe" control, which was carried out on an ad hoc basis, to a system based on maintaining the water fit for agreed or specific uses, that is, domestic, recreational, industrial and agriculture. The aquatic ecosystem, although recognised as a user of water, is now considered at part of the water resource which should not have to compete with other water users for the right to use water. The new approach therefore

focuses attention, not only at the quality of wastewater discharged, but also at the quality of the water body receiving that waste water (DWAF, 1991:14; DWAF, 1995a:9).

This new approach towards water quality management, referred to as the Receiving Water Quality Objectives approach, is based on the establishment of water quality objectives, for example a fluoride objective of 1 mg/l, for the various river reaches in that catchment. The establishment of objectives is usually achieved through a consultation process with all concerned users and impacters until some mutual agreement is met. Catchment management strategies are then formulated to ensure that these objectives are attained. However, in order to develop these objectives and catchment management strategies, the catchment characteristics and activities first need to be assessed in terms of their effect on the water resource, and an effective monitoring system needs to be established. Limited resources available to manage water resources dictate the need to prioritize issues which should be addressed. This requires an assessment of the significance of each issue/impact to allow for their prioritisation.

The recent amendments to South Africa's Constitution have instigated a revision of the nation's water policy as well as its water law. This, in turn, has brought about changes in DWAF's emphasis and approach to water resource management as a whole. Notable changes, in terms of water quality management and this dissertation, are the recognition that:

- The objective of managing the resource is to ensure its sustainable use. This means that not only the water quality and quantity should be managed, but also the ecological functioning of the aquatic ecosystems. In addition, water resource management needs to be carried out in an integrated manner which is in line with environmental management approaches (Principle 9 & 15, DWAF, 1997:35).
 - The water resource needs to be managed to ensure that the basic needs for humans and the environment be met (Principle 8 & 10, DWAF, 1997:35).
 - Management of water resources should be carried out on a catchment basis through the establishment of catchment management plans which are established through a public participation process (Principle 23, DWAF, 1997:36).
-

CHAPTER 2. METHODOLOGY**2.1 ASSESSMENT APPROACH**

This impact assessment consists of three components:

- A review of existing information on the catchment characteristics, landuse activities and water related activities. This information was obtained through a literature review, interviews and a scoping exercise with interested and affected parties.
- An assessment of the monitored water quality, ecological and hydrological data to determine the water quality and ecosystem health in the catchment. Details of the monitoring programmes are provided in this section.
- Use of environmental impact assessment methodologies and technologies to communicate the information/data collated above for management purposes. A description of the methods used in this assessment are described in Section 2.2.

Throughout the impact assessment, a public participation process was undertaken. Details of this process are supplied in Section 2.6.

2.2 MONITORING ACTIVITIES IN THE CATCHMENT

Carley (1986:287) defines monitoring as *“the systematic collection and organisation of information, which is to be used in improving the decision-making process; either directly or indirectly by informing the public; or directly as a feedback tool designed for purposes of project management, programme evaluation or policy development.”* Monitoring is therefore used to keep management actions responsive to unforeseen changes in the decision environment and is thus an important management function. Monitoring is used in EIA to:

- improve the knowledge base;
 - improve baseline information;
 - help the public, communities and social development groups to better understand the effects of development;
 - to assist the strategic policy maker in identifying those issues requiring attention;
 - assist developers in identifying the need for adjustments to activities;
-

- detect effects;
- provide information on the status of critical issues which need to be addressed;
- provide feedback on the success/failure of an action;
- test compliance with regulations;
- test impact forecasts; and
- test the effectiveness of mitigation actions (Carley, 1986:290).

The Regional Office of the DWAF initiated a comprehensive monitoring programme of the surface water in the Zwartkops Catchment in 1990, where most of these samples were analyzed for macro chemicals, trace metals and faecal bacteria. The surface water, above and below Uitenhage, was also monitored by Uitenhage and Port Elizabeth Transitional Local Councils and by Gubb and Inggs Wool-washery. Additional monitoring of faecal pollution within the surfzone was also been undertaken by the Department of Health and Port Elizabeth Transitional Local Council.

A monitoring exercise of the groundwater throughout the catchment was carried out in 1993 and, based on the data obtained from this exercise, routine sample points have been established for monitoring the primary aquifer. Details of these monitoring activities are given in Appendix D. A summary of the numbers of samples analysed for selected property and constituent groups for the period 1990 to 1996 is given in Figure 1.

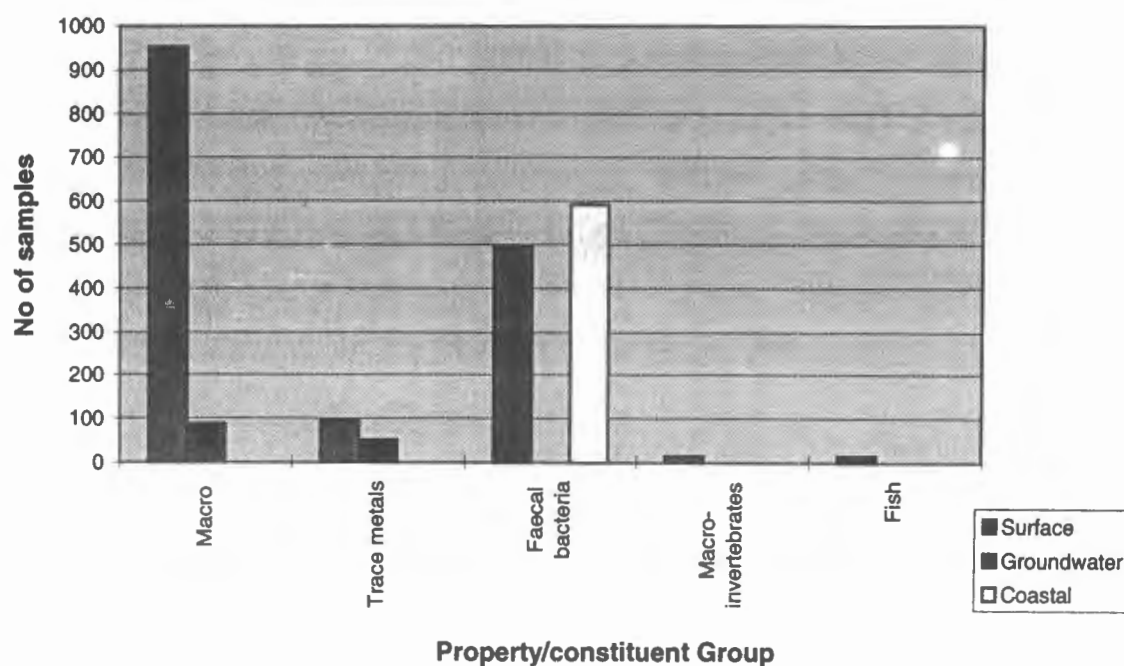


Figure 1. Number of samples per property/constituent group for the period 1990 - 1996

The only gauging stations presently in the catchment for measuring stream or river flow are situated at Longhill on the Elands River and a station, which was recently installed at Nivans Drift in Uitenhage. Continuous monitoring of flow is taken at these stations. There are also sites below the Sand River, Bulk River and Groendal Dams, as well as for the compensation water from the Groendal Dam. To make up for this shortage of data, results from Water Resources 90 simulation modelling of the hydrology were used.

2.3 DATA ASSESSMENT METHODS

The analysis of water quality data is usually complex due to the large variations and ranges of the results, the uncertainty of these results and often, a lack of data. A different set of analysis methods from the conventional statistical methods are therefore usually used to assess water quality data. The following methods were used to assess the chemistry and quality of the water resources in the catchment:

1. Maucha diagrams (Map 12) were used to describe the major ion composition of the surface and ground water. Maucha diagrams were developed in the 1920's and 1930s in order to summarise the major ions in water in a way which would allow rapid comparison between two water samples. Using trigonometry, an eight pointed star symbol was designed, where the anionic concentrations are on the left and the cations on the right. Concentrations are converted to milliequivalents per litre, so that the balance of cation and anion charge can be seen at a glance. The background circle indicates the appearance of a perfectly balanced sample with each ion in the same concentration. In the 1960's, a modification to the symbol was to scale the whole star in proportion to the logarithm of total dissolved salts (TDS) concentration. The diagram is therefore a convenient way to symbolise TDS on a map, while simultaneously giving an indication of salt ratios (Broch & Yake, 1969:933). These diagrams are however most useful in providing an indication of the origin of the water and whether contamination from any source has occurred.
2. Box and whisker plots were used to illustrate the nutrient concentrations measured in the surface water based on available data for the period 1993 to 1996. These plots consist of a box drawn from the 75th percentile to the 25th percentile, constituting the interquartile range. A horizontal line is drawn through the box at the median and the two

box proportions depict the quartile skew. A vertical line (whisker) is drawn from the box to the 5th percentile and the 95th percentile. These plots are therefore useful in assessing the distribution of measured concentrations at each point. In addition, the maximum and minimum values have been plotted on these graphs.

3. The 95th percentile of the available data for each constituent was used as a representative concentration of each constituent. Average or mean values were used for groundwater sampling due to the fact that there were only three data sets available. No time series or trend analysis was carried out as very little flow data was available to allow for an assessment of variability of constituent concentration. Analysis methods were also changed during the data collection period and may have influenced the results.
4. Correlation coefficients were used to determine the correlation between certain data sets. The significance of the correlation coefficients were determined using a critical or minimum values table with a 95% confidence level. The t-test was also calculated for each correlation coefficient and compared to t-distribution tables, also with a 95% confidence level. These tables were obtained from Statistical Methods, 5th edition, by G.W. Snedecor (1956:Appendix).

2.4 ECOSYSTEM HEALTH ASSESSMENT

Aquatic biological communities are important in riverine assessments as the abundance and distribution of aquatic species or groups of organisms reflect immediate to long-term changes in water quality conditions as well as the influences of habitat and flow (Roux *et al*, 1993:275; Dallas, 1995). Alterations of aquatic environments may be detected through changes in the community composition of benthic macroinvertebrates, where streams with rocky substrata and well oxygenated water usually support communities dominated by aquatic insects. A shift in dominance to more tolerant taxa often occurs in response to increases, for example, in sedimentation or nutrient enrichment. The number and types of fish species are also an indication of water quality conditions, where clean water streams support a variety of sensitive taxa such as the redbfin minnows (*Pseudobarbus* sp.). In contrast, fish communities found in polluted waters are frequently limited to tolerant

species such as carp (*Cyprinus carpio*) and mosquito fish (*Gambusia* sp.). In the Zwartkops River Catchment the following biological assessments were performed:

- an instream and riparian habitat assessment;
- a macroinvertebrate assessment;
- a fish assessment; and
- an assessment of the health of the estuary.

2.4.1 HABITAT ASSESSMENT

The habitat status of a river can be defined as a broad-based qualitative assessment of the river's health. This assessment is based on an evaluation of a number of key instream and riparian zone criteria to arrive at a descriptive outline of the status of both instream and riparian zone facets (Kleynhans, 1995:1).

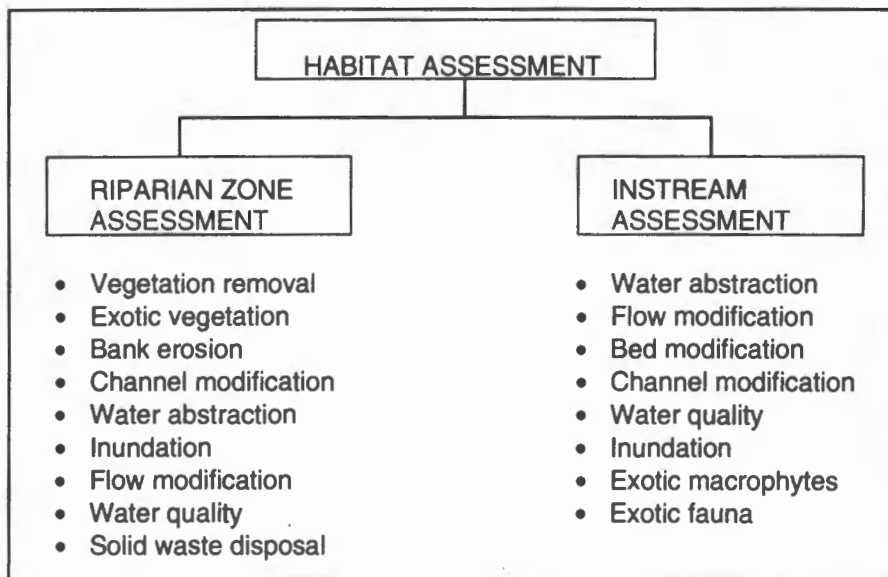


Figure 2: The key components taken into account during river habitat assessment

The habitat status of the Zwartkops River and its main tributaries was determined in March 1995, based on approximately 5 km long sectors of the rivers and making use of aerial photography. Reaches of the rivers subjected to tidal influences that were not included in this assessment, are:

- 1) The Zwartkops River downstream of Perseverance Bridge; and
- 2) The lower 5 km of the Chatty River (Map 1).

2.4.2 MACROINVERTEBRATE ASSESSMENT

Macroinvertebrate distribution is considered to reflect the chemical quality of the surface waters and the aquatic ecosystem health. The South African Scoring System (SASS) can be applied to obtain an index of the different macroinvertebrate families present at a site and is based on changes in macroinvertebrate communities with increasing environmental degradation. The SASS4 index, therefore, serves as an indication of the condition of the aquatic ecosystem and may assist in the identification of potential water quality problems in a river. Changes in aquatic biotic communities, or deviation from "natural" conditions, may not only be attributed to changes in water quality, but also to changes in the habitat condition. Therefore, in order to determine the state of the habitat at each site, the Habitat Assessment Matrix (HAM) is used together with SASS4 (Dallas, 1995:28).

An assessment of the macroinvertebrates of the Zwartkops Catchment was conducted in November 1995 for several sites in the Zwartkops River upstream of Perseverance and at least one site on each of its major tributaries. The Upper Elands River was selected as a reference point for the Lower Elands, Sand and Bulk River sites, while Bullmer Drift on the Zwartkops River was selected as the reference site for the Lower KwaZunga, Zwartkops, Brak and Chatty Rivers. A list of the monitoring sites and the monitoring results is given in Appendix B.

2.4.3 FISH ASSESSMENT

A survey of the fish in the Zwartkops River system was carried out in conjunction to the macroinvertebrate assessment. Where possible, fish survey sites were chosen in deeper water immediately adjacent to the invertebrate sites. Details of the methods used, as well as numbers and species of fish caught at each site, are included in Appendix C.

2.5 EIA METHODS

2.5.1 THE INTERACTION MATRIX

The most utilised matrix is the Leopold matrix, which consists of a horizontal list of development activities and a vertical list of environmental factors. The matrix is used to identify impacts by systematically checking the development activities against the environmental factors to determine which impact has a greater significance. Each cell is diagonally subdivided, with the upper triangle indicating the magnitude of the impact on a scale of one to ten and indicating the social importance or significance of the impact in the lower triangle as a number from one to ten, where a high score indicates the greatest impact. Plus signs can also be used to identify beneficial impacts. Other attributes could also be displayed such as the duration and probability of particular actions. The matrix is also accompanied by a text describing the significant impacts (Bisset, 1987:20; Bisset, 1980:29; Wathern, 1989:13; Fuggle, 1992:769). Such a matrix is used to assess the significance of all impacts identified, to allow for their prioritisation.

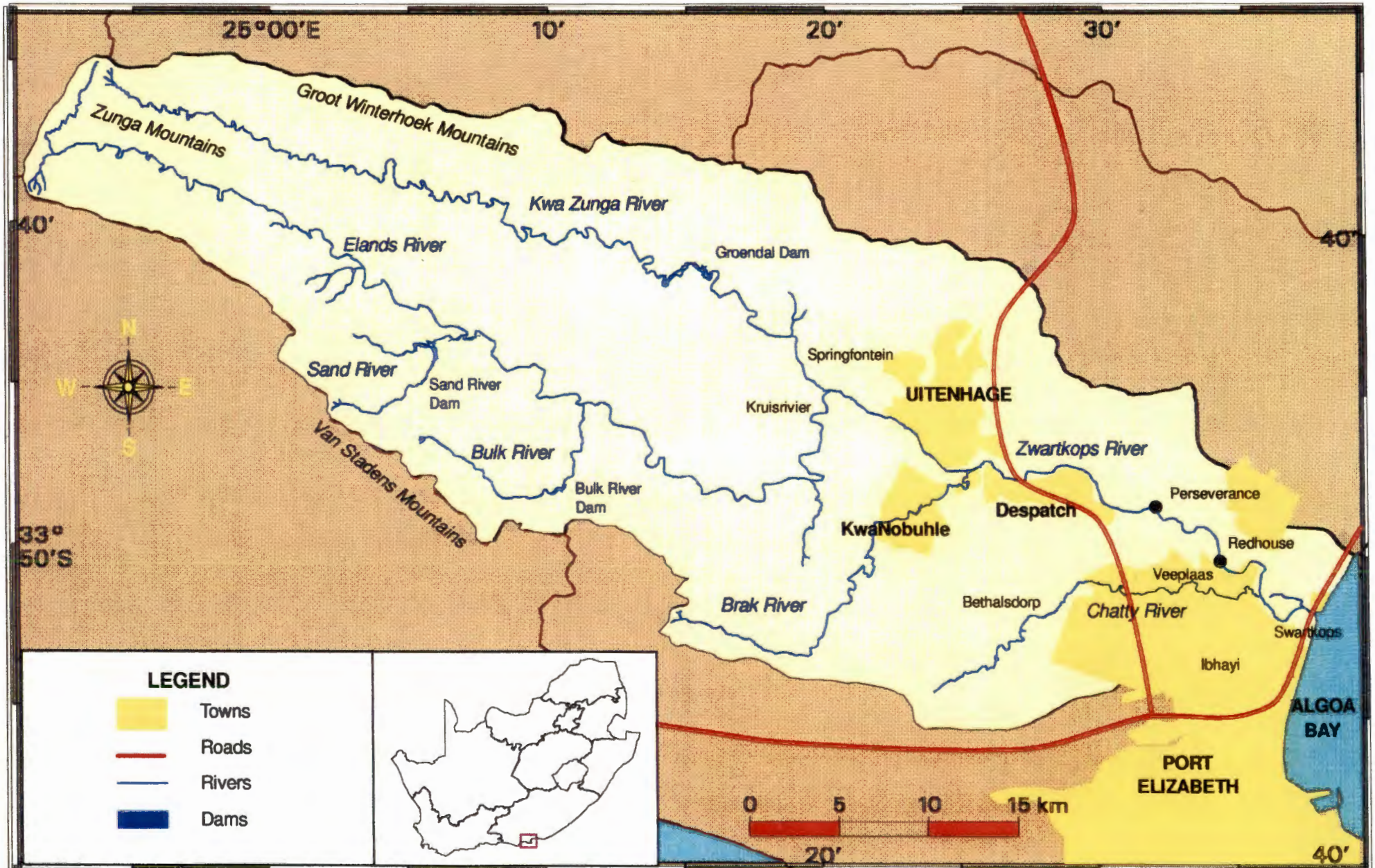
2.5.2 OVERLAY MAPPING

This method is a visual means of showing the spatial distribution of impacts, either individually or as a combination, and is most useful in identifying the cumulative effects of a number of activities such as in this assessment. The method is however less efficient in dealing with impact characteristics such as probability, time and irreversibility. Recent developments in computer software packages such as those developed as geographical information systems has improved the use of this method and reduced its complexity. Two other problems with overlay mapping is boundary definition and area heterogeneity. The clear demarcation of boundaries which appear on maps do not occur in reality, while very few characteristics which are represented on a map are homogeneous. Thus considerable amounts of information may be lost in the mapping process (Bisset, 1987:24; Wathern, 1989:15; Fuggle, 1992:770). These maps do however provide the water quality manager with useful information for management purposes and combinations of factors influencing water quality have been assessed by means of this method.

2.6 PUBLIC PARTICIPATION PROCESS

In 1994, members of the public were notified of the intention of the DWAF to develop a catchment management plan for the Zwartkops Catchment. Newspapers, radio broadcasts and pamphlets were used to invite public to a forum. This forum was used not only to inform the public about the intended project, but also to elect representatives of various sectors of the public to serve on an advisory committee. Three-monthly meetings were held with this advisory committee to inform the elected representatives of the public on the progress of the project and to obtain their approval on various interim management actions which needed to be taken.

An additional committee, consisting of representatives from national, provincial and local authorities, research organisations and environmental groups with the necessary technical background was also formed to steer the project. Representatives from both the advisory and technical committees were all consulted in a scoping exercise to identify and prioritise issues of concern within the catchment which required management attention. This information assisted in the determination of those aspects which needed to be investigated in this water quality impact assessment. The results from this exercise are included in Appendix G.



Map 1. General map of the Zwartkops Catchment

CHAPTER 3. IMPACT ASSESSMENT

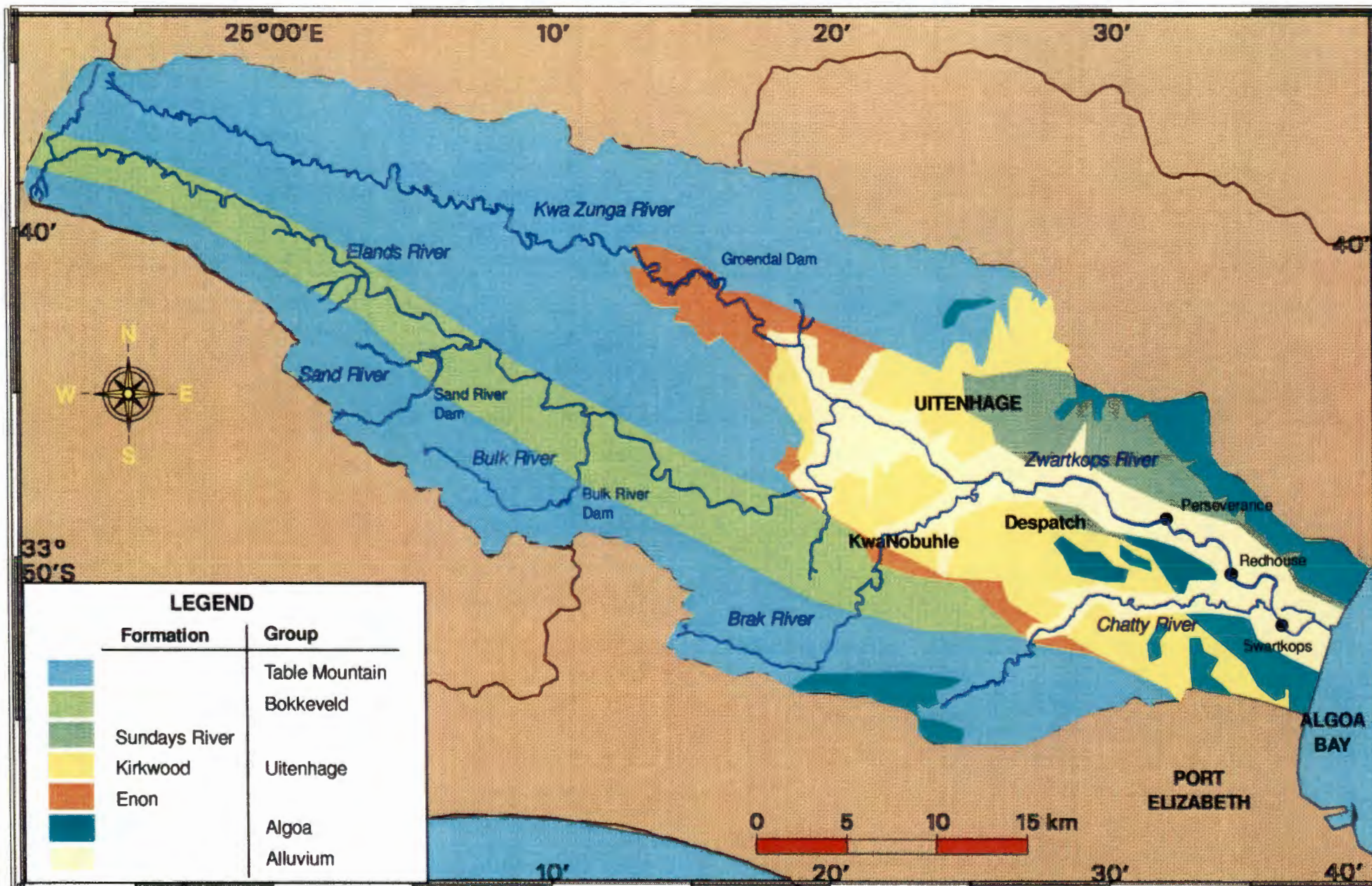
3.1 CATCHMENT CHARACTERISTICS AND PHYSICAL FEATURES

The flow, quality and aquatic ecosystem of a river system are influenced by both the natural physical characteristics of the catchment and by human activities in the catchment. Natural characteristics will also determine much of the activities that can occur within the catchment. This section describes these natural characteristics and the impacts they have on the water quality and on the water users, as well as the impacts they have had on development in the catchment.

3.1.1 GENERAL DESCRIPTION

The Zwartkops River Catchment is situated just north of Port Elizabeth in the Eastern Cape. The catchment is 120 km long and 42 km wide, with a total river length of about 155 km and a total area of 1360 km². The Groot-Winterhoek, Elands and Zunga Mountains dominate the western part of the catchment, with the lower lying Van Stadens Mountains in the south west. These mountain ranges are fringed in the east by low-lying coastal plains, an extensive alluvial floodplain and estuary (CSIR, 1993:5).

The two main tributaries, the KwaZunga and the Elands Rivers, have their source in the Groot Winterhoek Mountains and have numerous small tributaries which drain the steep valley sides. These rivers join just above Uitenhage in an area called Kruisrivier. Another tributary, the Brak River, flows through relatively flat bushveld and does not have a well defined channel. It forms a confluence with the Zwartkops River at Uitenhage. The section of the river system, downstream of the confluence of the Elands and KwaZunga Rivers, is referred to as the Zwartkops River. This section of the river system meanders across an alluvial plain past the residential areas of Despatch, Perseverance and Redhouse and is joined by the Chatty River just before Swartkops Village. Other important tributaries include the Bulk and Sand Rivers on the Elands River. These features can be seen in Map 1.



Map 2. Geology

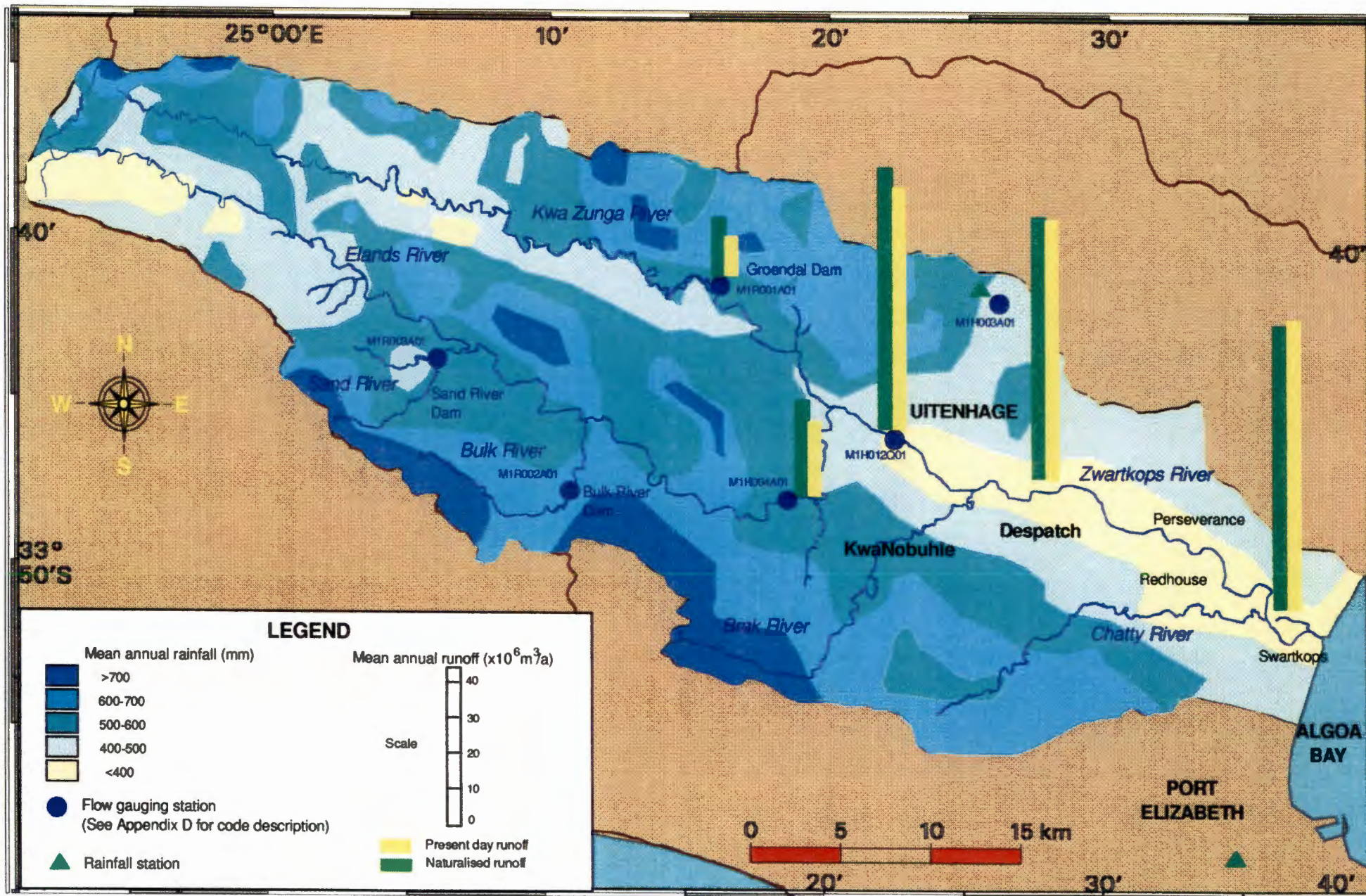
The tidal limit of the river is at Perseverance, approximately 16 km from the mouth, where a causeway prevents the intrusion of saltwater further upstream. The upper reaches of the estuary are narrow with steep muddy sand banks. In the middle to lower reaches, the estuary widens and the steep banks flatten. Large intertidal mudflats, islands and salt marshes increase in extent near the mouth, giving way to large sand banks and a rocky embankment north and south of the river mouth (Baird *et al*, 1986:13).

3.1.2 GEOLOGY

The geology of the Zwartkops Catchment is largely of marine or estuarine origin. The major geological formations are the Table Mountain Group quartzites, shales of the Bokkeveld Group and the Uitenhage Group, which underly the floodplains of the lower KwaZungu, lower Elands and the Zwartkops Rivers (Map 2). The Uitenhage Group is the most significant in terms of its impact on the water quality and comprises of:

- coarse, poorly sorted conglomerates interbedded with sandstone and mudstone of the Enon Formation;
- the greenish-grey shales and siltstones and sandstones of the Kirkwood Formation; and
- the thinly bedded greyish-green mudstones and siltstones of the Sundays River Formation (CSIR, 1993:6).

Deposits of the Algoa and Uitenhage Groups accommodate the eastern portion of the catchment, where the terrace scarp immediately north of the Zwartkops River is formed by the erosion resistant Alexandria Formation of the Algoa Group. Tertiary to Recent deposits, or alluvium, overlie the Uitenhage Group. They are generally less than 15 m thick, restricted to the river valleys, and consist of sand, gravel, silt and clay (Bush, 1985:10).



Map 3. Rainfall and hydrology

3.1.3 HYDROLOGY

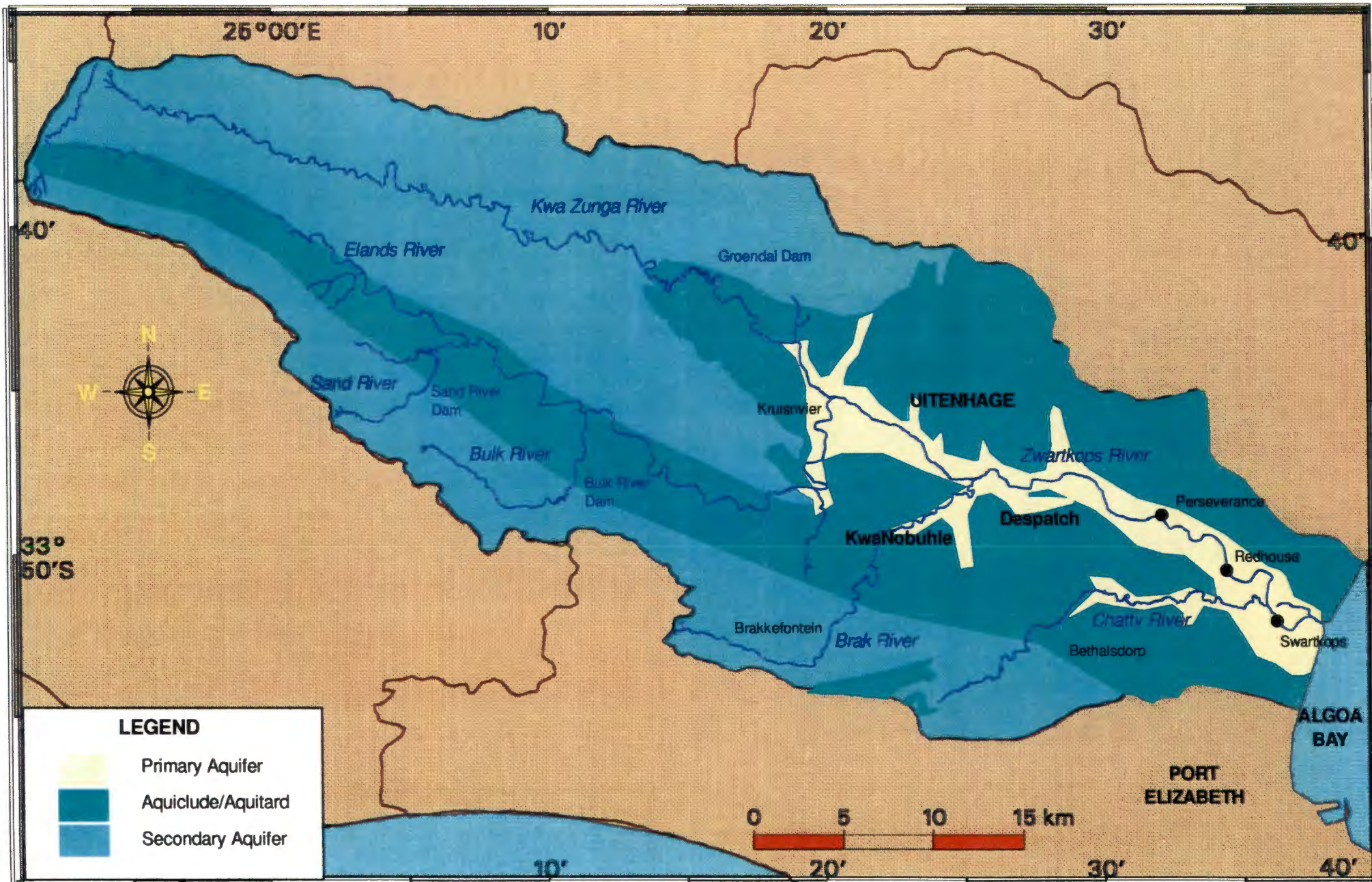
The rainfall within the catchment reflects the influence of the topography, where the maximum rainfall occurs at the headwaters of the Zwartkops River system and decreases towards the coast (Map 3). The rainfall is not strongly seasonal, although the coastal area falls with a winter rainfall area and the upper regions have a spring maximum. Average annual rainfall varies between 1000 mm in the upper regions to 500 mm on the dry north-eastern area near the coast, while the annual average evaporation for the area is 1700 mm with the highest evaporation rates occurring in the summer months (Ninham Shand, 1994d:62).

Developments in the upper catchment, apart from the Groendal Dam and the Sand and Bulk River Dams, which are likely to have altered the naturalised runoff, are 4.6 km² of tree plantations in the Bulk Sub-catchment and an estimated 50 km² of forested area in the Elands Sub-catchment. In addition, 0.424 km² of irrigated land and farm dams with a capacity of 24x10³ m³ in the Elands Sub-catchment, as well as farming activities within the Elands and KwaZunga Sub-catchments, have also reduced the natural flow in the system (Ninham Shand, 1994d:66; DWAF, 1994:8.1). The reduction in the present day runoff to the naturalised conditions is shown in Table 1 and on Map 3. The contribution of flow from the Kelvin Jones, KwaNobuhle and Despatch sewage treatment works, however, ensures that there is a net gain in flow in the lower reaches of the Zwartkops River. The results from the Water Resources 90 simulation modelling of the hydrology in the catchment are given in Table 1.

Table 1. Hydrological characteristics for the catchment (Weston, 1996):

Site	Naturalised MAR (10 ⁶ m ³)	Present Day MAR (10 ⁶ m ³)	Change in MAR
Below Groendal Dam in the KwaZunga	15.71	10.46	-33.4%
Elands River before the confluence with KwaZunga	26	20.21	-22.3%
Zwartkops River above Uitenhage	71.69	68.14	-5%
Zwartkops River below Uitenhage	71.69	70.98	-1%
Total catchment	78.73	80.02	+1.64%

MAR = mean annual runoff



Map 4. Geohydrology

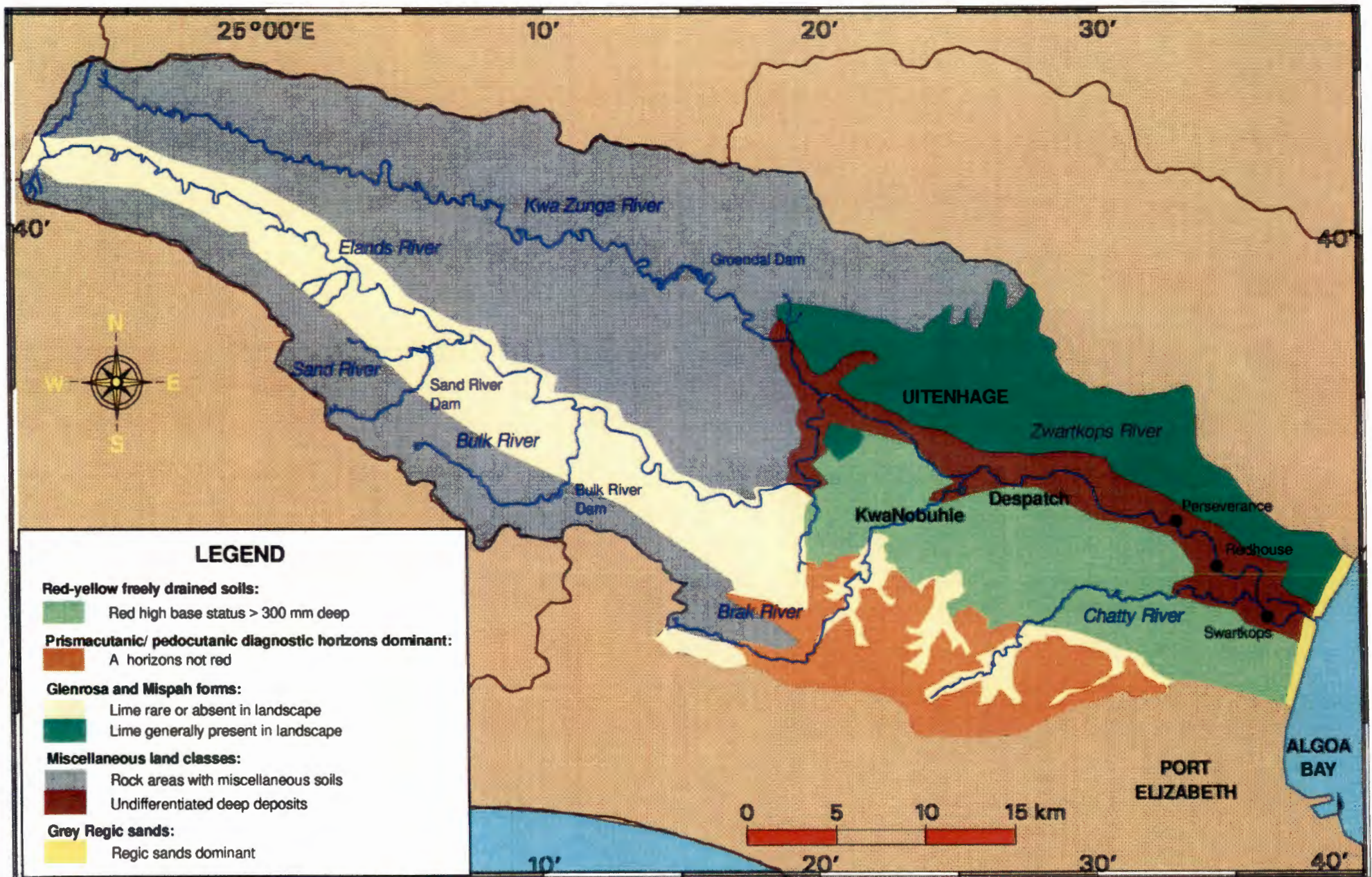
3.1.4 GEOHYDROLOGY

Two main types of aquifer occur in the catchment (Map 4):

- a primary alluvial aquifer which is underlain by impermeable shales and mudstones of the Uitenhage Group; and
- a fractured secondary aquifer in the quartzites of the Table Mountain Group.

The primary aquifer occurs from the confluence of the Elands and KwaZungu Rivers downstream to Perseverance, and constitutes a shallow (2 to 5 metres below the surface) unconfined aquifer within the alluvial deposits of the river system. Below the Zwartkops River primary aquifer, the mudstone layers of the Kirkwood Formation have very low permeabilities and confine the underlying groundwater. These layers form an aquiclude which contains small quantities of highly saline (up to 30 000 mg/l or 30 ppt) groundwater. The layer of sandy soil and silt overburden above the aquifer is referred to as the aquitard and plays an important role in the inhibition of the effective recharge to the alluvial aquifer by rain or river water. The aquitard in the lower Zwartkops Sub-catchment is highly impermeable and does not result in a high recharge rate (Bush, 1985:41; Maclear, 1993:40).

The secondary aquifer is not in hydraulic connection with the primary aquifer system or the surface flow. The groundwater levels are 20 m to 30 m below the surface in the high lying areas to surface artesian water at Perseverance. The major aquifer, in the Kruisrivier area, is formed by the Kirkwood sandstone and Enon conglomerate, while in the Bethelsdorp area, the major aquifer comprises of highly fractured Table Mountain quartzites. Both major secondary aquifers yield a good quality water. However, other aquifers within the secondary aquifer, such as at Brakkefontein, yield a poor quality water. Water from the secondary aquifer, especially in the Kruisrivier area, is utilised mainly for agricultural and domestic purposes (Maclear, 1993:32).



Map 5. Land types

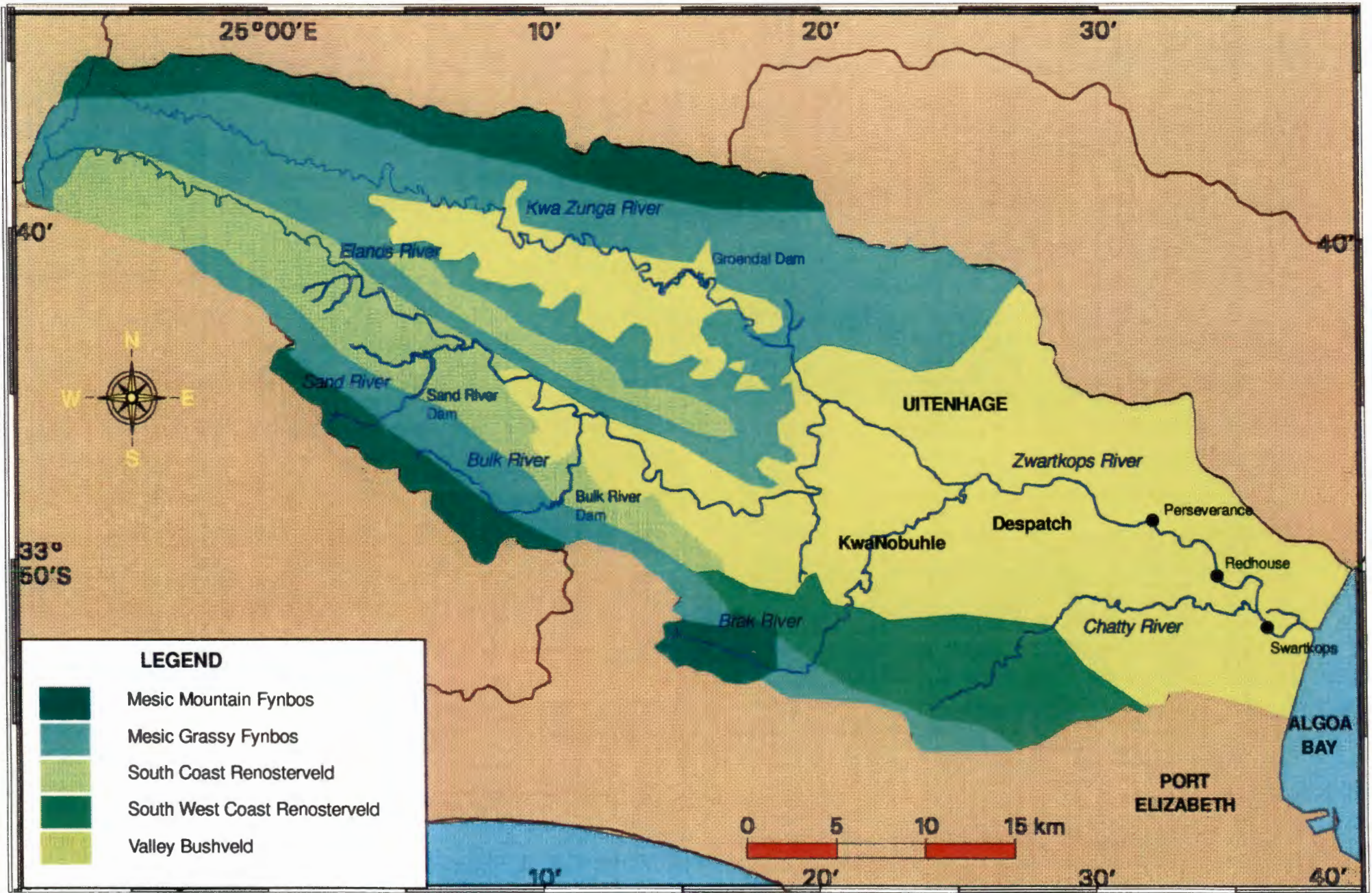
3.1.5 SOILS

Soil characteristics play an important role in ensuring the success of any irrigated farming practice. Although practically any soil could be irrigated, with the appropriate management techniques, certain soil properties are desirable to make the irrigation of crops economically viable. For example, the soil should be of sufficient depth and permeability (a low percentage of clay) to allow adequate internal drainage.

Table 2. The main soil and terrain forms in the Zwartkops Catchment (ARC, unpublished)

Sub-catchment	Main Soil Form	Depth (mm)	Texture	Slope
Upper Elands	Cartref	<350	49% rocks with fine to medium sand	20-50% slopes with gradient <8:100 and height diff. of 150-300m
Middle Elands	Glenrosa with Hutton	<300	fine sand & loam (<20% clay)	
Lower Elands	Glenrosa	200-350	fine sand & loam (<20% clay)	<20% slopes have <8:100 gradient, height diff. 150-300m
Bulk, Sand & KwaZunga	Cartref	<300	69% rocks with fine and coarse sand	<20% slopes with <8:100 gradient, height diff. >900m
Upper Brak	Kroonstad	700-1000	fine to medium sand (<15% clay)	>80% slopes with <8:100 gradient, height diff. 150-300m
Middle Brak & Upper Chatty	Cartref	50-150	medium sand (<15% clay)	20-50% slopes with <8:100 gradient, height diff. 90-150m
Lower Brak & Chatty	Hutton & Oakleaf	<1200	fine sand, loam & clay (<25% clay)	>80% slopes with <8:100 gradient, height diff. 90-150m
Upper Zwartkops	Swartland with Hutton & Mispah	<900 north of Uitenhage <250 south/west	fine sand, loam & clay (<30% clay)	20-50% slopes with gradient <8:100, height diff. ±90m flatter northwards
Zwartkops (north bank)	Mispah & Hutton	<200	fine sand & loam (<20% clay)	>80% slopes with <8:100 gradient, height diff. <30m
Zwartkops (floodplain)	Oakleaf & Dundee	>1200	Fine sand, loam & clay (<22% clay)	

The steeply sloping mountainous areas in the upper catchment consist mainly of bare rock with some shallow soils. These areas therefore have a low potential for agriculture. The upper reaches of the Brak Sub-catchment, however, have moderately deep to deep soils. The mid-slopes and hills of the catchment are predominantly covered by shallow soils to moderately deep soils, while the valleys have a better potential for agriculture and have deep soils. In the lower catchment, the Uitenhage area is covered by shallow to very shallow soils, which are poorly drained, while the Zwartkops River valley and floodplain are predominantly covered by deep soils. Map 5 indicates the land types in the catchment, which are composed by combining the climate, soil pattern and terrain forms.

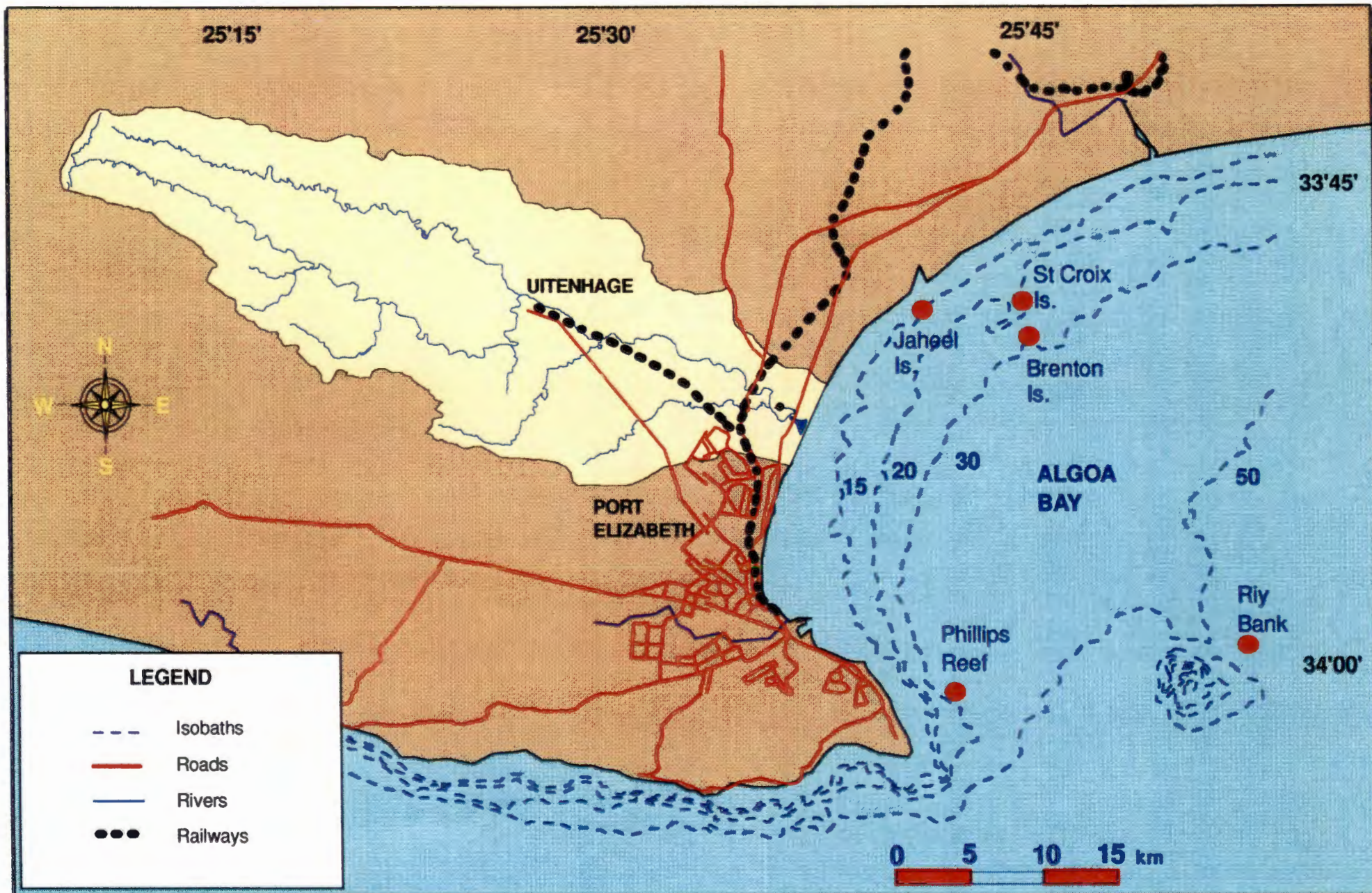


Map 6. Vegetation (after Acock, 1988)

3.1.6 VEGETATION

The natural vegetation distribution is mainly determined by the rainfall (Map 6). The upper south-facing slopes of the catchment, which have the highest rainfall throughout the year, are dominated by Mountain Fynbos. The lower, northern slopes and plains, where rainfall occurs more in summer, are covered predominantly by Grassy Fynbos. In the upper to middle Elands, Brak and Chatty Sub-catchments, South Coast and South West Coast Renosterveld are dominant. The rest of the lower-lying areas of the catchment are dominated by Bushveld or Succulent Thicket. An area of approximately 166 ha surrounding the estuary comprises of vegetated salt marsh, which is the third largest salt marsh in South Africa.

Encroachment of exotic or invader vegetation, such as *Acacia* spp. (Black Wattle and Port Jackson Willow) and *Eucalyptus* spp., have become prominent in the Zwartkops Catchment (Kleynhans, 1995:9). In the river bed, especially in the Uitenhage area, *Phragmites australis* occurs in dense beds. In other areas, both upstream and downstream of Uitenhage, the reed beds are replaced by indigenous vegetation and invader species. Invader aquatic vegetation such as *Eichhornia crassipes*, or water hyacinth, and *Salvinia molesta* occur extensively between Uitenhage and Perseverance (CSIR, 1993:9; Ninham Shand, 1994d:62).



Map 7. Coastal features

3.1.7 COASTAL MARINE FEATURES

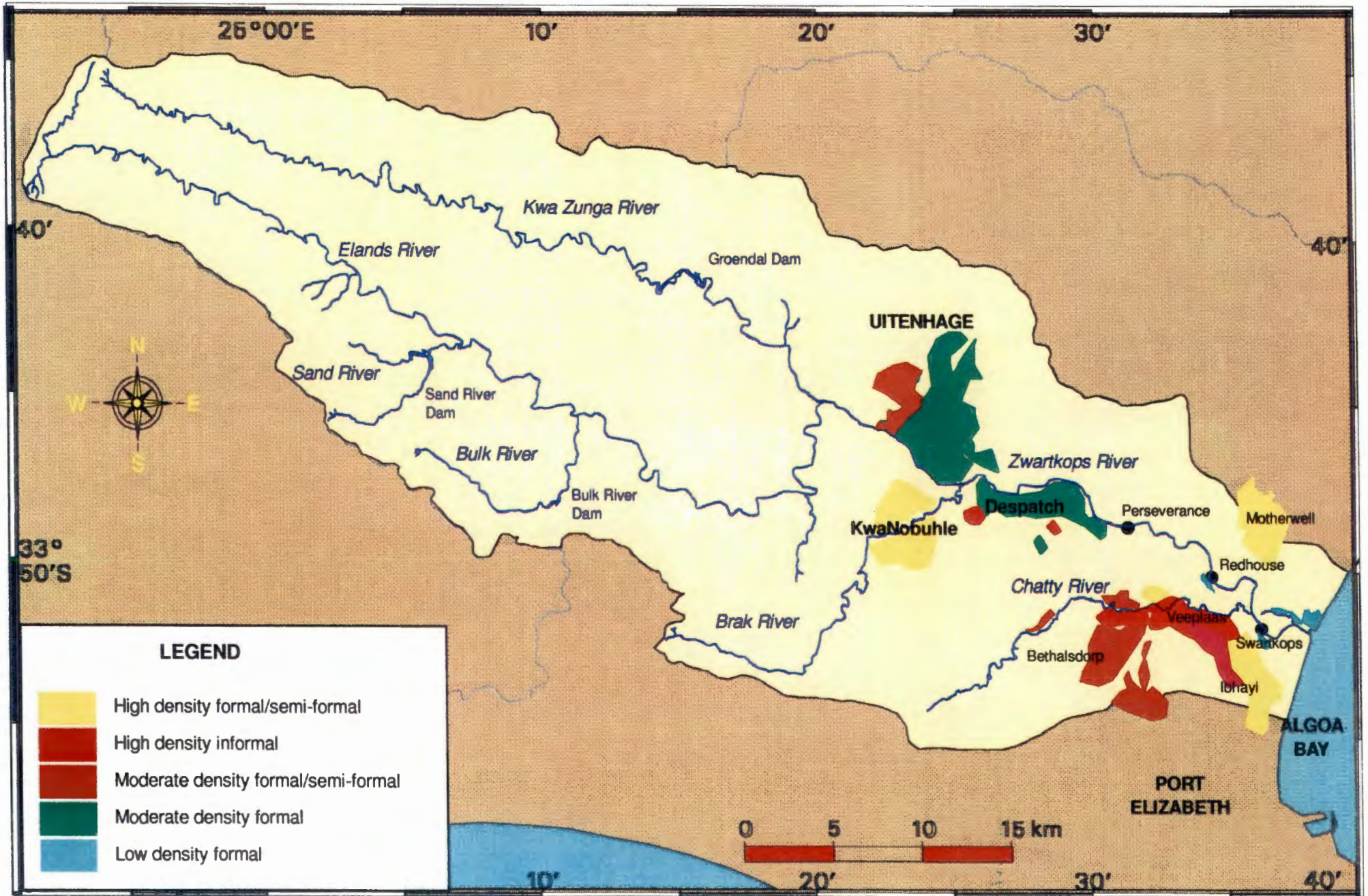
Algoa Bay can be described as a shallow bay, with the 70 m isobath defining its offshore boundary (Map 7). Surface water movement in the bay is driven mainly by wind and waves, where the dominant wind directions determine the transport of surface water, and therefore sediment and pollutants, in the bay. The dominant wind directions are shown in the table below.

Table 3. The significance of wind on surface water transport in the western sector of Algoa Bay (Lord *et al*, 1991:5)

Wind regime	Frequency*	Seasonality	Significance
SW (WSW-SSW)	24%	throughout year	Swift surface transport (0.1-0.15 m/s) northwards, parallel to coast
NE (ENE-E-ESE)	17%	summer	Surface transport southwards in longshore current (0.03 - 0.05 m/s)
NW (WNW-W)	45%	winter, mostly nocturnal	Surface transport offshore towards harbour (0.05 - 0.07 m/s)
SE (SSE-S)	10%	winter	Weak longshore surface transport along the coast and northwards (<0.05 m/s)

* This data was collected during a La Niña year when a greater proportion of easterlies can be expected.

The dominant wind is from the west, with a greater easterly component in summer. The temporal variation of the wind, with changes taking place within a few days, however, results in an erratic surface water movement. The net movement of pollutants and sand in the bay is nevertheless east and northwards, and appears to be carried by the longshore current. Of considerable importance to the long term water quality in the bay are the sporadic incursions of Agulhas Current water which flush out the western sector of the bay two to three times per year (Schumann, 1997:13).



Map 8. Population Density

3.2 POPULATION

Development within the Zwartkops Catchment, as a result of topography, has taken place mostly in the floodplain and lower catchment. Thus, the majority of the population occurs within the urban areas of Port Elizabeth, Despatch, KwaNobuhle and Uitenhage (Map 8). The present and projected population figures have been obtained from local authorities, the 1991 census and the Algoa Water Resources System Analysis by Ninham Shand (1994b:13). The annual average population growth rate for South Africa during the period 1980 to 1990 is 2,58% (DBSA, 1991).

Table 4. Present and projected population figures for the Zwartkops Catchment.

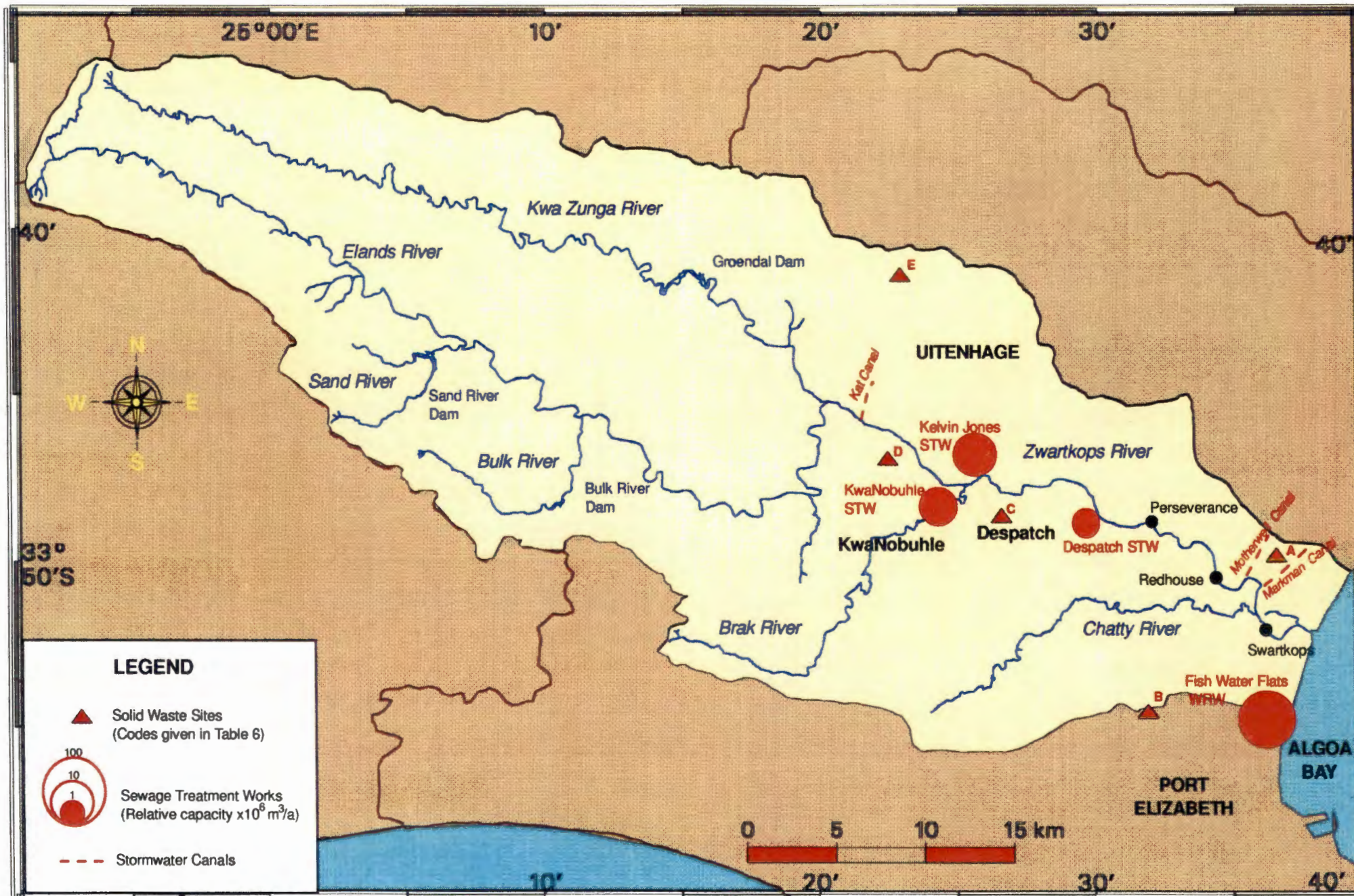
Area	1991	Percentage of total	1996	2001
Uitenhage	67 581	10%	76 761	87 188
KwaNobuhle	137 802	21%	156 519	177 779
Despatch	19 100	3%	21 694	24 641
Port Elizabeth (within catchment)	425 703	65%	483 526	549 203
Remainder of catchment	5 237	<1%	5948	6756
Total catchment	655 423	-	744 448	845 567

3.3 CATCHMENT INFRASTRUCTURE

This section highlights the water resources developments within the catchment which have an impact on the water quality.

3.3.1 WATER SUPPLY

The bulk of the water used in the catchment is imported from other catchments. Only three small water supply dams, the Bulk, Sand and Groendal Dams, are within the catchment. Both the Bulk and Sand River Dams supply water only for urban use, while the Groendal Dam to supplies Uitenhage and irrigation farmers downstream with water. These dams reduce the flow in the catchment, however, no allocations have been made for riparian users downstream or for the aquatic ecosystem. Details of these dams are given in Table 5.



Map 9. Water related infrastructure

Table 5. Bulk water supply details (after Ninham Shand, 1994a:A1)

Water Source	River	Area(s) supplied	Volume Ml/day
Groendal Dam	KwaZunga	Approximately 50% of Uitenhage supply	11.66
Sand River Dam	Sand	Less than 5% of total supply to Port Elizabeth	2.88
Bulk River Dam	Bulk		.65

where: PETLC = Port Elizabeth Transitional Local Council

UTLC = Uitenhage Transitional Local Council

3.3.2 SEWAGE TREATMENT WORKS

There are three sewage treatment works (STW) in the catchment, the Kelvin Jones STW in Uitenhage; KwaNobuhle STW, and Despatch STW. Fish Water Flats Water Reclamation Works (WRW) is also situated in the catchment but discharges the treated effluent into the surf zone in Algoa Bay (Map 9). This effluent could, however, influence the quality of seawater on the seaward side of the estuary. All the treatment works are activated sludge plants and chlorinate their final effluent.

Uitenhage Transitional Local Council (TLC) was issued with Exemption No. 468B from the requirements of Section 21 of the Water Act (Act 54 of 1956) by the DWAF to dispose of 8 833 000 m³/a of General Standard effluent from Kelvin Jones STW as follows:

- 1 095 000 m³/a (12.5%) to be reused by industry (e.g. East Cape Tanning, Tycon, Volkswagen, Transnet and Gearmax);
- 912 500 m³/a (10.3%) for irrigation of parks, gardens and sportfields; and
- 6 822 500 m³/a (77.2%) into the Zwartkops River below the Frans Claassen Bridge.

Disposal of sludge from the treatment works is on drying beds upstream of the Nic Claassen bridge, on the western bank of the Zwartkops River.

KwaNobuhle STW was, until recently, the responsibility of the KwaNobuhle City Council but is now operated by Uitenhage TLC. Exemption No. 1545B had been issued for the sewage works to dispose of 6 862 000 m³/a of General Standard effluent as follows:

- 912 500 m³/a (13.3%) irrigated on parks and sportfields;
- 3 102 500 m³/a (45.2%) irrigated on 740 ha of agricultural land in Uitenhage; and
- 2 847 000 m³/a (41.5%) in the Brak River before it joins with the Zwartkops River.

Sludge from the treatment works is buried at the sludge lagoons.

Despatch TLC has been issued with Exemption No. 374, allowing the discharge of 1 682 650 m³/a of treated General Standard effluent from Despatch STW as follows:

- 99 645 m³/a (5.9%) to be reused at Perseverance Wool Pullery;
- 730 000 m³/a (43.3%) irrigated on crops, Andre's Nursery in Despatch, sports grounds and public places; and
- 835 000 m³/a (49.6%) to the Zwartkops River below the Despatch Bridge.

Port Elizabeth TLC operates Fishwater Flats WRW which discharges a General Standard effluent, with the water quality exceptions and disposal methods, stipulated in Exemption No. 1084B as follows:

- 32 120 000 m³/a (69.1%) secondary treated and chlorinated domestic effluent, with a relaxation on *E. coli* to 1000 counts/100ml, to be discharged into the surf zone through a 142 m pipeline with a diffuser 2 m below the low water mark;
- 1 460 000 m³/a (3.2%) treated industrial effluent, with a relaxation on dissolved oxygen, to be reused in industry (e.g. Algorax); and
- 12 840 000 m³/a (27.6%) secondary treated industrial effluent, with a relaxation on chemical oxygen demand, oxygen absorbed, total dissolved salts, sodium and ammonia and *E. coli* to 1000 counts/100ml, to be discharged into the adjacent Paapenuils River, 800 m upstream of the mouth.

Approximately 56% of the treated sewage from the Kelvin Jones, KwaNobuhle and Despatch STW is discharged into the Zwartkops River System, of which 65% is from Kelvin Jones STW, 27% is from KwaNobuhle STW and 8% from Despatch STW.

3.3.3 SOLID WASTE

Information on the solid waste sites in the catchment (Map 9) is given below:

Table 6. Solid waste sites

No.	Solid Waste Site	Owner	Class
A	Aloes	WasteTech	G & H
B	Ibhayi	PETLC/Ibhayi TLC/ECFA	G
C	Wagensdrift	Despatch TLC	G
D	KwaNobuhle (Old site)	Uitenhage TLC	G & H
E	Koedoeskloof	Uitenhage TLC	G & H

where Class H is hazardous waste

Class G is domestic or general refuse

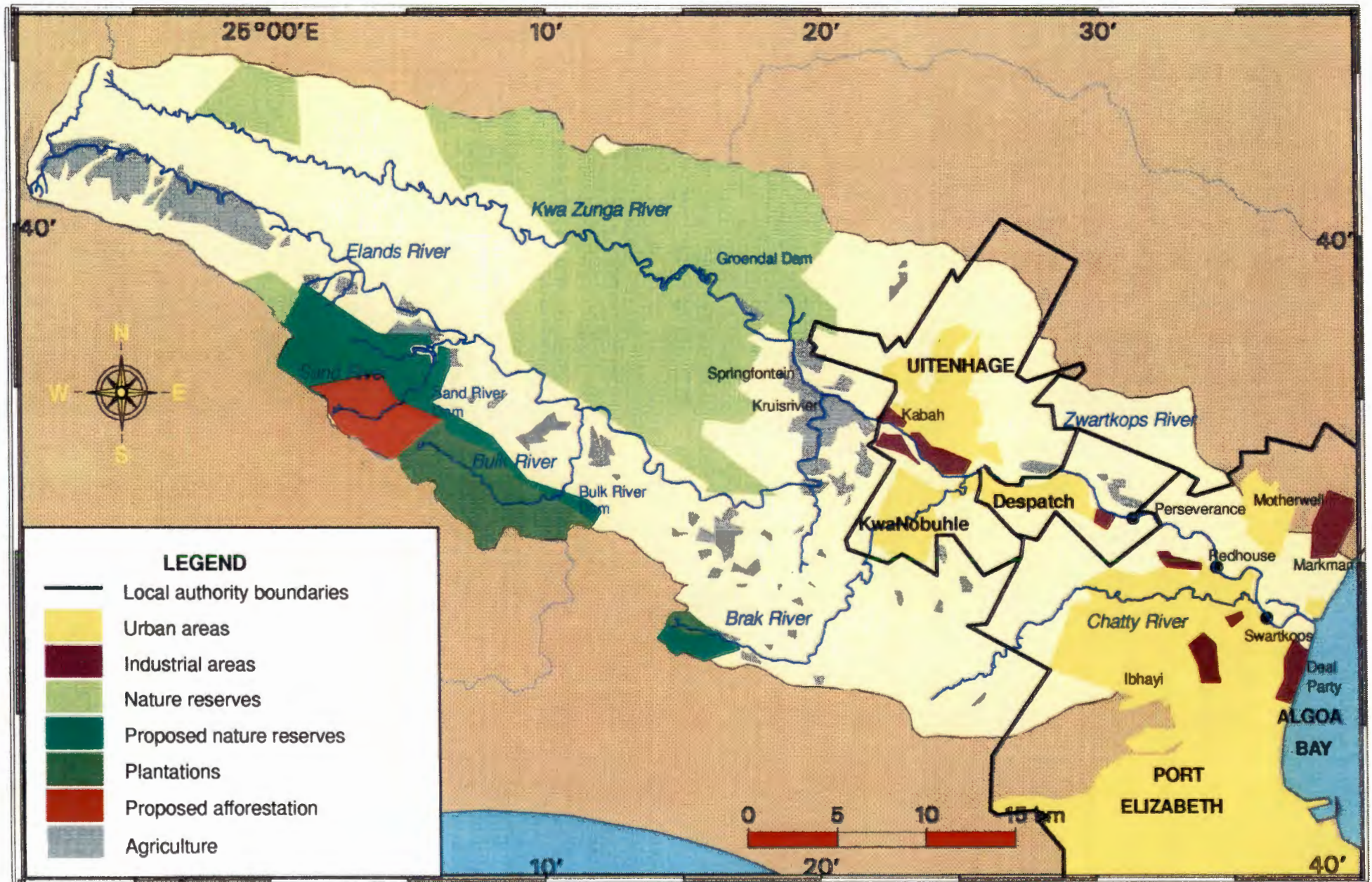
These waste sites are underlain by Kirkwood mudstones of the Uitenhage Group, which have a very low permeability. The Aloes waste site, which is of the greatest concern to residents in the catchment, receives hazardous waste from the Port Elizabeth, East London and KwaZulu-Natal industrial areas, and general waste from Port Elizabeth. The waste is co-disposed in trenches and immediately covered. Medical waste is incinerated south of the landfill site.

3.4 CATCHMENT ACTIVITIES

Activities within a catchment impact not only on the water quantity but also on the water quality. This section highlights those activities (both point and non-point sources) within the catchment which have an impact on the water quality. The spatial distribution of the landuse activities in the catchment can be seen in Map 10.

3.4.1 RESIDENTIAL

Urbanisation in the Zwartkops Catchment is a potential source of nutrients, pathogens and litter which wash off of these areas during rain events and impact on the quality of both ground and surface waters. The extent of this is dependent mainly on the sanitation services available to the community and on the population density. The informal residential areas in Motherwell, Ibhayi and Kabah have a high pollution potential. Information on services supplied to the informal and formal settlements for each of the Local Transitional Council areas in the catchment is given below. Population data were obtained from the 1991 census and from PETLC.



Map 10. Land Use

Table 7. Water supply and sanitation services in the Port Elizabeth Transitional Local Council Area within the Zwartkops Catchment

Residential Area	Area (km ²)	Population	Population density (person/km ²)	Water supply service	Sanitation service
Bethelsdorp	64,8	79229	1223	Some taps in community, some with full water supply	Sewered
Motherwell	290,5	72997	251	Some taps in community, some with full water supply	Bucket system, pit latrines, sewer
Ibhayi	20,6	257053	12478	Some taps in community	Bucket system, sewer
KwaMagxaki/ KwaDwesi	6	12168	2028	Full water supply	Sewered
Redhouse	20,5	795	39	Full water supply	Conservancy tanks
Swartkops	11,1	901	81	Full water supply	Sewered
Bluewater Bay/ Amsterdamhoek	4,5	2560	569	Full water supply	Conservancy tanks, sewer

Table 8. Water supply and sanitation services in the Despatch Transitional Local Council Area within the Zwartkops Catchment

Residential Area	Area (km ²)	Population	Population density (person/km ²)	Water supply service	Sanitation service
Despatch	10,5	17352	1653	Full water supply	Full reticulation
Sans Souci	0.25	1200	4800	Full water supply	Full reticulation (99%)
Perseverance	6.75	548	81	Boreholes	Conservancy tanks, Pit latrines

Table 9. Water supply and sanitation services in the Uitenhage Transitional Local Council Area within the Zwartkops Catchment

Residential Area	Area (km ²)	Population	Population density (person/km ²)	Water supply service	Sanitation service
KwaNobuhle	7.34	92381	12586	Water supply & taps stands in community	Sewered & buckets
Kabah, Thomas Gamble, Gerald Smith Rosedale	6,01	67581 in urban areas 5237 in non-urban areas		Water supply & taps stands in community	95 % sewer 5 % buckets
Uitenhage *	24,5			Full water supply	Sewered
Excelsior	0,25			Boreholes	Conservancy tanks/Pit latrines

* Includes :College Hill, Drosdy, Penford, Valleisig, Van Riebeeck Hoogte, Mosel, Fairbridge Heights, Levyvale and Vanes Estate

Stormwater drains or canals from informal settlements are of particular concern as they often carry raw sewage, high in pathogens and nutrients, from those areas where no

formal sewage system exists or where problems with the sewage system are often experienced. Problem areas in the catchment are:

- the Kabah township, with the Kat Canal (Map 9);
- KwaNobuhle in the Brak Sub-catchment;
- KwaZakele and other informal settlements in the Chatty Sub-catchment;
- Motherwell, with the Motherwell Canal input into the estuary (Map 9); and
- New Brighton and Deal Party with stormwater outlets into the Paapenkuils River and the coastal zone.

3.4.2 MINING

The removal of sand and river gravel from river beds in the Zwartkops Catchment occurs at the following sites:

- in the lower KwaZunga River, at Springfontein; and
- in the Zwartkops River above Uitenhage, and above and below Perseverance.

Readymix Quarry is the only non-point source mining activity within the catchment which has been issued with a water use permit and an exemption to dispose of its wastewater. The quarry is licensed to use 1660 m³ of water per day from the river for industrial purposes (Permit No. 460N) and to dispose of the resulting waste water in excavated depressions in the river (Exemption No. 635B).

Salt mining also occurs within the floodplain of the Zwartkops River. Much of the lower reaches of the Chatty River have been restricted to a narrow channel as a result of the establishment of a number of salt pans. A large portion of the floodplain surrounding Redhouse has also been developed into salt pans. Salt water is pumped from the estuary initially into pans on the north and south banks of the estuary and then finally into pans south of Redhouse. The Redhouse saltpan, on the north bank of the estuary is a primary concentration pan of 104 ha. The area was originally a temporary vlei, but is now an important area for breeding seabirds in the eastern Cape and has been recommended as a nature reserve once the lease to Swartkops Sea Salt has expired. In the Chatty River, salt pans are also used for feeding and roosting of seabirds. The other salt pans, however, support very few birds (Martin and Randall, 1987:80).

3.4.3 INDUSTRIAL

Industrial areas within the catchment are:

- the Uitenhage Riverside industrial area (Riverside, Cape Road and Alexander Park);
- the Perseverance industrial area;
- an industrial area in KwaZakele; and
- a small industrial area in Despatch;
- the Deal Party and Markman industrial areas on the boundaries of the catchment. Most industries in this industrial area discharge their effluent to the Fishwater Flats WRW, to be treated and discharged into the Paapenkuils River.

Permit/exemption details on the water use and effluent discharges for the major industries within the catchment are given in Table 10.

Stormwater drains from industrial areas, especially in Uitenhage, are an intermittent source of oil and chemical pollution, although most industries now sewer their stormwater runoff from the premises. In the Port Elizabeth TLC area, the Markman Canal (Map 9) carries stormwater runoff from the Markman industrial area to the estuary. Reeds have been established in the canal to reduce the amount of polluted runoff from reaching the estuary.

Table 10. Industrial water use and effluent disposal

Industry	Permit	Quantity Water Used - Source	Exempt.	Industry Type	Disposal Manner	Permit Quantity	Permit Quality
East Cape Tanning	448N	500m ³ /d - UTLC 170m ³ /d - KJSTW	605B	Tannery	Evaporation ponds	370 m ³ /d	None
Gubb & Inggs	73N	1500 m ³ /d - UTLC 450 m ³ /d - river	825B	Wool processing	Evaporation ponds	820 m ³ /d	None
Perseverance Wool Pullery	400N	273 m ³ /d - DTLC & DSTW 67 m ³ /d - river	513B	Wool processing	Evaporation ponds	127 m ³ /d	None
Cape of Good Hope Woolcombers	432N	1137 m ³ /d - UTLC	1039B	Wool processing	Evaporation ponds	280 m ³ /d	None
Swartkops Power Station	826N	750 m ³ /d - PETLC 71 233 m ³ /d - estuary	1099B	Power station	Estuary & reuse	71300 m ³ /d	General Std waived Temp<35C pH 5.5-9.5 ss<25mg/l Oil<2.5mg/l
Transnet Cuyler Manor		740 m ³ /d UTLC 40 m ³ /d KJSTW		Transport	Settling dam/river		
Grahams Poultry				Chicken products	Irrigated on land/ponds		
St Albans Prison			1415B		Irrigated on land	722 m ³ /d	General Std.
Industex	1175N	200 m ³ /d - PETLC	578B	Towelling manufact.	KJSTW & WasteTech	unspecified	None
Gearmax		80 m ³ /d - UTLC 8 m ³ /d - KJSTW (irrigation)		Car parts & machinery	Settling tanks & KJSTW		
National Standard	1276N	800 m ³ /d - UTLC PETLC & springs		Wire manufact.	KJSTW & reuse		
Algorax	381N	1591m ³ /d -PETLC 227m ³ /d- FWFWRW		Carbon manufact.	FWFWRW & reuse		
Welfit Oddy	1141N	197 m ³ /d - PETLC		Truck/car bodies	FWFWRW & soak away		
Volkswagen	764N	3300 m ³ /d - UTLC & PETLC		Car manufact.	KJSTW		
Pillsbury Brands Africa	428N	1860 m ³ /d - PETLC		Frozen foods	FWFWRW		
Hella	1076N	220 m ³ /d - UTLC		Car parts	KJSTW		
Guestro Dorbyl	1307N	225m ³ /d - PETLC, UTLC & springs		Machinery	KJSTW		
Tycon	76N	2273 m ³ /d - UTLC		Tyres	KJSTW		
Union Cotton Mills		640 m ³ /d - UTLC		Cotton mill	KJSTW	544 m ³ /d	
Rocklands Poultry	1450N	450 m ³ /d - UTLC		Chicken products	KJSTW		

where: KJSTW = Kelvin Jones Sewage Treatment Works
 FWFWRW = Fish Water Flats Water Reclamation Works
 UTLC = Uitenhage Transitional Local Council
 DTLC = Despatch Transitional Local Council
 PETLC = Port Elizabeth Transitional Local Council
 DSTW = Despatch Sewage Treatment Works
 Std. = standard
 ss = suspended solids

3.4.4 AGRICULTURE

There are three main areas where farming occurs within the catchment:

- in the Elands River Sub-catchment;
- in the lower KwaZunga and upper Zwartkops Sub-catchments, especially at Kruisrivier; and
- between the Despatch Highway bridge and Perseverance (Map 10).

Dryland farming is practised higher up in the Elands Catchment, while intensive irrigation is practised in the Kruisrivier area. This area forms part of the Zwartkops Irrigation District, which covers an area of 948 ha. The Irrigation District consists of approximately 260 ha of vegetables (potatoes, lettuce, cabbage, carrots, beetroot, sweet potatoes, beans, peppers and brinjals), 190 ha of cultivated pastures and 21 ha of citrus. The remaining 477 ha is undeveloped. Most of the water used is from groundwater (580 ha) and abstracted from the Elands and KwaZunga Rivers (326 ha) (CSIR, 1993:69; Ninham Shand, 1994c:47).

Livestock farming is mostly practised at Kruisrivier and Perseverance and on a small scale in the upper catchment. Livestock farmed are mostly dairy cattle, sheep, chickens and ostriches.

3.4.5 FORESTRY

Forestry operations can provide a source of suspended solids, organic debris and nutrients, as well as cause a reduction in the surface runoff to rivers. Areas under commercial forestry are as follows:

- 4,6 km² or 14% of the Bulk Sub-catchment;
- 27,6 km² commercial forestry or 6,2% and 22 km² of natural forest or 4,9% of the Elands Sub-catchment (includes Bulk and Sand Rivers), and
- 2 km² at the top of the Brak River (Map 10).

The total area under commercial and natural forest in the Zwartkops Catchment is 57 km² or 4,23% of the total catchment area (Van der Zel, per. Comm.; DWAF, 1994:8.1).

3.4.6 NATURE CONSERVATION

The upper portion of the Zwartkops Catchment, consists mainly of 21 793 ha of fynbos in the proclaimed Groendal Wilderness Area, which is under the control of Eastern Cape Nature Conservation (DWAF, 1994:8.1). The area comprises approximately 30 % of the total catchment area (Map 10). The Swartkops Nature Reserve is situated on the northern bank of the Zwartkops River to protect the Valley Bushveld and covers an area of approximately 800 ha between Perseverance and the Motherwell canal. The Proposed Aloe Reserve which is approximately 180 ha in extent, is just north of Amsterdamhoek. These areas form a buffer zone between urban development on the northern side of the river and the river itself.

3.5 ASSESSMENT OF POTENTIAL POLLUTION SOURCES

Each activity with a known or suspected impact which is of significance to the water chemistry and quality in the catchment is discussed in this section in greater detail with regards to their impact. These activities are the tanning and wool processing industries, intensive agricultural activities, residential activities and the sewage treatment works.

3.5.1 TANNING AND WOOL PROCESSING INDUSTRIES

East Cape Tanning is one of the largest tanneries in South Africa which tans and softens animal hides. Treatment of the hides involves curing with salt, cleansing, application of a lime-sulphide solution to remove the excess hair and flesh, softening with a weak acid and ammonium salts, pickling in sulphuric acid and tanning with chrome tanning salts. The tanning industry is a non-consumptive user of water, converting almost all water used into an effluent with a high pH, total dissolved salts (sodium/chloride dominated, with sulphides and potassium) and chromium. This effluent is difficult and expensive to treat, therefore the most common form of disposal in South Africa is to evaporation ponds, which may leak (Natsurv 10, 1989:3).

Wool processing plants in the catchment are the wool-washing and wool-combing plants, Gubb & Inggs and Cape of Good Hope, and the wool-pulling plant at Perseverance. These industries also convert much of the water used to an effluent which is difficult to treat and

make use of evaporation ponds. The wool-washing process involves scouring of the raw wool with sodium carbonate and detergents, carbonising with sulphuric acid and fulling (cleaning and thickening) of the wool with an alkaline detergent to produce a semi-processed wool-top and to recover the lanolin grease. This wool is then combed to remove the solids. Effluent from the wool-washing process is high in pH, TDS, potassium, sodium, chlorides, carbonate and phosphates, while effluent from the scouring process has very high organic and inorganic loads. The wool-pullery process consists of curing of the hides with salt and then soaking them in detergents and produces an effluent with a high TDS which is sodium/chloride dominated (Natsurv 13, 1993:4).

Potassium, because it does not occur naturally at high concentrations in either the surface or groundwater, is a good indicator of pollution originating from the woolwashing industry. Raised potassium levels are easily detected when considering the potassium/sodium ratio. There are very few freshwaters where the potassium concentrations nearly equal or exceed the sodium concentration (they are usually present at a ratio of 1:10 or more). The reversal of the potassium/sodium ratio to 2:1 at Gubb and Inggs both in the surface and groundwater therefore indicates the impact of man's activities on the water quality. This impact is discussed further in the following section.

3.5.2 INTENSIVE AGRICULTURAL ACTIVITIES

Intensive animal feedlot farming generates large amounts of waste in a relatively small area. Graham's Poultry is such a feedlot which has been identified as having a significant impact on both the surface and groundwater above Uitenhage. The potential impacts of chicken farming can best be evaluated by considering the annual waste load generated by a single chicken, i.e. 35 kg per year of which approximately 1.3% is nitrogen, 0.5% is phosphorus and 0.5% is potassium (DWAF, 1995a:135). This waste is disposed of as fertilizer on the property which consists of steep slopes and lies in close proximity to a minor tributary of the Zwartkops River.

3.5.3 RESIDENTIAL DEVELOPMENT

The typical pollutant loads exported from residential areas in South Africa are: suspended solids of 198 kg/ha/a; total nitrogen of 3.9 kg/ha/a and 0.58 kg/ha/a of total phosphorus (DWAF, 1995a:133). These loads will vary depending on the level of development in each residential area. Microbiological contaminants from residential areas vary widely depending on the level of sanitation and the population density of the area. They are especially of concern in the less formal areas of Uitenhage, KwaNobuhle, Motherwell and Ibhayi and are most probable of reaching the Zwartkops River System through transport in stormwater canals such as the Kat and Motherwell Canals.

3.5.4 SEWAGE TREATMENT WORKS

The unlined sewage treatment dams, maturation ponds and sludge lagoons/drying beds at Uitenhage, Despatch and, to some extent, at KwaNobuhle are a potential source of pollution. Treated sewage effluent is polished through microbial breakdown and ultra-violet light degradation in these ponds and is a potential source of nutrients to the surrounding groundwater, as the discharge of treated sewage is to the surface water. Conservancy tank sewage disposal systems at Perseverance, Redhouse and Amsterdamhoek are also a source of concern, particularly in terms of nitrate pollution.

3.6 WATER USE

3.6.1 SURFACE WATER USE

The main abstraction of surface water from the river system is the municipal abstraction of water from the Sand, Bulk and Groendal Dams and the abstraction of water for irrigation. The other users of surface water are all non-consumptive. The present reuse of treated sewage within the catchment is 4.1 Ml/day from Fish Water Flats and 0.8 Ml/day from Kelvin Jones Sewage Treatment Works (STW), which is used for industrial purposes and for irrigation of public open areas, sport fields and gardens (Ninham Shand, 1994a:27).

3.6.2 GROUNDWATER USE

Groundwater abstractions are controlled and regulated by the Uitenhage Subterranean Water Control Area. This was proclaimed in 1957 in terms of Government Proclamation No. 260, due to a lowering of groundwater levels and a rapid decline of artesian flows in the catchment. The present total groundwater abstraction from boreholes is approximately 2 600 000 m³/a and a further 21 500 m³/a is abstracted from dug-wells (Maclear, 1993:32).

3.6.3 WATER USERS

The term water quality is used to describe the physical, chemical, biological and aesthetic properties of water which will determine its fitness for use and its ability to maintain the integrity, or health, of the aquatic ecosystem. Many of these properties are determined by constituents which are dissolved or suspended in water and make up the water chemistry. Therefore, in order to determine the water quality of the Zwartkops catchment, the use of that water must first be established. The aquatic ecosystem is recognised as part of the water resource and not as a water user.

Domestic

The majority of domestic water users within the catchment are supplied by water supply schemes with most of the water sources outside of the catchment. A large proportion of the population, however, does not have treated water supplied to each household. Use of water directly from the Zwartkops River and its tributaries only occurs on a very small scale by inhabitants in informal developments next to the river, while the use of borehole water in the upper catchment occurs on a far greater scale by the farming community.

Recreation

Full and intermediate contact recreational activities such as swimming, angling and boating occur mainly in the estuary and coastal zone. Recreational activities, such as boating, fishing and hiking, also take place above the estuary in the Zwartkops and KwaZunga Rivers. A number of people in the catchment also fish for a living, particularly in the Uitenhage area and in the estuary and coastal zone.

Industrial

Industrial use of surface water is minimal. The majority of industries within the catchment are supplied with municipal water and/or treated effluent from the Kelvin Jones STW and Fishwater Flats WRW. Permits have been issued by the DWAF to Gubb & Inggs, Perseverance Wool Pullery and Swartkops Power Station to abstract water from the Swartkops River, while National Standard and Guestro Uitenhage Dorbyl have permits to abstract water from springs. Gubb and Inggs and Perseverance Wool Pullery no longer abstract water from the river and the Swartkops Power Station is kept operational but is not often utilised to generate electricity.

Irrigation

Irrigated agriculture occurs predominantly in the Kruisrivier area, above the confluence of the Elands and KwaZunga Rivers. Crops grown are mainly vegetables such as potatoes, lettuce, cabbage, carrots, beetroot, sweet potatoes, beans, peppers and brinjals. These tend to be salt sensitive crops. Pastures and citrus are also irrigated in this area. As the Elands River has intermittent flow, groundwater is the major source of water for this use. Most of the farming above Kruisrivier is dryland farming. Irrigation, mostly of pastures, is also carried out on smallholdings at Perseverance (Ninham Shand, 1994c:47).

Livestock Watering

Cattle, sheep and poultry, mainly ostriches, are farmed. Water is mostly abstracted from boreholes in the Elands, KwaZunga and upper Swartkops Sub-catchments, as well as at Perseverance.

Mariculture

Oysters and mussels are harvested commercially from the Blue Hole and an adjacent area near the mouth of the estuary.

3.7 WATER QUALITY CHARACTERISATION

This section provides a general overview of the water chemistry of the surface, ground and coastal water within the catchment.

3.7.1 SURFACE WATER

A general description of the surface water chemistry is given below, based on data collected from the monitoring points shown on Map 11.

Total Dissolved Salts/ Electrical Conductivity

To rationalise the sampling in the catchment, the analysis results received from DWAF, Gubb and Inggs and Uitenhage were compared using median electrical conductivity measurements at commonly monitored points and are shown below.

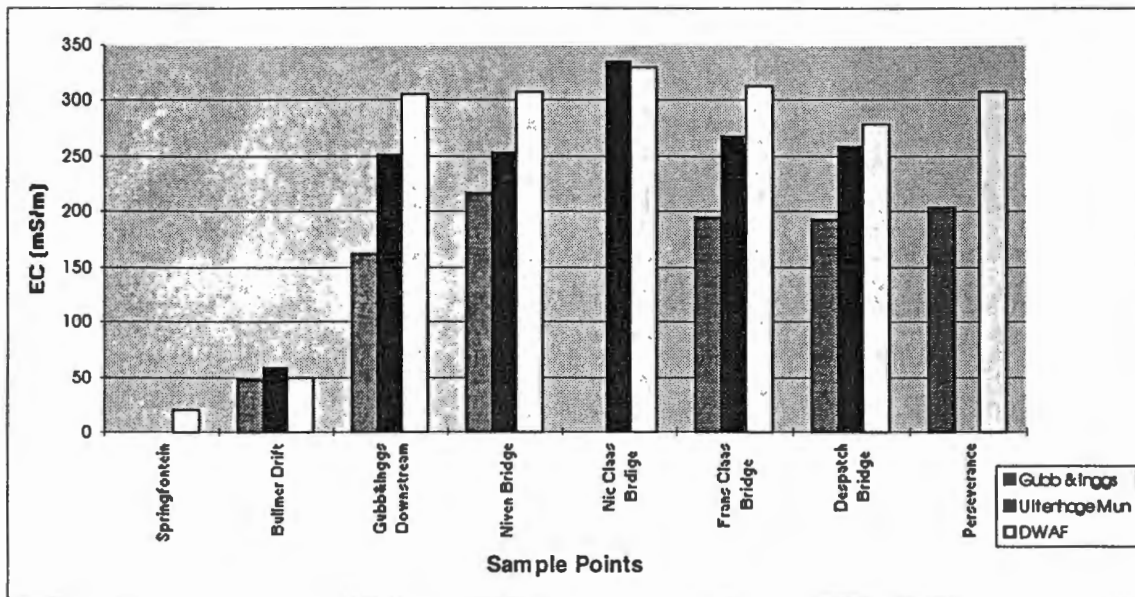
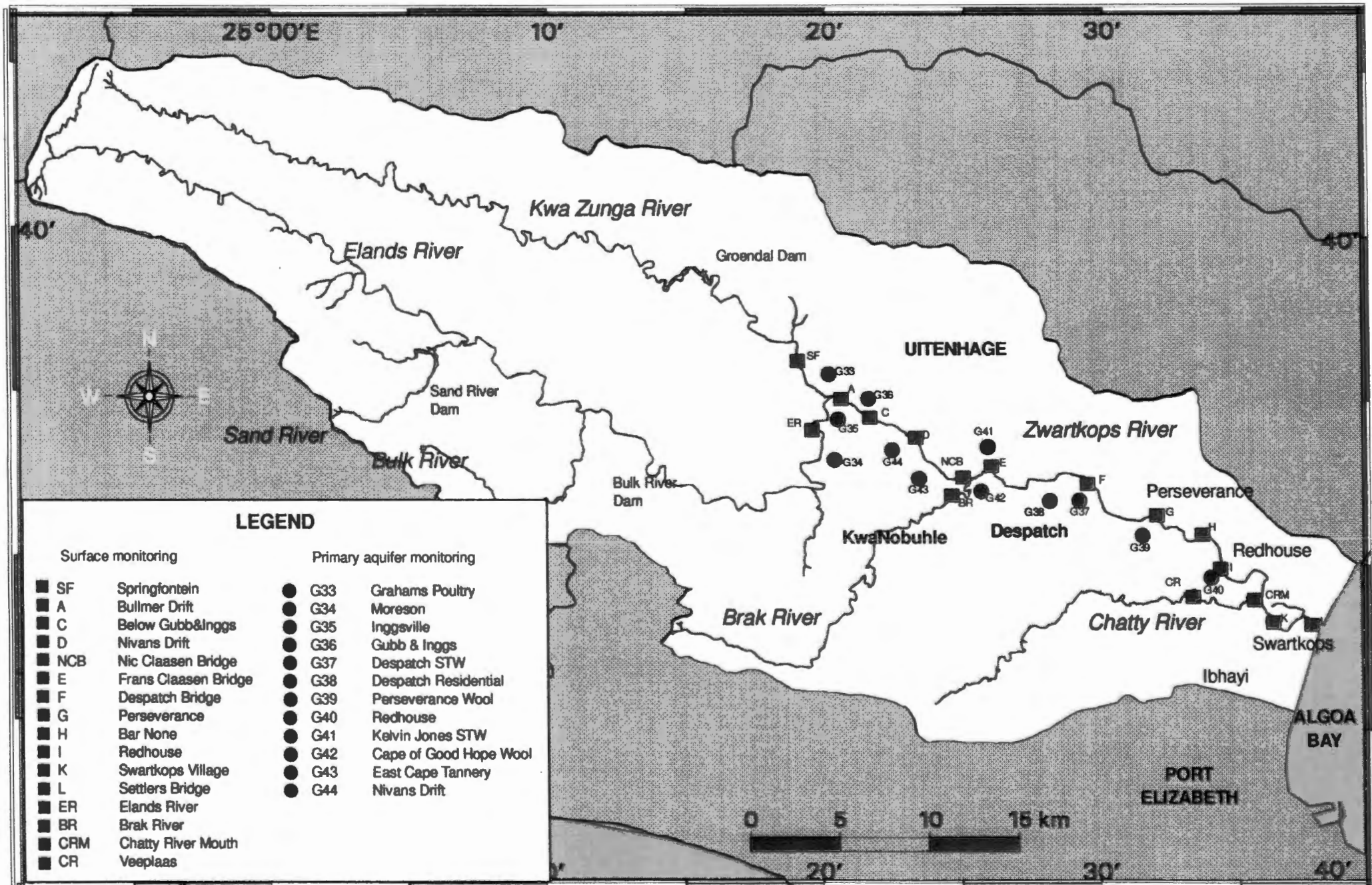


Figure 3. Comparison of electrical conductivity results

This comparison revealed that, while the sample point descriptions were the same, the results varied significantly. This disparity mainly resulted from the difference in the purpose for sampling between these three organisations, i.e. for pollution detection, compliance monitoring and determination of the fitness of the water for use, which led to a difference in sampling sites although the descriptions for these sites were the same. In order to rationalise sampling programmes in the catchment these differences needed to be resolved with the objective of the sampling programme being for management purposes, that is, to ensure the fitness of the water quality for its recognised uses.

These and other electrical conductivity measurements were also used to determine which of the existing monitoring points could best be used for the intended management



Map 11. Water quality monitoring points in the surface water of the Uitenhage area.

purposes, i.e. monitoring the receiving water quality and not an effluent plume. The median electrical conductivities for all the monitoring points are shown below. The high conductivities or salinity in the estuary is clearly visible by the sharp rise in the conductivity values to approximately 5000 mS/m.

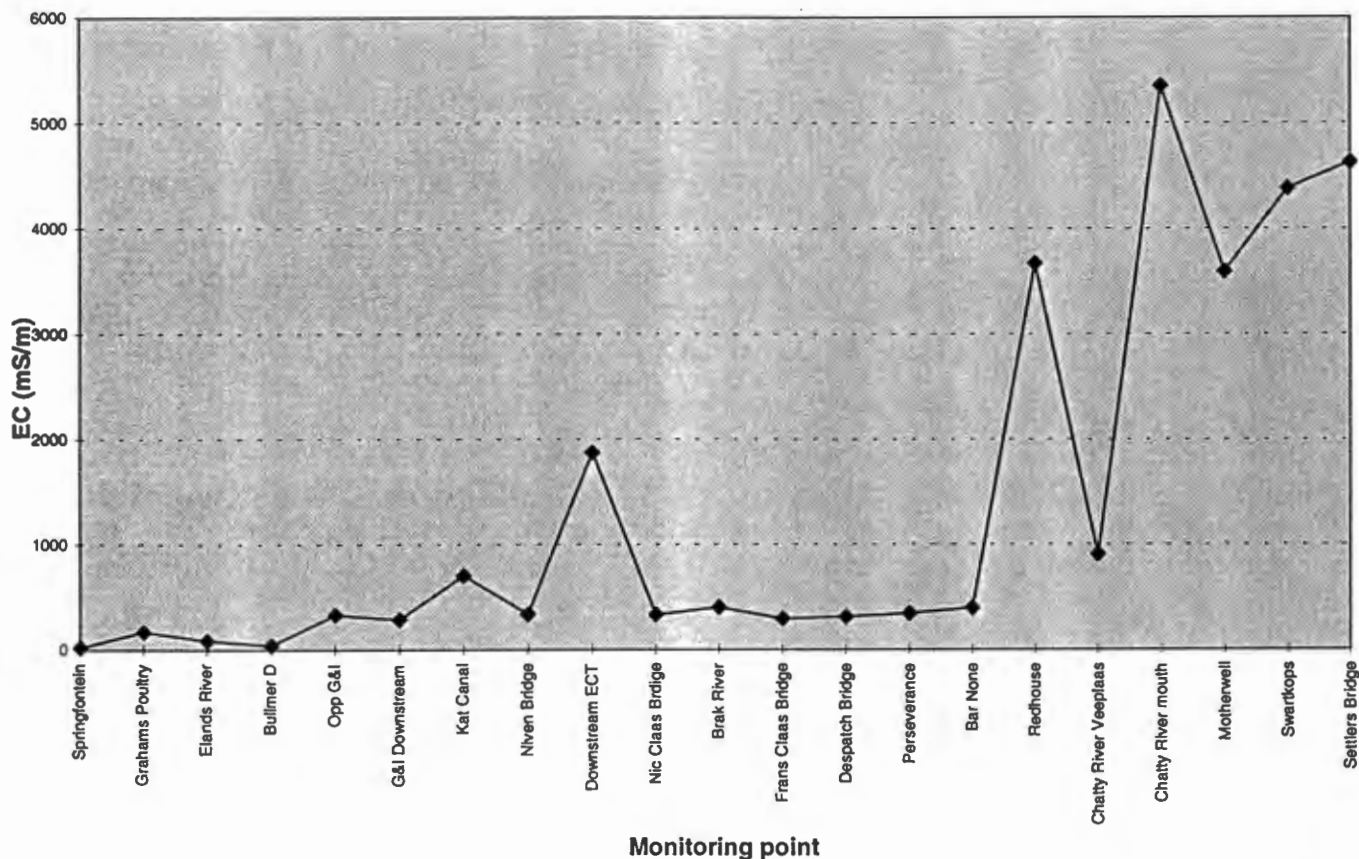
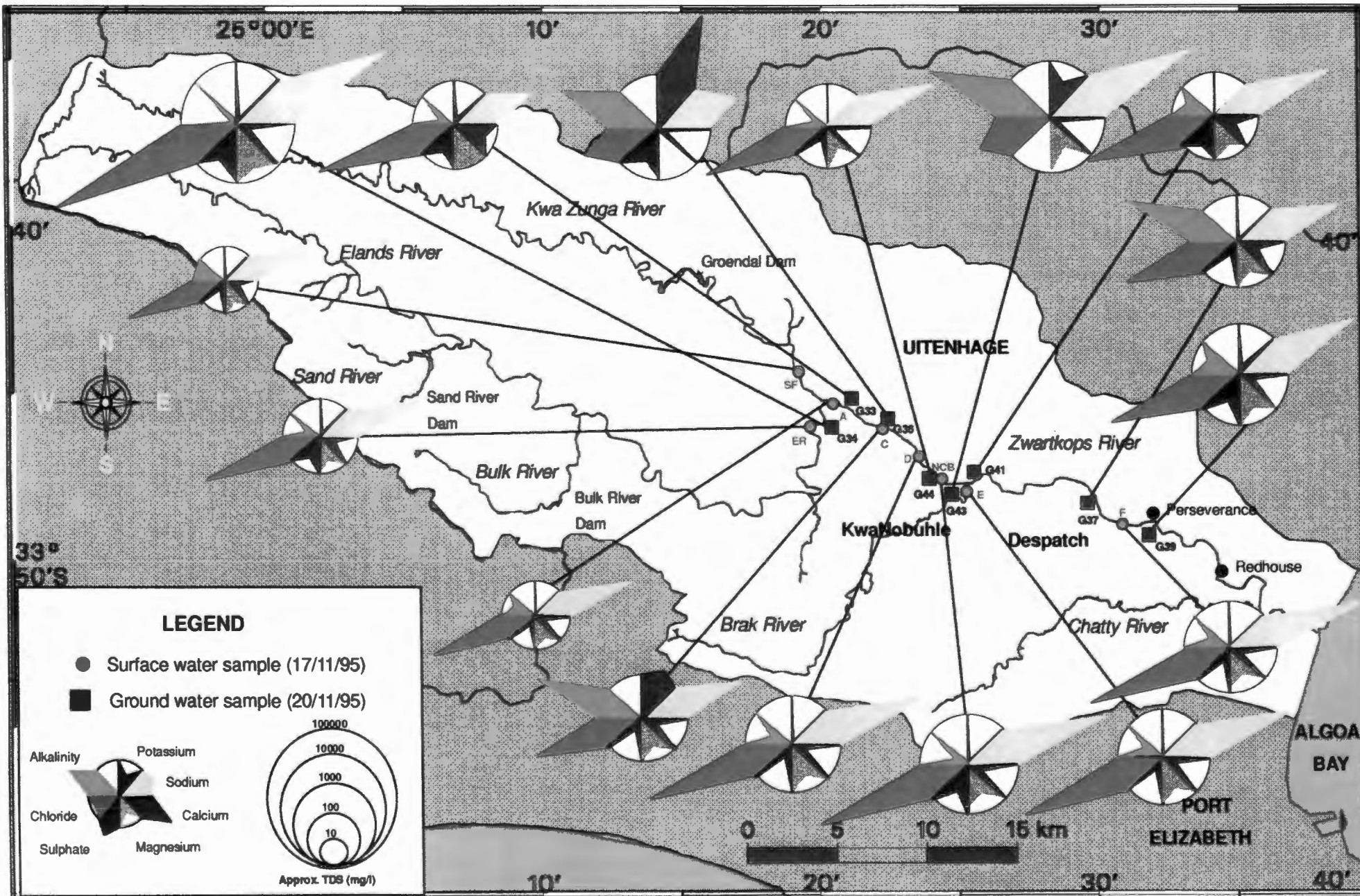


Figure 4. Median electrical conductivity for all monitoring points of surface water in the Zwartkops Catchment

A close examination of those monitoring points where changes to the electrical conductivity were noticeable, as well as where calculations of the expected quality of effluents once diluted in the receiving water body differed from those measured, revealed the following points to be within an effluent plume and hence not suitable for the intended management purposes: Graham's Poultry, opposite Gubb and Inggs, Kat Canal, downstream from East Cape Tanning and the Motherwell Canal, as well as in the Chatty River which consisted mainly of stagnant pools. Once a final set of representative sample points of the quality of the surface water was selected, Maucha diagrams, shown in Map 12, were used to "fingerprint" the water chemistry in the catchment. As previously



Map 12. Surface and Ground Water Chemistry

stated, these diagrams provide an indication of the origin of the water and whether contamination from any source has occurred.

The Maucha diagrams show that the surface water chemistry of the catchment is dominated by sodium and chloride salts as a result of the marine geology. In the upper catchment, the influence of Table Mountain Sandstone on the water chemistry is indicated by elevated bicarbonate (HCO_3) ion concentrations (alkalinity in the Maucha diagrams). The presence of potassium below Gubb and Inggs and at Nivans Drift is an indication of the influence of the wool processing activities on the water chemistry. The only section of the river system which became hypersaline, with salt concentrations of more than 35 000 mg/l or 35 ppt (the concentration in seawater), during the period of monitoring was in the Chatty River at Veeplaas.

Nutrients

Elevated nutrient concentrations result from human activities such as sewage discharges, industries using detergents, feedlots, and agricultural use of fertilisers, as well as from urban runoff. Box plots of phosphate, nitrate and ammonia concentrations measured in the surface water can be seen in Figure 5. Phosphate concentrations increase sharply below the Nic Claasen Bridge in Uitenhage and remain at high concentrations, even in the estuary. These raised levels can be attributed mainly to the treated sewage discharges from KwaNobuhle, Uitenhage and Despatch STWs.

Higher nitrate concentrations were noted at Bullmer Drift, Nivans Drift and between Nic Claasen Bridge and Bar None. These raised concentrations are probably not only as a result of the sewage discharges mentioned above, but also as a result of intensive agricultural practices, such as those undertaken at Grahams Poultry. Nitrates and ammonia concentrations were raised at and below Bullmer Drift due to agriculture and at and below Nic Claasen Bridge mainly as a result of urban activities and the discharges from sewage treatment works. Ammonia is also present at high concentrations in the Kat and Motherwell Canals. Ammonia, however, is rapidly oxidized to nitrate and no high concentrations were observed in the Zwartkops River.

Raised phosphate and nitrate concentrations in the Zwartkops River, contribute to the eutrophication of the river. This has promoted the prolific growth of water hyacinth (*Eichhornia crassipes*) in the river between Uitenhage and Perseverance.

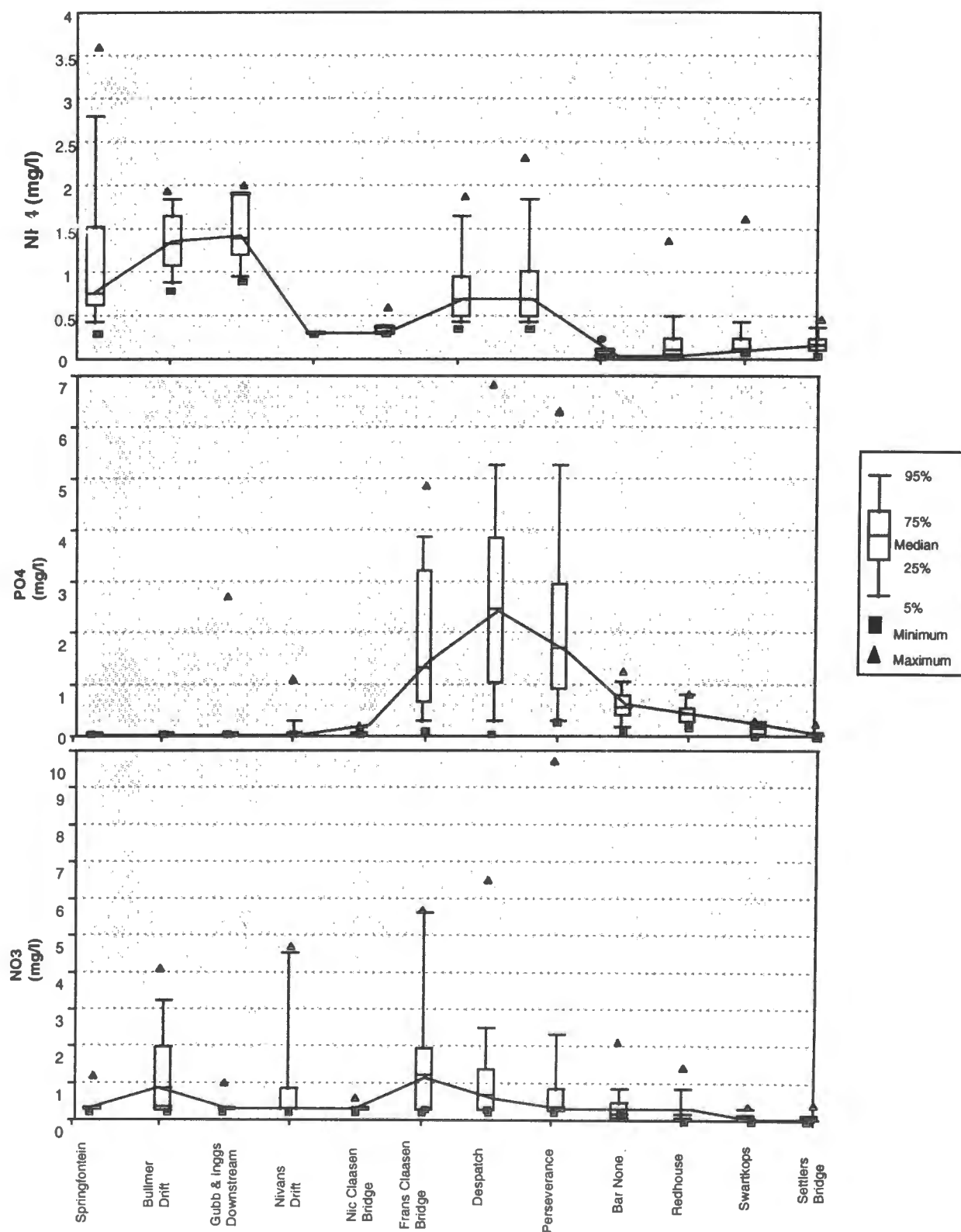


Figure 5. Box and whisker plots of nutrient concentrations in the Zwartkops surface water

Bacteriological

Faecal coliforms are one of the most commonly used bacterial indicators of faecal contamination and indicate the possible presence of pathogens responsible for the transmission of infectious diseases. *E. coli* is a more specific indicator of faecal pollution of human or warm-blooded animal origin. *E. coli* counts have been used to assess the bacteriological state of the water resources in the catchment (Figures 6 to 12). In general, stormwater and urban runoff, as well as the discharge of treated sewage appear to be the major sources of faecal contamination in rivers. The type of sanitation services and their maintenance can also have a major impact on the quality of the runoff.

One would expect a reasonably close relationship between the average monthly rainfall and the faecal coliform or *E. coli* counts measured in the surface waters, as faecal matter which has accumulated on the surface is readily washed into river courses during rainfall events. However, should other factors effect the *E. coli* counts in the river, the relationship between the rainfall and observed *E. coli* counts would not show any close relationship. In the following paragraphs these relationships are investigated by making use of calculated correlation coefficients (*r*).

In the Zwartkops catchment, a high level of faecal contamination is evident at Nivans Drift and in the lower estuary, as well as in the lower Chatty River (Figure 9). Very little faecal contamination therefore originates from the discharges from the sewage treatment works.

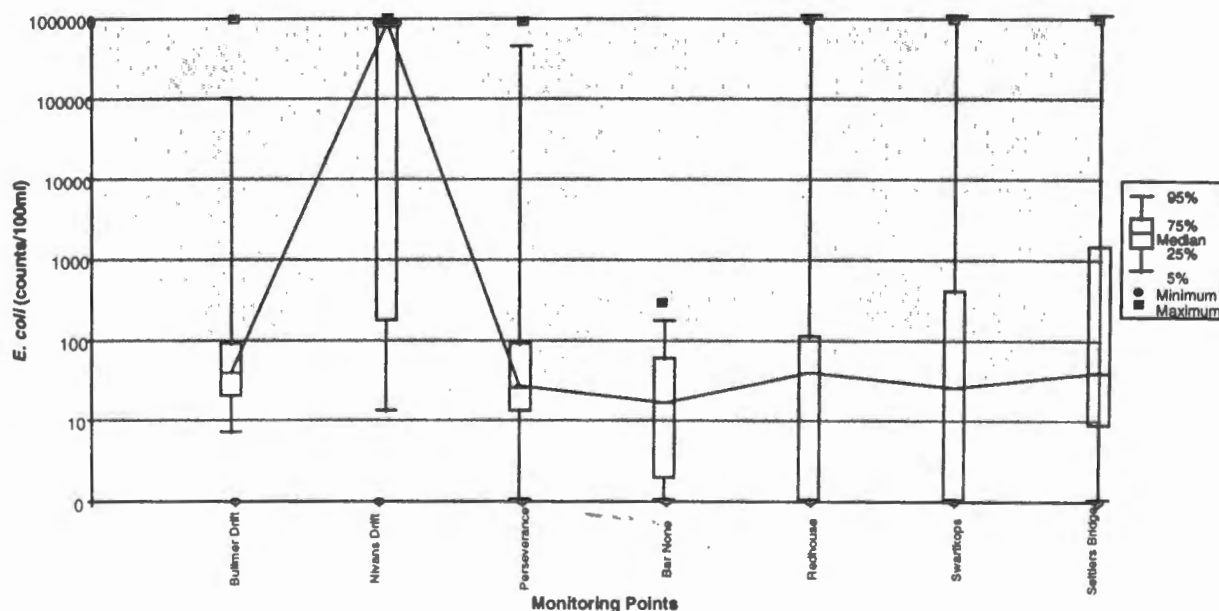


Figure 6. Box and whisker plots of the *E. coli* counts per 100ml for the Zwartkops River

An examination of the bacteriological data revealed the following:

1. High *E. coli* counts in the upper Zwartkops River, with the exception of at Perseverance, appeared to show some correlation to the high rainfall months for the upper Zwartkops Catchment (Figure 7). This implies that the elevated faecal coliform counts are mostly from urban runoff upstream and infiltration from leaking sewers and conservancy tanks.

A statistical comparison of the data sets for *E. coli* counts per 100ml at these sites and the average monthly rainfall at Uitenhage, however, revealed a low correlation coefficient (Table 11). Since the correlation coefficients are lower than the table value of 0,53 on the 95% confidence level, and in the case of Perseverance a negative correlation exists, the relationship is statistically insignificant. This would therefore indicate that the faecal contamination at Bullmer Drift not only originates from surface runoff but also from other sources such as the intensive feedlot practice at Grahams Poultry and the continual faecal contamination from the Kat Canal due to poor sanitation services in the catchment area of the canal.

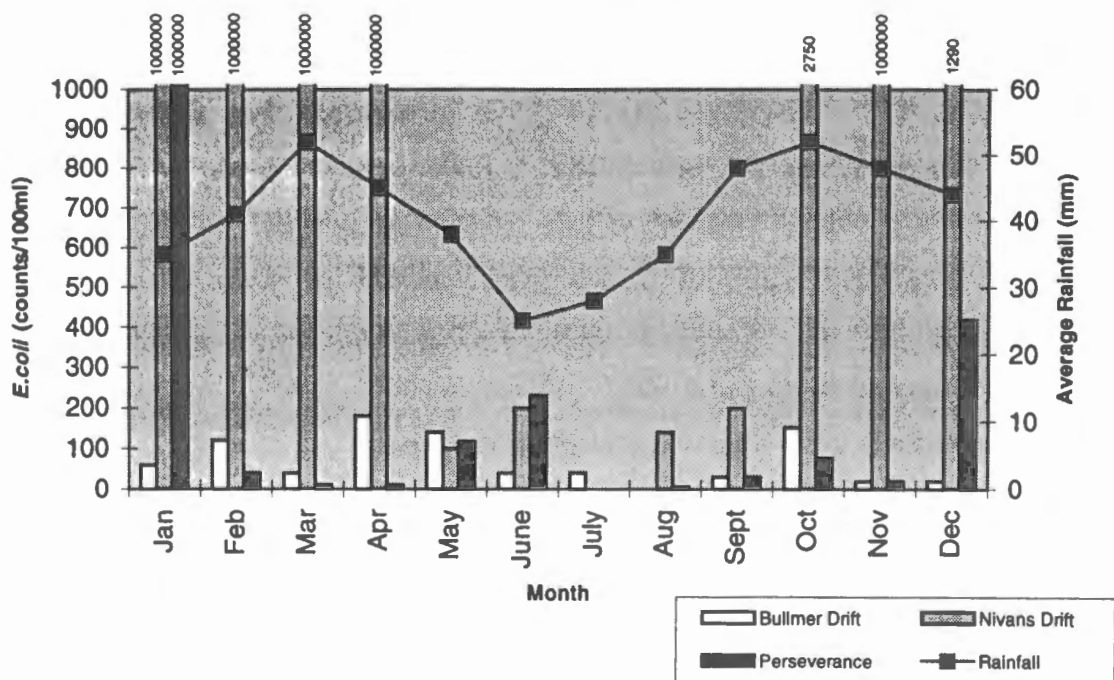


Figure 7. *E. coli* counts per 100ml at Bullmer Drift, Nivans Drift and Perseverance during 1995 plotted against the average monthly rainfall measured at Uitenhage

Table 11 Correlation between *E. coli* counts in the upper Zwartkops River and the average monthly rainfall

Monitoring Point	Calculated r	Tabulated r (95%), n=12	Calculated t	Tabulated $t_{0.05}(10)$
Bullmer Drift - 94	-0.19	0.53	-0.61	2.23
Bullmer Drift - 95	0.17	0.53	0.55	2.23
Nivans Drift - 94	0.06	0.53	0.19	2.23
Nivans Drift - 95	-0.03	0.53	-0.10	2.23
Perseverance - 94	-0.28	0.53	-0.92	2.23
Perseverance - 95	0.32	0.53	1.07	2.23
Redhouse - 94	0.41	0.53	1.42	2.23
Redhouse - 95	0.28	0.53	0.92	2.23

2. The high *E. coli* counts at Redhouse appeared to show some correlation to the high coastal rainfall months for the coastal area (Figure 8). This implies that the elevated faecal coliform counts here are also mostly from urban runoff and infiltration from leaking sewers and conservancy tanks. The correlation coefficient for these two data sets was however low (Table 11). Statistically, the correlation was therefore found to be insignificant, indicating that the faecal contamination at Redhouse is not only linked to rainfall events but is due to other sources, such as possibly the Motherwell Canal. The lack of correlation could also be as a result of other factors such as tidal action and die-off rates.

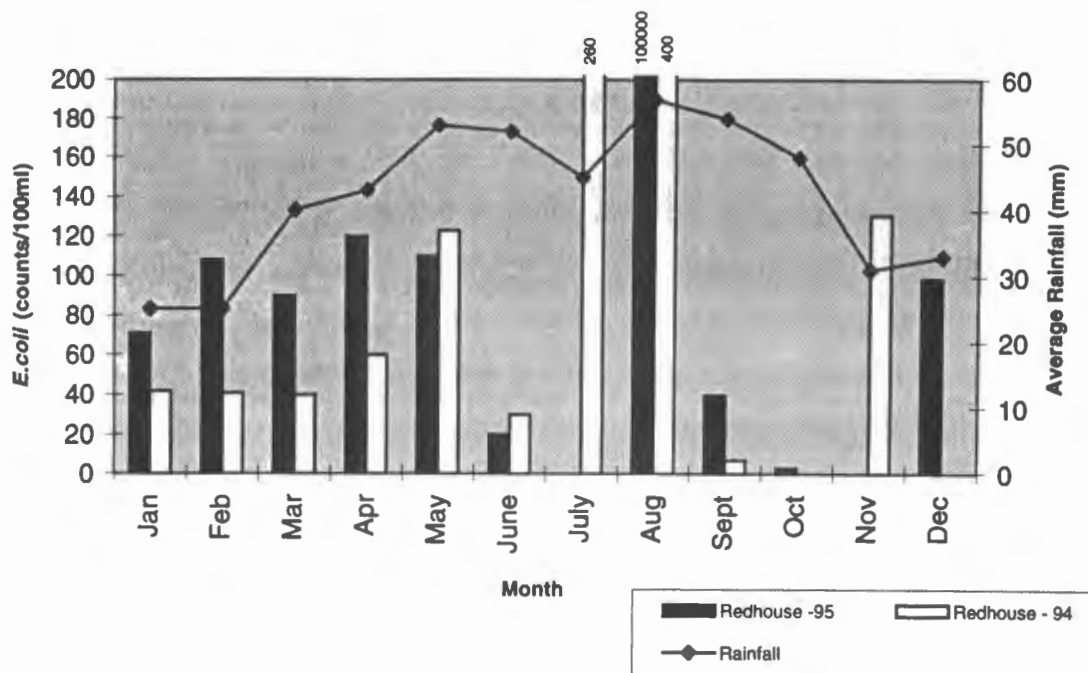


Figure 8. *E. coli* counts per 100ml at Redhouse during 1994 and 1995 plotted against the average monthly rainfall measured at Port Elizabeth

- High *E. coli* counts often occurred in the Chatty River at Veeplaas. However, high *E. coli* counts occurred only occasionally at the mouth (approx. 5 km downstream), indicating that faecal bacteria in the Chatty River did not often reach the estuary (Figure 9). The Chatty River is therefore not a regular source of faecal bacteria to the estuary. Statistically, however, the correlation coefficient between these two data sets was relatively high at 0,67. The minimum value for the correlation coefficient to be significant is, as previously, 0,53 on a 95% confidence level, with a data set of 12. The t-test results were $t=2,89$, where $t_{0,95}(10)=2,23$. The correlation is therefore significant indicating that the kind of source of faecal contamination at these two sites is probably similar, that is, through contamination from poor sanitation services.

A negative correlation coefficient (-0,71 at Veeplaas and -0,48 at the mouth) could be seen between the high *E. coli* counts and high rainfall months, indicating are that the source of faecal bacteria in the lower Chatty River is not linked to runoff.

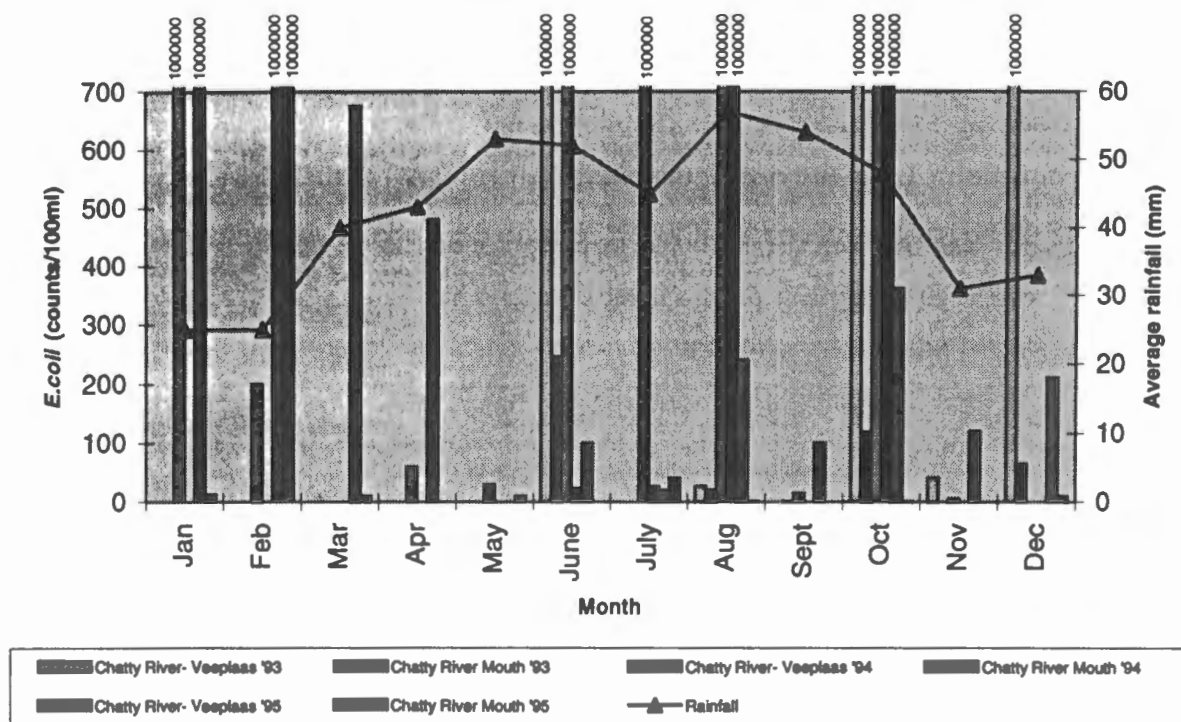


Figure 9. *E. coli* counts per 100ml in the Chatty River at Veeplaas and the above the confluence of the Chatty River with the Zwartkops River for the period 1993 to 1995 plotted against the average rainfall measured at Port Elizabeth.

- From Figure 10, no strong correlation was apparent in the estuary, either between the high *E. coli* counts measured in the estuary and high rainfall periods or the high *E. coli* counts measured at the Motherwell Canal. Statistically, however, a relatively high correlation existed between the data sets for Settlers Bridge and Swartkops Village and to a lesser extent between Swartkops Village and Motherwell Canal. This indicates that the source of faecal contamination at Swartkops Village and Settlers Bridge is similar and that there could be a link to contamination from the Motherwell Canal. The correlation coefficients are given in the table below.

Table 12. Correlation coefficients for *E. coli* counts measured in the estuary

Monitoring Point	Motherwell	Redhouse	Swartkops	t
Settlers Bridge	0.33			1,63
Swartkops	0.41			2,08
Redhouse	-0.13			0,58
Bar None		-0.15		0,70
Chatty mouth			0.11	0,51
Settlers Bridge			0.65	3,98

Where the minimum value for the correlation coefficient to be significant is 0,39 on confidence level of 95%, with a data set of 24 and where, for the t-test $t_{0,05}(22)=2,07$.

There are however a number of factors which affect the *E. coli* counts in the estuary which should be taken into account during such a comparison, such as die-off rates due to sunlight and the high salinity in the estuary. Therefore a cause and effect relationship could not be established here, although it would appear that there is some relationship between the faecal contamination at Motherwell, Swartkops Village and at Settlers Bridge.

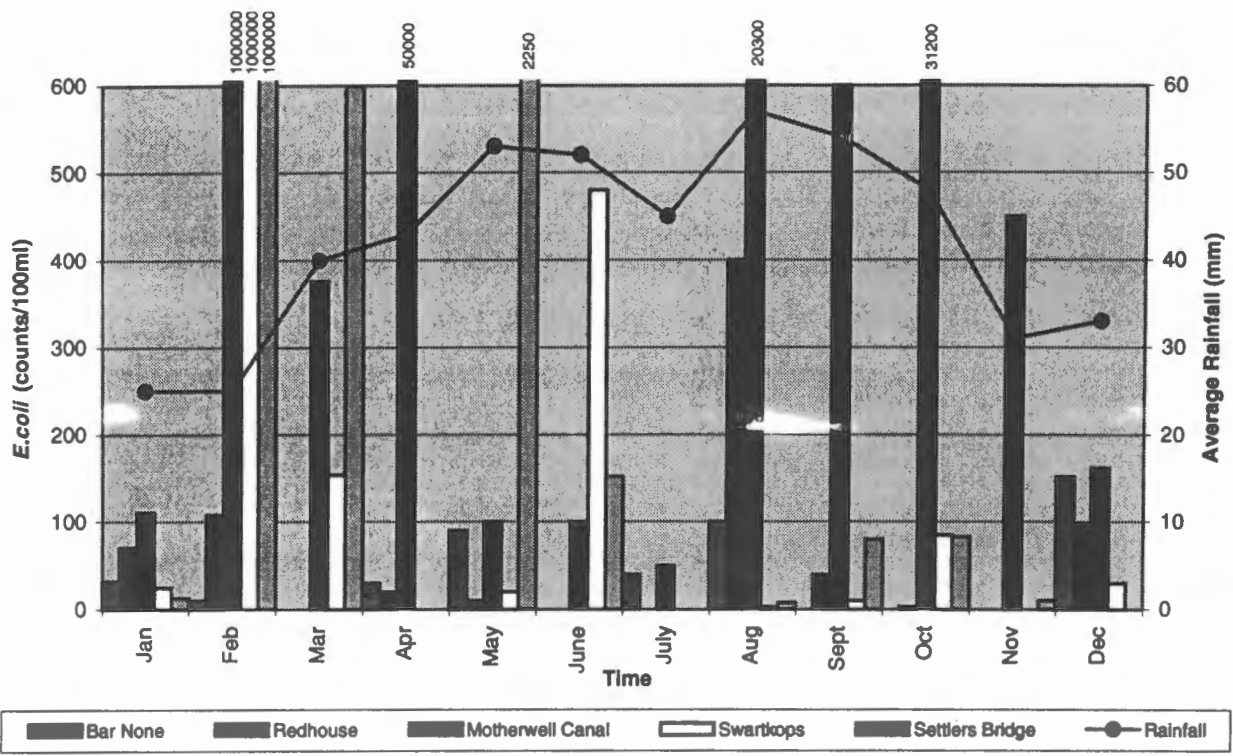


Figure 10. *E. coli* counts per 100ml in the Zwartkops Estuary for 1995 plotted against the average rainfall measured in Port Elizabeth

- Observed high flows and the occurrence of high *E. coli* counts in the Motherwell and Kat Canals did not appear to be linked only to rainfall events, suggesting a constant source of faecal bacteria (see Table 13 for correlation coefficients).

Table 13. Correlation coefficients between rainfall and *E. coli* counts in the Kat and Motherwell Canals

Monitoring Point	Rainfall	t
Motherwell Canal 1994	-0.06	0,21
Motherwell Canal 1995	-0.46	1,66
Kat Canal	0.20	0,64

Where the minimum value for the correlation coefficient to be significant is 0,53, allowing for a 95% confidence level and where for the t-test $t_{0,05}(10)=2,23$.

In Figures 11 and 12, a significant improvement in the quality of the water in these canals can be seen, which is as a result of mitigation actions taken by both the Uitenhage and Port Elizabeth TLCs during 1995.

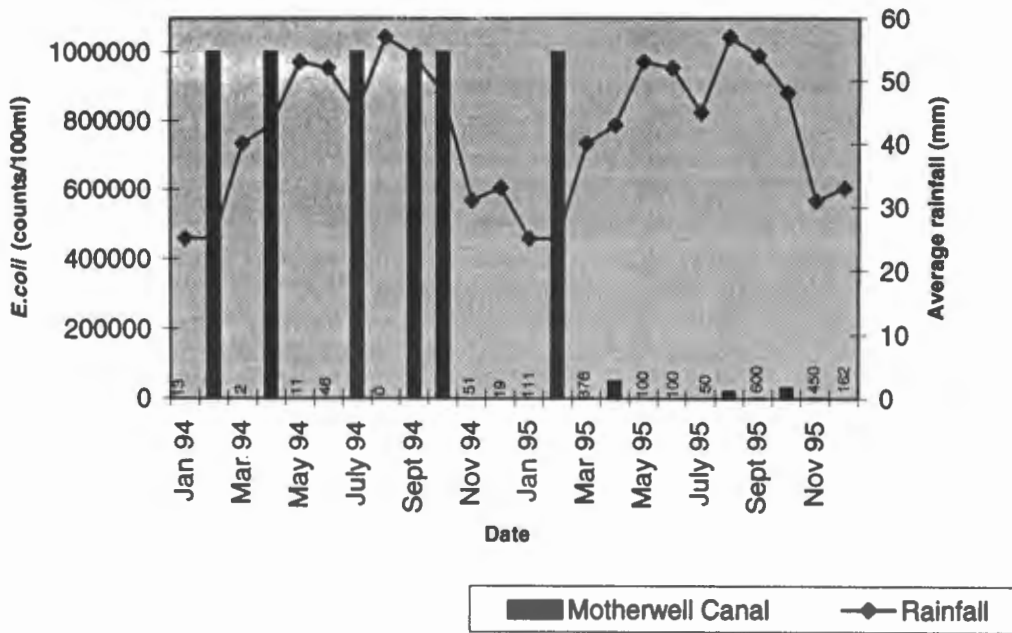


Figure 11. *E. coli* counts/100ml in the Motherwell Canal for 1994/95 against monthly rainfall¹

¹ Note: The maximum number of *E. coli* counts/100ml which can be analyzed for is 1 000 000.

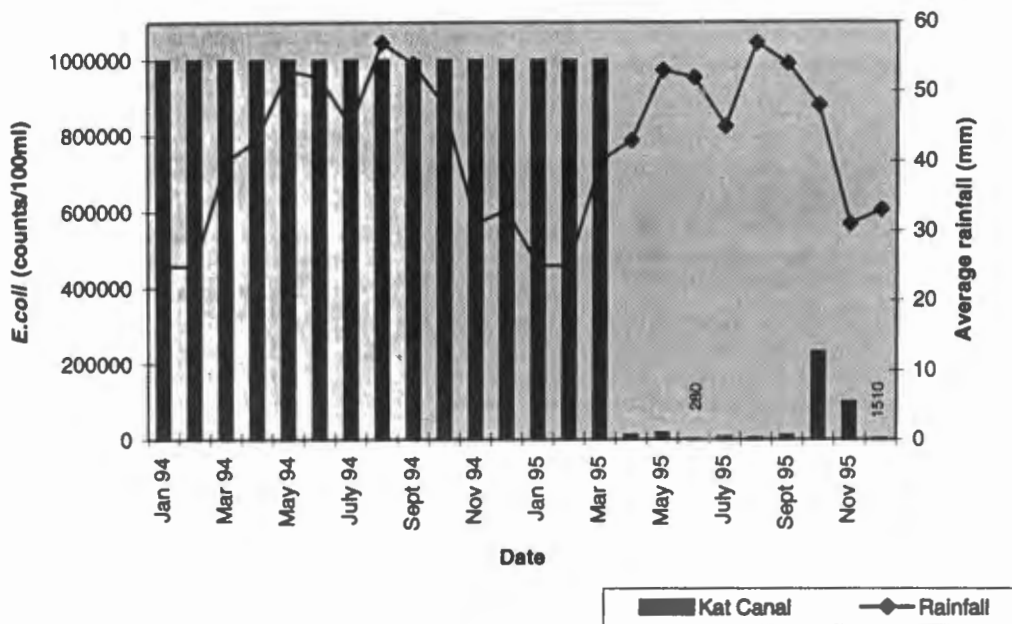


Figure 12. *E. coli* counts/100ml in Kat Canal for 1994/95 against monthly rainfall¹

¹Note: The maximum number of *E. coli* counts/100ml which can be analyzed for is 1 000 000.

3.7.2 GROUND WATER

Groundwater movement from the Table Mountain Sandstone in the upper catchment to the lower lying alluvial areas, involves a change from a calcium, magnesium and bicarbonate dominated water chemistry to one dominated by sodium and chloride salts. This is due to the different geological formations which are encountered along its flow path. The quality of the secondary aquifer is mainly a function of rock strata and residence time, with some local contamination from poorly maintained borehole casings (Maclear, 1993:40). A census of all groundwater sources in the Zwartkops Catchment by Maclear (1993:41), showed a deterioration in the quality of the primary aquifer, mainly around Uitenhage and Despatch. A monitoring network has been initiated specifically to assess the extent of this deterioration. The following information is based on three sets of data taken in the primary aquifer (Map 11), as well as one set of data, excluding trace metals, for the secondary aquifer. No bacteriological monitoring of the groundwater has been undertaken.

Total Dissolved Salts/Electrical Conductivity

The average electrical conductivity levels measured in the primary aquifer are shown in Figure 13.

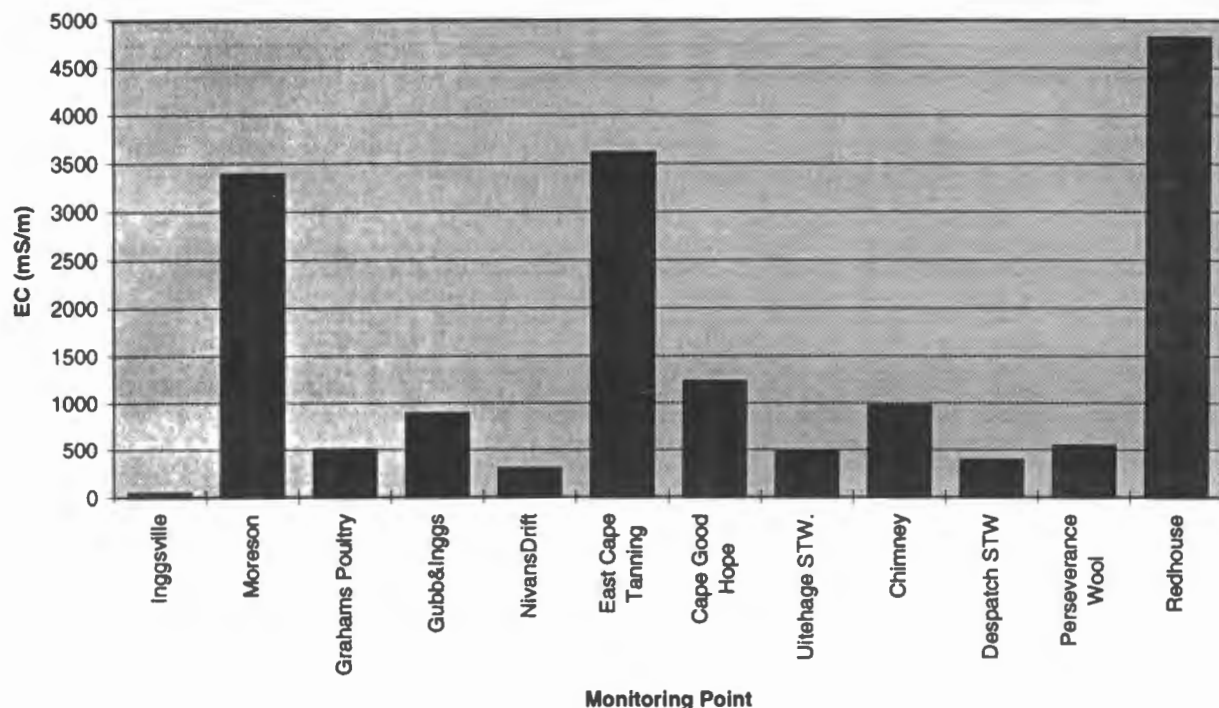


Figure 13. Average electrical conductivity in the primary aquifer

There are localised occurrences of high salt concentrations in the groundwater, especially at Moreson, East Cape Tanning and Redhouse. The origin of these high salt concentrations can be identified as natural or from a landuse activity by investigating the major ions making up that salt content.

Maucha diagrams were also used to determine the groundwater chemistry (Map 12). The naturally high salt concentrations predominant in the catchment can mostly be attributed to the mudstone and siltstone of the Kirkwood and Sundays River Formations. This water, as for the surface water, has a dominance of sodium and chloride ions. Observed localised occurrences of high salt concentrations, especially at the sites above and below Nivans Drift, do not have this dominance and are indicative of an altered water chemistry. Potassium was also observed at high concentrations at these sites as a result of the wool processing activities at Gubb and Inggs and Cape of Good Hope (Figure 14).

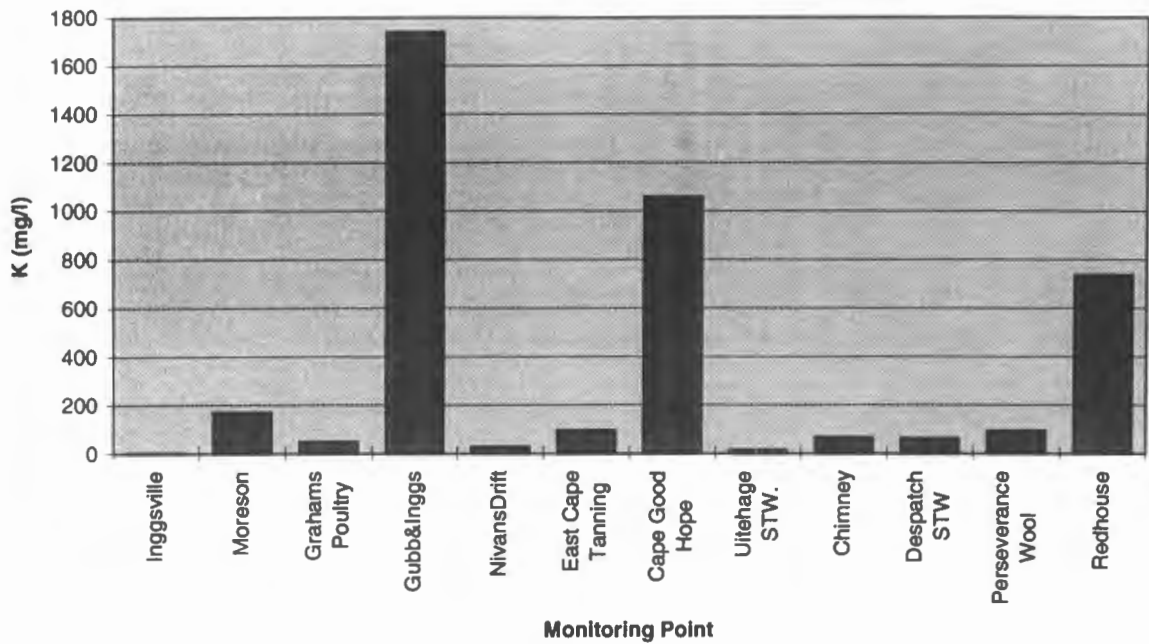


Figure 14. Average potassium measured in the primary aquifer

Nutrients

Agricultural application of fertilisers and manure is a major contributor of nitrate/nitrite to the groundwater. However, no significant levels were measured in the groundwater directly below the Kruisrivier farming area. Localised incidents of high nitrate/nitrite concentrations, together with high sodium, magnesium and chloride concentrations, were observed below Moreson and Grahams Poultry, where intensive feedlot farming occurs (Figure 15). Elevated nitrate/nitrite concentrations were also observed below the residential areas of Despatch and Redhouse and may be from leaking sewer pipes and conservancy tanks (Maclear, 1993:42). These concentrations are unlikely to result in significant water quality problems.

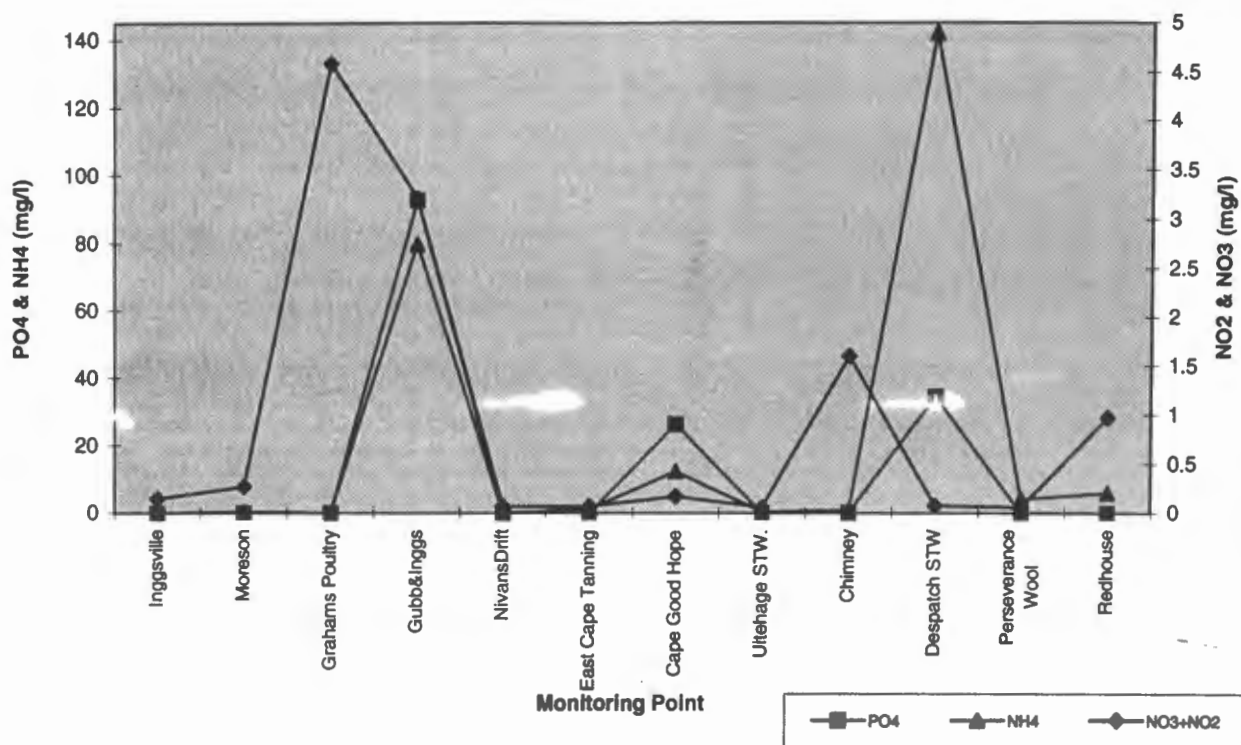


Figure 15. Average nutrient concentrations in the primary aquifer

Both phosphates and ammonia resulting from agricultural runoff are adsorbed onto sediments and will only be released under anoxic conditions or high flows. High concentrations were however measured below Despatch Sewage Works maturation ponds and below Gubb and Inggs where detergents are used. This indicates leaking evaporation ponds.

3.7.3 COASTAL WATER

Although the ocean has a large capacity to assimilate waste, its ability is limited by the rate at which the natural processes of mixing, degradation and dispersion can occur. Coastal waters are especially at risk, where pollutants from land remain trapped in the surfzone. Possible sources of faecal bacteria found in the surf zone off the Zwartkops River are:

- the Paapenkuils River;
- the Fish Water Flats discharge;
- the Zwartkops River; and
- stormwater discharges at Deal Party and Bluewater Bay.

A study of observed *E. coli* counts by Lord *et al* (1991:4) revealed that during strong onshore winds and light north-west to northerly winds, sporadic high *E. coli* counts are observed alongshore, north and south of the Paapenkuijs River. During south to south westerly winds less high *E. coli* counts are mainly observed north of the Paapenkuijs River as a result of better mixing processes. Monitoring results during the period 1990 to 1996 (Figure 16) showed an infrequent occurrence of *E. coli* counts which were highest at the Paapenkuijs River and have a decreasing trend northwards, however slight increases were usually observed at the Deal Party stormwater outlet, the Fish Water Flats outfall and occasionally at the Zwartkops River mouth.

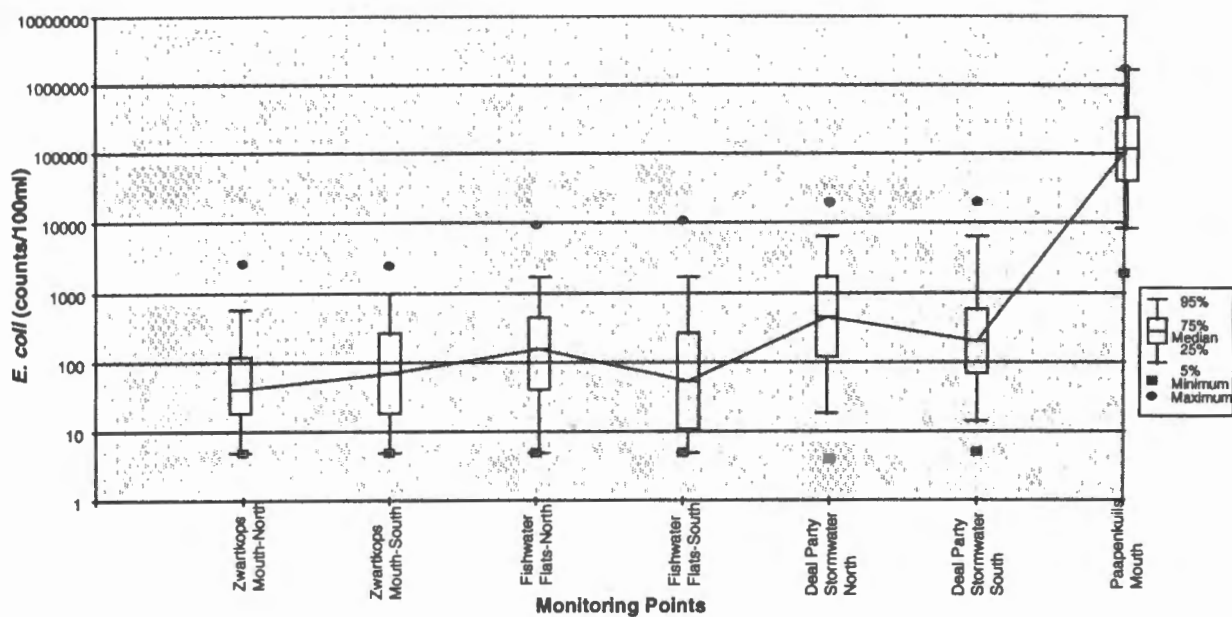


Figure 16. Box and whisker plots of the *E. coli* counts per 100ml for the coastal zone between Bluewater Bay Beach and the Paapenkuijs River mouth

A closer examination of the *E. coli* counts on the south bank compared to those on the north bank of the river mouth, revealed that the counts were generally higher on the southern bank (Figure 17). This would indicate that either the river discharge served to disperse the faecal contamination at this point, that the *E. coli* counts were reduced due to a net movement of water and *E. coli* into the estuary at the time of sampling, that there was a natural die-off of faecal bacteria or a combination of the above. Unfortunately the time of sampling, and thus the tide at the time of sampling, has not been recorded to allow for the cause of the reduction of faecal contamination to be investigated in more detail.

A more detailed investigation therefore is required to determine the impact of faecal pollution in the coastal zone on the water quality in the estuary. Based on the examination of the bacteriological quality of the surface water in the estuary, however, it would appear that the reduction in *E. coli* counts at the river mouth is as a result of natural die-off and dispersion action.

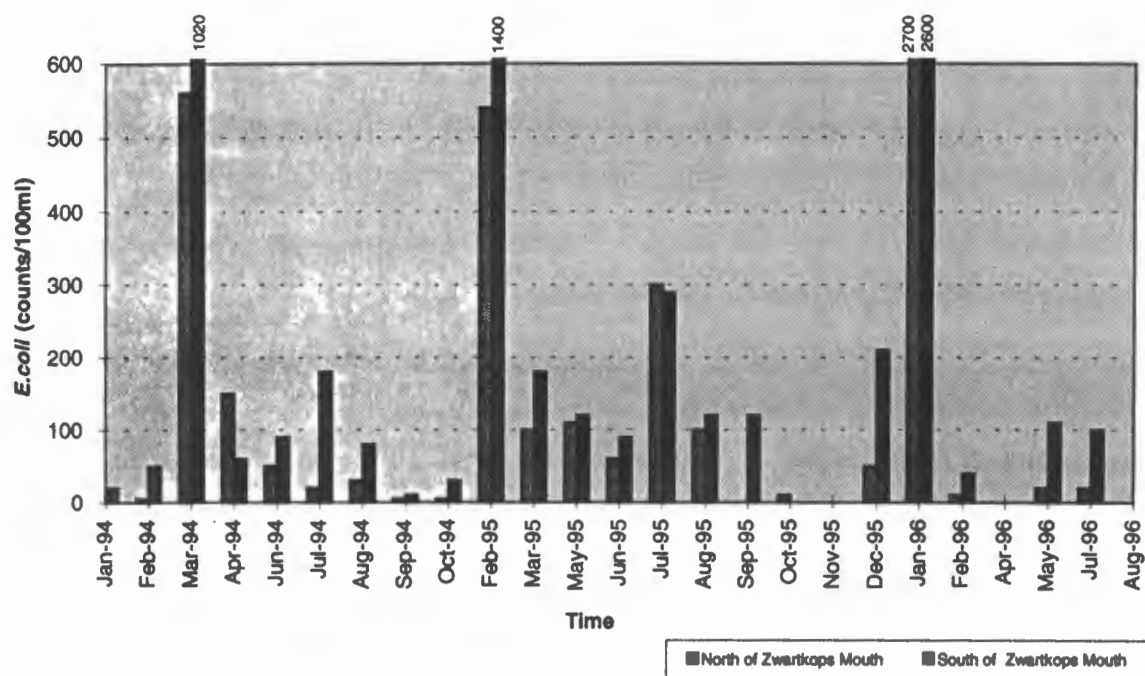


Figure 17. *E. coli* counts per 100ml north and south of the Zwartkops River Mouth for the period 1994 to 1996

Toxic chemicals occur in relatively low concentrations in treated sewage effluent and are of little significance to human health during recreational activities, but may be detrimental to ecosystem health. Toxicity tests of the Fish Water Flats final domestic and industrial effluents showed dilutions of five and twenty five were necessary to render the effluents non toxic (Lord *et al*, 1991:6). These dilutions are likely to be achieved at the discharge points since the mixing and dilution processes in the coastal zone are dynamic.

3.8 WATER QUALITY ASSESSMENT

This section provides an assessment of the quality of the water resources of the Zwartkops Catchment. The quality of water is determined by the use that water is put to. Water quality must therefore be assessed according to the requirements of each user sector.

Each water user, as well as the aquatic ecosystem, has water quality requirements which are expressed in terms of the South African Water Quality Guidelines. Guidelines for the water quality constituents of concern in the catchment are given in this section for domestic use, recreation, irrigation, livestock watering, mariculture and industry. The quality of the surface, ground and coastal water within the catchment is assessed according to its suitability for each user sector, using the guidelines. This classification of the suitability of the quality of the water in the catchment is based on the available data.

3.8.1 DOMESTIC

A classification system (Kempster, 1996:1) is used to assess the suitability of ground and surface water in the Zwartkops Catchment (excluding the estuary and coastal zone) for drinking water purposes only. The four classes within the classification system are defined as follows:

- Class 0: Ideal drinking water quality suitable for long term use.
- Class I: Water quality is still fit for long term use, but with rare and mild health effects, as well as aesthetic effects.
- Class II: Water quality fit for short term or emergency use only.
- Class III: Not suitable for use as drinking water without adequate treatment.

The classification system is summarised in Appendix A.

The suitability of the ground and surface water quality for domestic use, has been classified below according to each sub-catchment. Bacteriological data is an important consideration in assessing the suitability of water for domestic use, however, very little data exists on faecal bacteria or *E. coli* counts, especially in the upper catchment.

KwaZunga Sub-catchment:

Table 14. Summary characterisation of water quality for domestic use - KwaZunga

Site	Class	Problem
Secondary aquifer	Class 0	
KwaZunga River	Class II	Only iron was not in class 0 range.

Naturally occurring iron is found at elevated concentrations below the Groendal Dam, where it is present as an iron oxide precipitate. The effects of iron on the domestic water

user are aesthetic, and appliances will become discoloured. No health effects are expected at these concentrations. The available data indicates that, in the KwaZunga Sub-catchment, the ground and surface water are suitable for domestic use.

Elands Sub-catchment:

Table 15. Summary characterisation of water quality for domestic use - Elands

Site	Class	Problem
Secondary aquifer - upper catchment	Class 0	
Primary and secondary aquifers - Kruisrivier area	Class 0 & Class III	Occasional boreholes had conductivity, chloride, sodium and magnesium concentrations within the class III range. Some pH values within the class II range were observed.
Elands River - upper	Class I	Only iron was not in the class 0 range.
Elands River - lower	Class II	Conductivity, sodium, chloride, manganese and iron concentrations were within the class III range.
Sand/Bulk Rivers	Class II	Only iron was not in the class 0 range.

The effects of marine geology and runoff from agricultural areas on the water quality are apparent for the surface water in the lower catchment and in the groundwater at Môreson and De Rust in the Kruisrivier area. The high sodium and chloride concentrations may cause a salt imbalance and nausea in individuals, while high magnesium concentrations may cause diarrhoea. High chloride concentrations also cause corrosion of appliances, while high magnesium concentrations cause scaling problems in appliances.

Naturally occurring manganese and iron are found at elevated concentrations in the lower catchment and may cause staining problems in appliances. No health effects are expected at these concentrations. The available data indicates that the ground and surface water in the upper Elands Sub-catchment are suitable for domestic use. However, groundwater at Môreson and De Rust in the Kruisrivier area, and water from the lower Elands River during low flow conditions, is not suitable for domestic purposes.

Brak Sub-catchment:

Table 16. Summary characterisation of water quality for domestic use - Brak

Site	Class	Problem
Primary and Secondary aquifer	Class III	Conductivity, sodium, chloride and magnesium concentrations in the middle to lower reaches were within the class III range. Sulphates were within the class II range.
Brak River - upper	Class II	Conductivity, sodium, chloride, manganese and iron concentrations were within the class III range, with magnesium in the class I range.
Brak River - lower	Class III	Conductivity, sodium, chloride, and magnesium concentrations, as well as faecal bacteria counts/ <i>E. coli</i> , were within the class III range. Iron and sulphate were in the class II range.

Naturally high salt concentrations as a result of the marine geology occur in the secondary aquifer at Brakkefontein and in the surface water in the upper catchment. However, the high concentrations in the surface and groundwater in the lower catchment are as a result of urban and industrial activities. The high sodium and chloride concentrations may cause a salt imbalance and nausea in individuals, while high magnesium and sulphate concentrations may cause diarrhoea. High chloride concentrations also cause corrosion of appliances, while high magnesium concentrations cause scaling problems in appliances. Naturally occurring manganese and iron are found at elevated concentrations in the lower catchment and may cause staining problems in appliances. No health effects are expected at these concentrations. The high faecal coliform/*E. coli* counts in the lower reaches of the river indicate a high risk of disease transmission.

The data available shows that both the groundwater of the primary and secondary aquifer and the surface water in the lower Brak Sub-catchment are not suitable for domestic use. Water in the Brak River and in the secondary aquifer above Brakkefontein is still suitable for use. The effects of the water in the upper catchment are aesthetic and health effects may only occur in salt-sensitive individuals and infants.

Chatty Sub-catchment:

Table 17. Summary characterisation of water quality for domestic use - Chatty

Site	Class	Problem
Chatty River - upper	Class III	Sodium and chloride concentrations were within the class III range. Conductivity was within the class II range.
Chatty River - lower	Class III	Conductivity, sodium, chloride concentrations and faecal coliforms/ <i>E. coli</i> counts were within the class III range. Ammonia, magnesium and sulphates were within the class II range.

Only the surface water has been monitored in this sub-catchment. Sodium and chloride concentrations were naturally high as a result of the marine geology. In the lower reaches, however, these high concentrations were contributed to by urban landuse activities. The high sodium and chloride concentrations may cause a salt imbalance and nausea in individuals, while high magnesium and sulphate concentrations may cause diarrhoea. High chloride concentrations also cause corrosion of appliances, while high magnesium concentrations cause scaling problems in appliances. The high faecal coliform/*E. coli* counts in the lower reaches of the river indicate a high risk of disease transmission. Elevated ammonia concentrations, also as a result of urban activities, cause the water to taste bitter.

The data available shows that the surface water in the Chatty Sub-catchment is not suitable for domestic use, especially in the lower reaches where faecal bacteria/*E. coli* counts are high. No data exists for the groundwater in the secondary aquifer, except for the conductivity of two springs used by Bethelsdorp in emergencies. The water from these springs has elevated salt concentrations, but no health effects are expected.

Zwartkops Sub-catchment (excluding the estuary):

The water quality throughout the Zwartkops Sub-catchment has been impacted by landuse activities (Table 18). This reduction in water quality has the following impacts on the water users:

- * High sodium and chloride concentrations may cause a salt imbalance in individuals and nausea. High chloride concentrations also cause corrosion of appliances.
 - * High magnesium and sulphate concentrations may cause diarrhoea. High magnesium concentrations also cause scaling problems in appliances.
 - * Manganese and iron elevated concentrations may cause staining problems in appliances. No health effects are expected.
 - * Fluoride is naturally present at elevated concentrations at Uitenhage, Perseverance and Redhouse. These raised concentrations may cause teeth and bone damage with persistent use of water.
 - * Ammonia was present at high concentrations, mostly as a result of urban activities. The effects are predominantly taste effects.
-

- * Elevated potassium concentrations in the primary aquifer are probably from industrial activities, as well as a naturally high concentration in seawater and hence in the primary aquifer at Redhouse. The effects of raised potassium concentrations are a bitter taste and a salt imbalance with nausea.
- * Arsenic was observed at raised concentrations in the primary aquifer at Uitenhage, probably from industrial activities. Severe health effects may occur after long term use.
- * The presence of high *E. coli* counts as a result of urban runoff pose a high risk of infection.

Table 18. Summary characterisation of water quality for domestic use - Zwartkops

Site	Class	Problem
Secondary aquifer	Class O	
Primary aquifer	Class I to Class III	Conductivity, sodium, chloride, sulphates and magnesium concentrations were within class III ranges throughout the sub-catchment. Manganese concentrations within the class III range were observed below wool processing factories and tannery, as well as iron and arsenic below Gubb & Inggs and Cape of Good Hope Wool Pulleries. Ammonia concentrations were within the class III range at Gubb & Inggs, Cape of Good Hope and Despatch, with class II concentrations at Perseverance and Redhouse. Potassium ranged from class I to class III concentrations at Gubb & Inggs, Cape of Good Hope and Redhouse. Fluorides of class II concentrations occurred at Gubb & Inggs and Redhouse, and at Perseverance in class III ranges.
Zwartkops River: Bullmer Drift	Class II	Ammonia and chloride concentrations were within the class II range, while sodium and conductivity were within class I ranges.
Below Bullmer Drift to Perseverance	Class III	All sites had class III concentrations for sodium, chloride and conductivity. Faecal coliforms/ <i>E. coli</i> counts were in class III range at Nivans Drift and Perseverance. Potassium at class III concentrations occurred at Gubb and Inggs. Sulphate at class I concentrations occurred at all the sites. Potassium at class I concentrations were present at Nivans Drift, Nic Claasen and Frans Claasen bridges. Also present at class I concentrations were iron below Gubb and Inggs, ammonia at Nivans Drift and magnesium at Frans Claasen Bridge.

3.8.2 RECREATION

The water quality requirements for recreation are given for the most sensitive user, contract recreation (e.g. swimming) in freshwater.

Table 19. Water quality requirements for recreational use (DWAF, 1996a:50)

Constituent	Target range	Slight risk/ acceptable	Moderate risk	Increasing risk/severe
<i>E. coli</i> (counts/100ml)	0 - 130	130 - 600	600 - 2000	>2000

The target water quality for recreation in marine waters for *E. coli* is as follows: a maximum acceptable *E. coli* count per 100ml of 100 counts for 80% of the samples or 2000 counts for 95% of the samples (DWAF, 1995b:5.13).

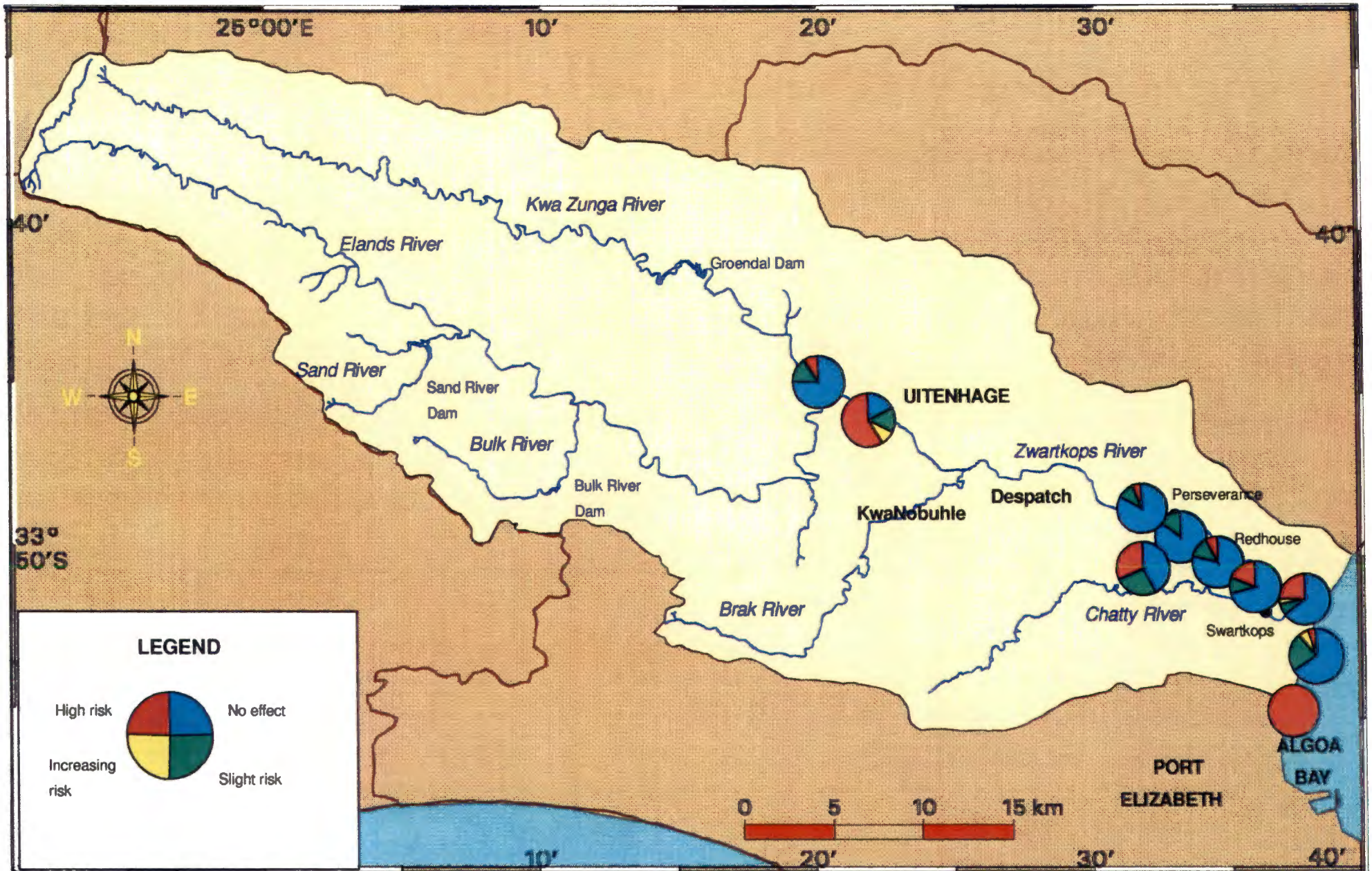
The suitability of the surface waters within the Zwartkops Catchment has been assessed according to the number of samples taken within the period 1993 to 1996 for each site which occurred within the target, slight risk, moderate risk and increasing or severe risk ranges and are represented by means of pie diagrams in Map 13. The areas that pose the greatest health risk are at Nivans Drift and in the lower estuary. A high risk also occurs in the Chatty River at Veeplaas. The suitability of the surface water for recreational use, for the relevant sub-catchments, is given below.

KwaZunga Sub-catchment:

No bacteriological monitoring of the KwaZunga River is undertaken where recreational activities occur. However, elevated counts of *E. coli* are unlikely in this area, as urban development is limited. No water quality problems which are related to recreation are therefore expected in this sub-catchment.

Zwartkops Sub-catchment:

No bacteriological monitoring of the upper Zwartkops River is undertaken, except at Bullmer and Nivans Drift. This system should be monitored, especially at Despatch, where recreational activities occur. High *E. coli* counts occur at Nivans Drift and occasionally at Bullmer Drift and pose a high health risk to recreational users in the area. In the estuary, the *E. coli* counts increase from the head of the estuary to the mouth, indicating a trend of decreasing suitability for recreational use from Perseverance to Settlers Bridge. This implies that the main sources of faecal pollution are in the lower estuary.



Map 13. Fitness for recreational use

Zwartkops Coastal Zone:

The coastal water in the vicinity of the Zwartkops River mouth was assessed for its suitability for recreational use, making use of the same approach and water quality requirements as for the surface water in the catchment. The data was provided by Port Elizabeth Transitional Local Council for the period 1990 to 1996 for the sample points from the Paapenkuis River to Bluewater Bay Beach. The pie diagrams on Map 13 and the box plots in Figure 16, indicate an increasing trend of suitability of the water for recreational use from the Paapenkuis River to Bluewater Bay Beach, with decreases at the stormwater outlet in Deal Party and at Fish Water Flats.

3.8.3 IRRIGATION

Irrigation water classes are determined by the permeability of the soils and the crop sensitivity to salts:

- Class I: Suitable for even the most sensitive soils and crops
- Class II: Suitable for all but the most sensitive soils and crops
- Class III: Special management practices are needed for soil drainage and reduced economic viability
- Class IV: Not economically viable

The following ranges are given for the key water quality constituents:

Table 20. Water quality requirements for irrigation (DWAF, 1996c:26)

Constituent	Class I	Class II	Class III	Class IV
Electrical conductivity (mS/m)	0-40	40-90	90-270	270-540
Boron (mg/l)	0-0.2	0.2-0.9	0.9-1.5	1.5-3
Chloride (mg/l)	0-105	105-140	140-350	>350
Fluoride (mg/l)	0-2		2-7.5	7.5-15
Iron (mg/l)	0-5		5-10	10-20
Manganese (mg/l)	0-0.2		0.2-5	5-10
Arsenic (mg/l)	0-0.1		0.1-1	1-2
Sodium (mg/l)	0-70	3-5	5-7	7-9
(SAR ,mmol/l)	0-3			

SAR = Sodium adsorption ratio

Electrical conductivity, sodium and chloride are the main water quality constituents in the surface and groundwater of the catchment which render the water unfit for irrigation. A

classification of the suitability of the water quality in the catchment for irrigation is discussed below according to the relevant sub-catchments.

KwaZunga Sub-catchment:

The surface and groundwater is suited to irrigation of even the most salt sensitive crops and soils.

Elands Sub-catchment:

Only the groundwater at Kruisrivier is suitable for irrigation of the most sensitive crops and soils. Some sites in the Kruisrivier area (Môreson and De Rust) are however only suitable for more salt tolerant crops and soils. The surface water in the upper catchment above Bullmer Drift, is suited to irrigation of even the most salt sensitive crops and soils, except in the lower Elands River. Here conductivity, chloride and sodium concentrations increase substantially in stagnant pools and may result in significant crop yield reductions when used for irrigation.

Zwartkops Sub-catchment:

Water from both the primary and secondary aquifer at Uitenhage and Despatch is not suited to irrigation. Boron, manganese, fluoride and arsenic concentrations are also high at these sites. The surface water at Bullmer Drift should only be irrigated on more salt-tolerant crops. The salinity of the water in the Zwartkops River below Bullmer Drift, including the Brak and Chatty Rivers, becomes too high for irrigation to be economically viable and special management practices should be used to improve soil drainage. The water supplied by the Orange/Sundays River Scheme has a raised salt content and is not suited to the irrigation of salt-sensitive crops.

3.8.4 LIVESTOCK WATERING

Only the target water quality ranges for the key water quality constituents are given in Table 22 for livestock watering. Above these ranges the water generally becomes unfit for use. This is with the exception of electrical conductivity or total dissolved salts, for which more detail is given in Table 21 below.

Table 21. Table of effects for electrical conductivity and total dissolved salts, with regards to livestock watering (DWAF, 1996d:143)

Electrical conductivity (mS/m)	Total dissolved salts (mg/l)	Suitability
0-154	0-1000	Target range
154-770	1000-5000	Some health effects in sensitive livestock and in poultry
770-1540	5000-10000	Unsuitable for poultry, dairy cattle and sensitive livestock
>1540	>10000	Unsuitable for all livestock

Sensitive livestock = young, pregnant or lactating animals

Table 22. Water quality requirements for livestock watering (DWAF, 1996d:41)

Constituent	Target Range
Chloride (mg/l)	0-1500 (non-ruminants) 0-300 (ruminants)
Nitrate (mg/l)	0-100
Nitrite (mg/l)	0-10
Sodium (mg/l)	0-2000
Sulphate (mg/l)	0-1000
Faecal coliforms (counts/100ml)	0-1000
Fluoride (mg/l)	0-2 (non-ruminants) 0-6 (ruminants)
Iron (mg/l)	0-10
Manganese (mg/l)	0-10
Aluminium (mg/l)	0-5
Boron (mg/l)	0-5
Arsenic (mg/l)	0-0.5
Magnesium (mg/l)	0-500

The water quality requirements for electrical conductivity, chloride and sodium, although less stringent than for irrigation, are the determining factor for suitability of both surface and groundwater for livestock watering. A classification of the suitability of the water in the catchment for livestock watering is discussed below according to the relevant sub-catchments.

KwaZungu Sub-catchment:

The surface and groundwater is suited to watering of all livestock.

Elands Sub-catchment:

In the secondary and primary aquifer, some sites at Kruisrivier area (Môreson and De Rust) are unsuited for livestock watering, especially of poultry and dairy cattle. The surface water, and the remainder of the groundwater, is suited to watering of all livestock.

Zwartkops Sub-catchment

In the secondary aquifer, sites at Uitenhage and Despatch, as well as some sites in the middle Brak Sub-catchment and the Kruisrivier area are unsuited for livestock watering, especially of poultry and dairy cattle. At Perseverance, fluoride concentrations are above the target guideline range for non-ruminants and ruminants. At all the sites in the primary aquifer, the water is poorly, or completely unsuited for livestock watering, especially within Alexander Park Industrial area and below Despatch. Similarly, the surface water in the catchment, below Bullmer Drift is not suitable for livestock watering, with some health effects occurring in poultry, as well as young and sensitive animals. Faecal coliform counts do not fall within the target guideline range at Bullmer Drift, Nivans Drift and Perseverance.

3.8.5 MARICULTURE

The suitability of water in the Zwartkops Catchment has only been assessed at the Blue Hole, which is periodically linked by a narrow channel to the mouth of the Zwartkops River.

The maximum acceptable number of *E. coli* counts per 100ml, established as a target guideline range for mariculture is:

20 counts/100ml for 80% of the samples

60 counts/100ml for 95% of the samples (DWAF, 1995c:5.89).

Bacteriological monitoring carried out by the Department of Health at Blue Hole from January 1993 to July 1996, showed that *E. coli* counts never exceeded the target guideline range for mariculture. Of the samples taken by the DWAF over the same period, at the mouth of the Zwartkops River, 55% exceeded 20 counts per 100 ml and 44% exceeded 60 counts per 100 ml. On the seaward side of the mouth, samples taken by Port Elizabeth Transitional Local Council showed that 64% of the samples exceeded 20 counts per 100 ml and 49% exceeded 60 counts per 100ml. There is therefore probably a poor interchange between the Blue Hole and the estuary and a water quality problem in the Blue Hole due to the high *E. coli* counts in the estuary is not expected. Mariculture should, however, not be undertaken in the estuary.

3.8.6 INDUSTRIAL USE

The water quality guidelines are given in Table 23 according to the treatment costs to the wool processing industry for deteriorating water quality.

At present, there is no industrial use of raw water, with the exception of abstraction water from springs by National Standard and Guestro Uitenhage, as well as the abstraction of estuary water by the Swartkops Power Station for cooling water. No water quality monitoring is undertaken for the water abstracted by industry and no reports of water quality problems have been received from these industries.

The key water quality constituents for cooling water, i.e. electrical conductivity, sodium, chlorides and sulphates are naturally high in the estuary. The treatment and use of this poorer quality water has, however, been catered for during the construction of the power station.

Table 23. Water quality requirements for industrial use (DWAF, 1996b:22)

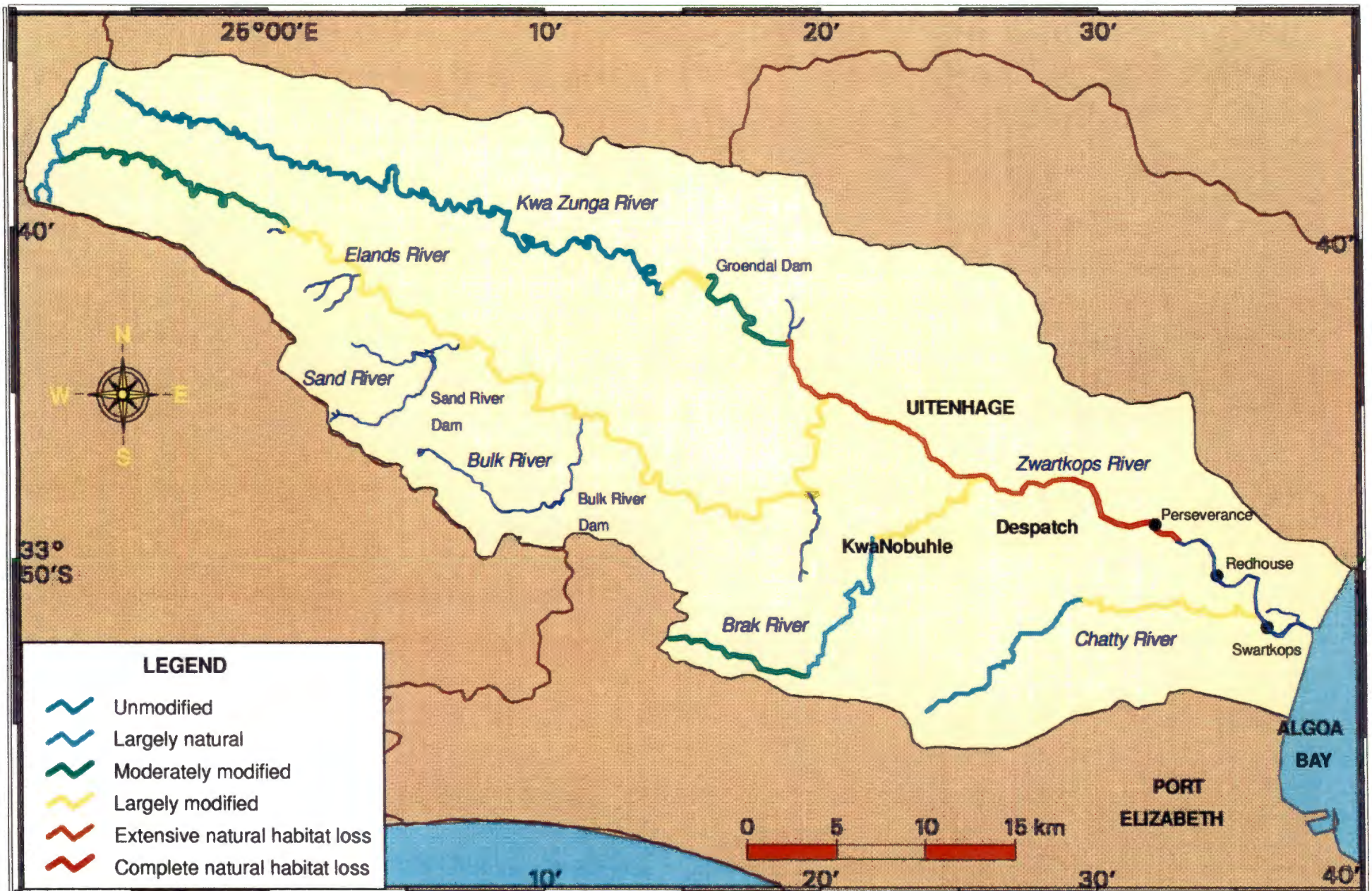
Constituent	Target Range	Mild cost	Moderate cost	Substantial cost
pH (pH units)	7-8.5	6.5-7 or 8.5-10	<6.5 or >10	
Total hardness (mg/l)	0-25		25-150	150-500
Alkalinity (mg/l)	0-100		100-200	>200
Iron (mg/l)	0-0.2		0.2-5	5-50
Manganese (mg/l)	0-0.1		0.1-1	1-10
Chemical oxygen demand	1-10	10-30	30-50	

3.9 AQUATIC ECOSYSTEM HEALTH

3.9.1 INSTREAM AND RIPARIAN HABITAT

A summary of the results from the report "*Preliminary assessment of the habitat integrity of the Swartkops River Catchment*" (Kleynhans, 1995) follows and can be seen on Maps 14 and 15. The monitoring results from this survey are also summarised in Appendix B.

The KwaZungu River upstream of the Groendal Dam is still in an excellent condition, except for alien vegetation in the upper reaches. From Groendal Dam to its confluence



Map 14. Instream habitat integrity

with the Elands River, the instream integrity of the KwaZunga River decreases to being moderately to largely modified. The main reasons for this decrease are:

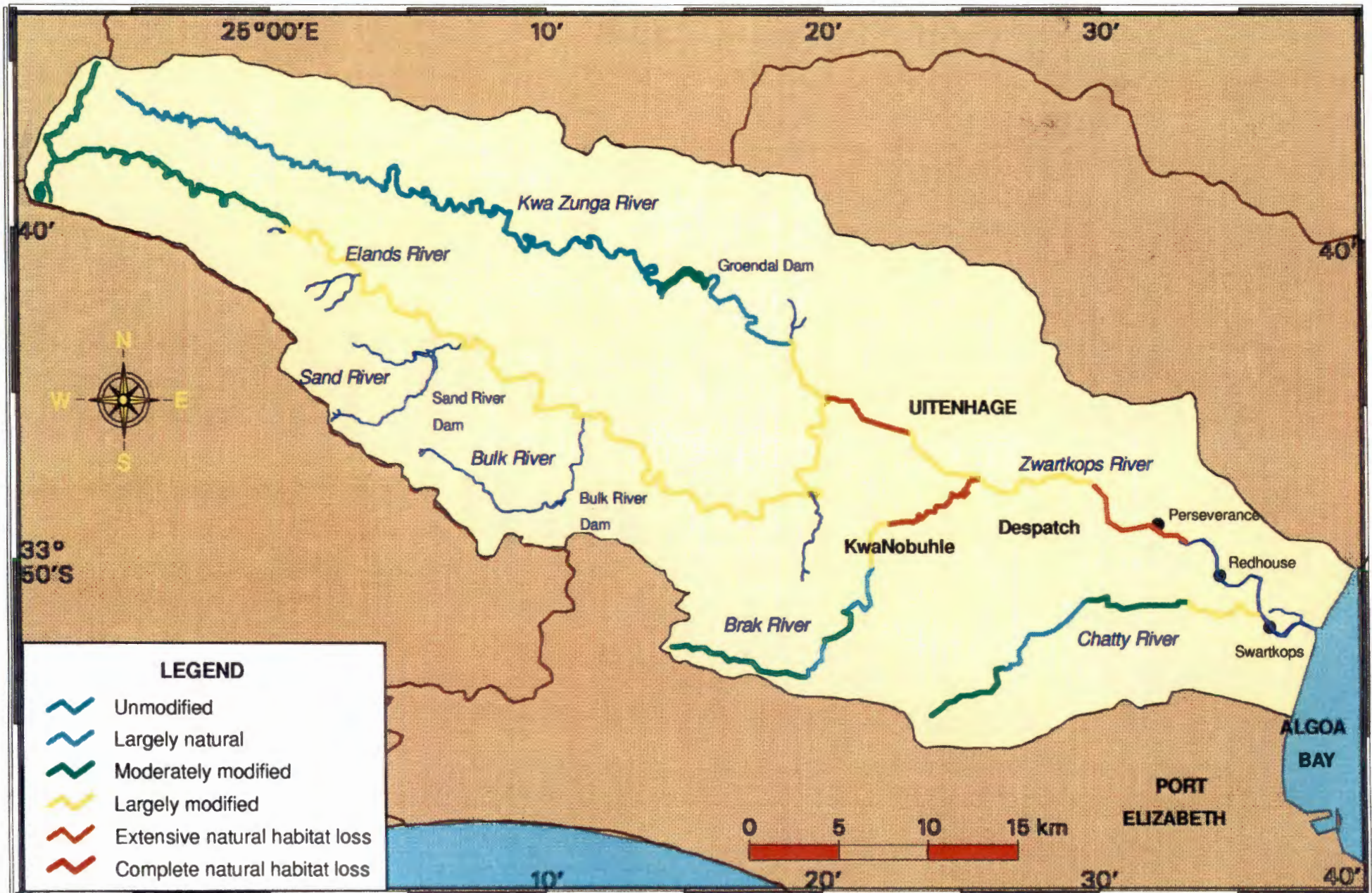
- Water abstraction from Groendal Dam.
- Flow modification due to the effect of Groendal Dam.

The instream habitat of the Zwartkops River from the confluence of the KwaZunga and Elands Rivers up to the Perseverance bridge is very poor. The main contributors to this low status are:

- Water abstraction and the resultant loss of flowing water habitats during low rainfall periods.
- The removal of vegetation due to farming and industrial activities.
- Exotic encroachment.
- Flow modification at Groendal Dam.
- Bank, channel and bed modification due to artificial disturbances of the river bed (i.e. sand quarries) and river banks (some farming activities and exotic vegetation, bridges, levees for flood control, encroachment by industrial sites and urban development, roads and causeways). Sedimentation is also a problem as a result of Groendal Dam and a decreased river slope.
- Water quality modification: The upper section has good water quality but is reduced downstream by: the Kat Canal which carries detergents, litter and untreated sewage to the river; discharges from the stormwater drains in the Uitenhage industrial area; infiltration from evaporation ponds and treated sewage effluent discharges from the KwaNobuhle, Uitenhage and Despatch STWs which result in eutrophication and the prolific growth of water hyacinth (*Eichhornia crassipes*) downstream.

Development along the Elands River has degraded the river considerably. Most of the Elands River has been largely modified with the contributors to its degradation being:

- Water abstraction for irrigation purposes and an abundant exotic riparian vegetation contributes substantially to the removal of water from the system. The loss of flowing water during low rainfall periods is expected to occur extensively and regularly.
 - Flow modification due to weirs in the river may reduce the effect of high flows. No compensation water is released from the Sand and Bulk River Dams, contributing to the change from a perennial river to a seasonal one.
-



Map 15. Riparian habitat integrity

-
- Bed modification and bank erosion due to disturbances from cultivated lands, roads and bridges and destabilisation of the river banks by exotic vegetation enhance the movement of sediments into the river. A decrease in the depth of pools due to sedimentation is evident. Agricultural utilization of low flows probably also limits the flushing of sediments, while eutrophication is expected to enhance algal growth on the river bed.
 - Encroachment of exotic vegetation, mostly wattles and eucalyptus.
 - Vegetation removal due to farming activities.

Of the above-mentioned issues, water abstraction is the main contributor to the degradation of the Elands River.

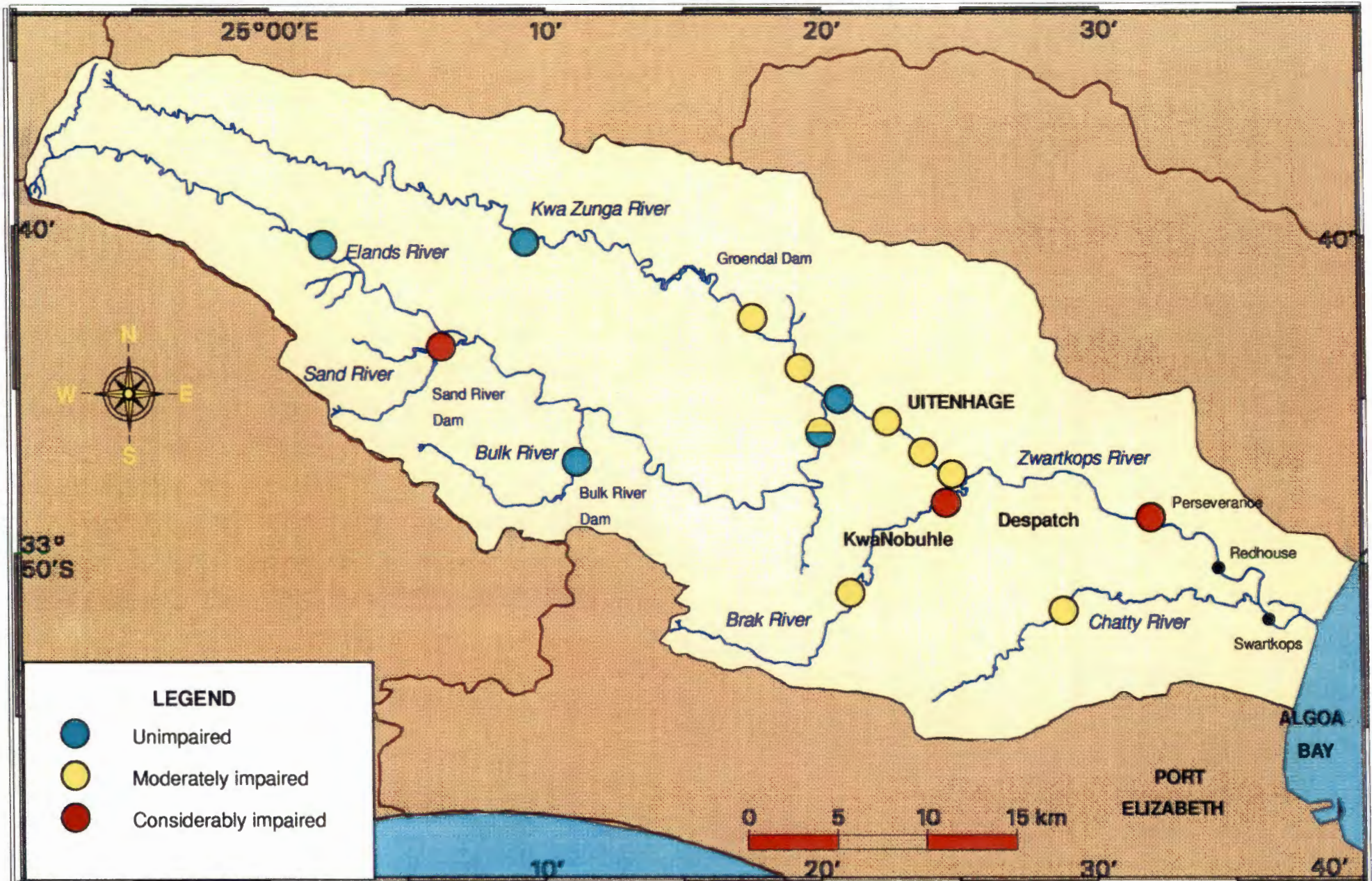
The Brak River has a relatively good habitat in its upstream and middle sections, although exotic vegetation has reduced the integrity of the riparian habitat. The middle section in particular has not been subjected to large scale development and is possibly of high conservation importance due to its natural state. Lower sections, however, have been largely modified. This change is closely associated with urban activities, such as:

- Bed modification caused by erosion due to exotic vegetation.
- Channel modification due to the removal of bank vegetation, some canalisation and bridges.
- Vegetation removal and bank erosion.
- Water quality modification as a result of treated sewage flows from urban areas.
- Solid waste disposal.

The Chatty River also has a relatively high instream habitat status in the upstream and middle sections. Exotic vegetation has however reduced the riparian habitat integrity in these reaches. Both the instream and riparian integrity decrease in the lower sections. This decrease is closely associated with urban activities similar to those mentioned above for the Brak River.

3.9.2 MACROINVERTEBRATES

Below is a summary of the results from the report *“Zwartkops River Catchment Management Program: Assessment of biological integrity using invertebrate*



Map 16. Instream biotic health (macroinvertebrates)

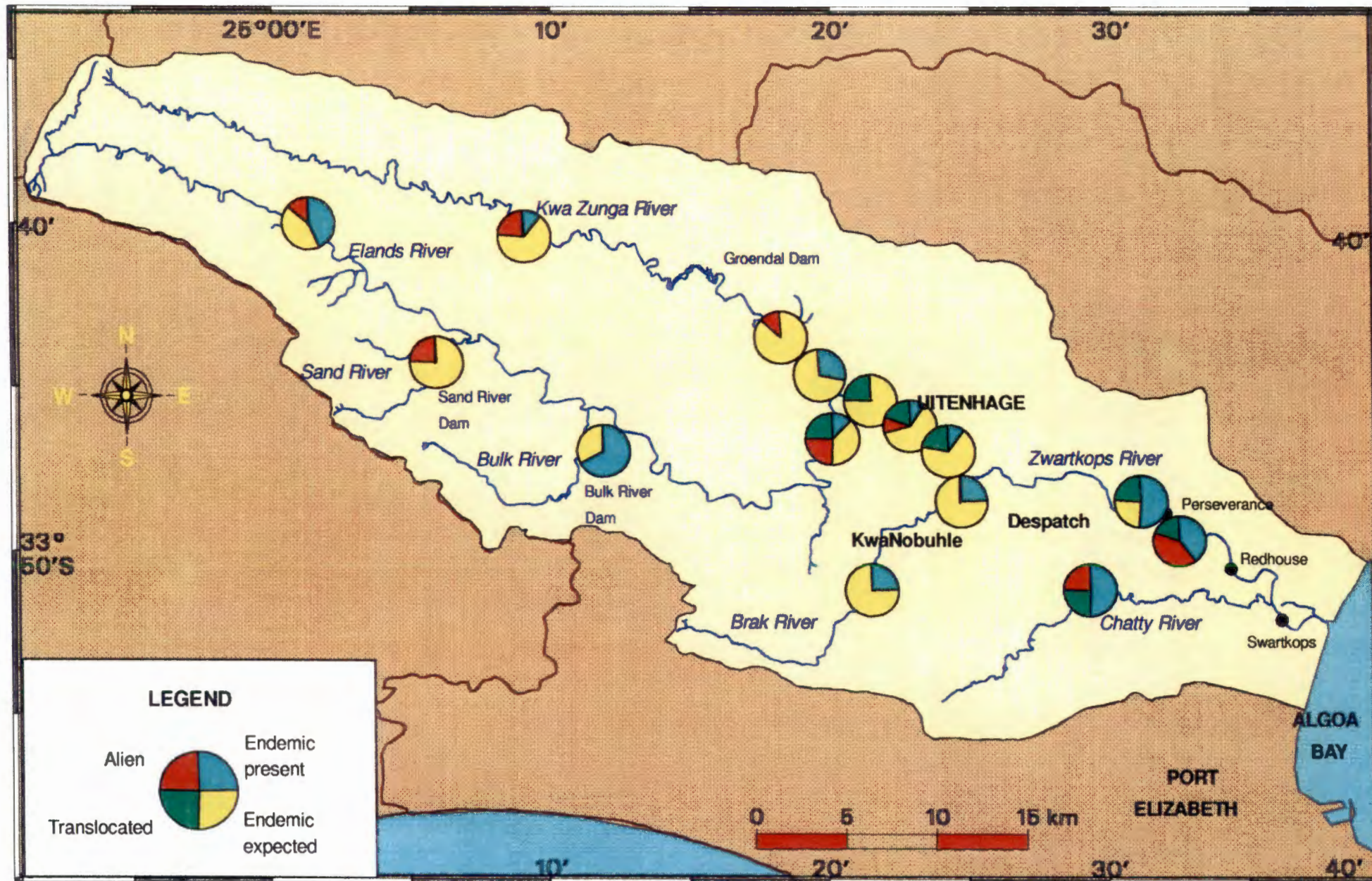
biomonitoring (SASS4)" (Uys & Soxujwa, 1996). These results are also summarised on Map 16.

The monitoring site in the upper KwaZunga River was unimpaired. Below Groendal Dam the sites were found to be moderately impaired. Flow was marginal and the dissolved oxygen unexpectedly low (75%). A reddish iron precipitate was abundant in the more stagnant waters. The site at Springfontein had been subjected to quarrying activities and poor habitat conditions were considered to account for the low SASS4 scores.

The upper Elands River site and the site on the Bulk River were unimpaired. The site on the lower Elands River was unimpaired to moderately impaired. The deterioration was largely due to low-flow conditions, with the river channel and surrounding environment visibly impaired. SASS4 scores at the site in the Sand River were particularly low, with low-scoring, pollution-tolerant fauna present, due mainly to a lack of flow.

The site at Bullmer Drift in the Zwartkops River was considered unimpaired as a reference site. Low SASS4 scores at Gubb and Inggs reflected the first major impact of water quality. The entire channel was covered with the exotic waterweed, *Azolla filiculoides*, suggesting disturbed and eutrophic conditions. At Nivans Drift, there was little flow and dense algal growth in the shallow water, probably due to high temperatures and nutrient enrichment. Although the habitat was adequate, SASS4 scores were fairly low reflecting the low-scoring, pollution-tolerant fauna present. Frans Claasen Bridge had low SASS4 scores, with only low-scoring and pollution tolerant taxa. Perseverance Drift reflected the cumulative effects of industrial and urban activities, runoff from small-scale agricultural activities, inputs of treated water from sewage works and quarrying. Despite diverse habitat availability, SASS4 levels were the lowest recorded in the catchment and suggest serious water quality impairment

The site in the Upper Brak River is located in agricultural land and was the site of a gold mine. There was no flow in the river and despite the presence of sensitive taxa, those organisms requiring flow were absent. A relatively low SASS4 score was obtained. Flow in the lower Brak River is contributed to by input from the KwaNobuhle Sewage Works. Nonetheless, the SASS4 score here was extremely poor. The water is considered to be of a poor quality.



Map 17. Instream biotic health (fish)

The results of the Upper Chatty River site were unexpectedly low, with few invertebrate groups present. The poor scores at the site are linked to the lack of flow in the system, as water quality appears to be good and habitat was not seriously impaired.

3.9.3 FISH

The following is a summary of the results from the report "*Zwartkops River Water Resources Management Plan: Fish survey of Zwartkops River System: November 1995*" (Bok, McCartney & Haselau, 1996). Results from the survey are shown on Map 17.

The KwaZungu River, upstream of the Groendal Dam, was almost pristine but has been markedly affected by the presence of two exotic predatory species. Species that are known to occur at this site were not found. Below the dam and at the East Cape Nature Conservation picnic site, poor water quality (low oxygen coupled with an iron precipitate) and low flows resulted in low catch numbers.

In the upper Elands River, above the confluence of the Sand and Bulk River tributaries, exotic fish species and some sensitive endemic species were present. Lower in the Elands River, migratory mullet were expected but not found. These results have been attributed to the low river flow at the time of the survey. No indigenous fish species were found at the site in the Sand River, possibly as a result of the presence of exotic predators. The Bulk River is still an excellent habitat for the sensitive fish species.

In the upper catchment of the Brak River, sensitive indigenous species occur. Low flow conditions are however a problem. Lower in the catchment, the water is high in nutrients and only hardy fish species occurred.

Sensitive fish species were found in the upper reaches of the Chatty River and indicate that the water quality there is still good. Low flows in the river, however, ruled out the presence of other expected endemic fish.

In the Zwartkops River at Gubb and Inggs, eutrophic conditions, together with the exotic weed, *Azolla filiculoides*, and the shallowness of the water resulted in the low catch numbers of mostly tolerant fish. Conditions at Nivans Drift were eutrophic and only

tolerant fish were found in large numbers. This was also found at Frans Claasen Bridge, where three tolerant fish species were caught. At Perseverance, the river was highly enriched with abundant hyacinth growth. Moderately sensitive fish species were caught. Downstream of Perseverance, the river has been largely modified by sand mining activities and only moderately sensitive fish species occurred.

Fish distribution interpretation was complicated by the presence of exotic predator species, which have resulted in the removal of small indigenous species. This effect, together with the effect of low river flows, makes it difficult to separate these effects from the effects of a poor water quality on the fish distribution.

3.9.4 ESTUARINE ECOSYSTEM

Sandy estuaries, such as the Zwartkops Estuary, are generally wide and shallow and are much more efficiently flushed, giving pollutants a lower residence time. They are also less stratified (Reddering, 1988:156). An important feature of the estuary is the salt marsh, which is the third largest in South Africa and forms an important link in the estuarine system (Baird *et al*, 1986:44).

A survey of the health of the Zwartkops estuary, carried out by the CSIR in 1996, indicated that the estuary had a good fish assemblage. A total of 30 fish species were caught, of which 9 species breed in southern African estuaries and the remaining 21 species are inshore marine species which depend on estuaries during the juvenile phase of their life cycle. A moderate impairment of trophic status, was however expected due to raised surface phosphate concentrations (CSIR, 1996:70; Emmerson, 1985:197).

3.10 SUMMARY AND DISCUSSION OF RESULTS

The suitability of the water quality in the catchment, according to the quality requirements of domestic use, irrigation and livestock watering, was assessed throughout the surface and groundwater, excluding the estuary and coastal zone, regardless of whether that use actually occurs. A major water quality issue is the high salts in the lower catchment which make the surface and groundwater not viable as a source of water for future development. Alternative sources of water must be found. Also of particular concern, is the high faecal

pollution in the lower catchment. These water quality issues, together with their most likely causes and effects, are discussed in more detail in Table 24.

Table 24. Summary of water quality assessment issues

Water Quality Constituent	Problem	Sub-catchment
Salts: Electrical conductivity Sodium Chloride	Result mostly from geology, but also from agriculture and industry. Some health effects occur from domestic use as a result of a salt imbalance, especially in infants. Water also has a bitter taste and causes a deterioration of domestic appliances. Some health effects also occur for livestock, especially in sensitive livestock and poultry. If used for irrigation, crop yield reductions of more than 20% can be expected.	Lower Elands, Brak, Chatty & Zwartkops
Sulphate	Largely natural with some impact from industry. Diarrhoea results from the domestic use, particularly in infants and sensitive individuals. Water also has a bitter taste. Water is unsuitable for livestock watering only in the Zwartkops Sub-catchment.	Brak, Lower Chatty & Zwartkops
Magnesium	Largely natural. Diarrhoea results from domestic use, particularly in infants and sensitive individuals. Water also has a bitter taste. Water is unsuitable for livestock watering from the groundwater in the Zwartkops Sub-catchment at Mõreson, Uitenhage and Despatch.	Lower Elands, Brak, Lower Chatty & Zwartkops (primarily in groundwater)
Manganese	Largely natural. Severe aesthetic effects and staining occur in domestic water. Irrigation water from the primary aquifer will result in toxicity to a number of crops over the longer term.	Lower Elands, Brak, Lower Chatty & Zwartkops
Iron	Largely natural. Effects are mostly aesthetic for domestic water, from a brown discolouration.	KwaZunga, Elands, Brak and Zwartkops
Fluoride	Largely natural. Detrimental damage to teeth and even bones with persistent use as domestic water at Uitenhage, Perseverance and Redhouse. Similarly the water at these points is not suited for livestock watering. A reduction in the crop yield of sensitive crops will also occur from the irrigation of water at the above points.	Zwartkops groundwater
Arsenic	Of industrial origin. Exposure over a long period could cause skin lesions in domestic users. This water is also not suitable for irrigation of sensitive crops.	Zwartkops primary aquifer
Ammonia	Of agricultural, residential and industrial origin. Predominantly taste effects with a slight potential for toxicity in infants from domestic use.	Lower Chatty & Zwartkops
Potassium	Of industrial origin. Indicates an altered water chemistry in the Zwartkops River and primary aquifer. Some health effects occur from domestic use as a result of a salt imbalance, especially in infants. Water also has a bitter taste.	Zwartkops
Boron	Largely natural. If used for irrigation, large crop yield reductions may occur.	Zwartkops
Faecal coliforms	Result mostly from urban runoff and from feedlots. A high risk of gastrointestinal illness in recreational users. Water in estuary and coastal zone, excluding the Blue Hole is not suitable for mariculture. Not suitable for livestock watering.	Zwartkops, Lower Chatty & coastal zone

All of the above issues have been translated in terms of the importance and magnitude of each impact on the surface, ground and coastal water quality in the form of the Leopold matrix (Table 25). This matrix highlights that the major water quality impacts are the high bacteriological counts in the surface and coastal water, as well as the high salt concentration of the surface and groundwater. The high nutrient concentrations in the surface water are of a lesser concern, while there are few other water quality issues. With regards to the impact of specific activities, the informal residential areas, together with the Motherwell and Kat stormwater systems are the major impacters on the bacteriological water quality, while the wool processing and tanning industrial activities have a major impact on the salt concentrations of the surface and groundwater. The positive impact of nature conservation, which acts as a buffer zone, is shown by means of the plus sign which precedes the magnitude of the impact.

Shortcomings of this matrix is that it only demonstrates to the manager the significance of each activity in the catchment on the water quality. The matrix does not take into account the impact of natural features such as geology or the spatial distribution of the impacts. In addition, the matrix does not address the cumulative impacts of the catchment activities but assesses them on an individual basis. Another shortcoming of this method is that the values assigned to each impact are subjective and are not based on actual measurements. The matrix does however provide the manager with a checklist of the summarised impacts for all the major activities in the catchment.

An overlay mapping technique was also used to illustrate or highlight the impact of various landuse activities on the water quality for management purposes. The product of a number of overlay maps have been combined to produce a single map for each major water quality issue. These maps can be seen on the following pages. The first overlay map, Map 18, depicts the impact of geology, industrial activities and agricultural return flows on the salt concentrations of the surface water. A combined map showing the Kirkwood Formation, key industrial activities and Maucha diagrams was produced. This map provides the manager of a good indication of the influence that each of these major factors has on the salt concentration in the groundwater of the lower catchment. That is, there is a major increase in the salt concentration due to the geology but there are also significant localised increases

caused by some of the major industrial activities. This map is especially useful since all three influencing factors occur mostly in the highly impacted area surrounding Uitenhage.

A map, Map 19, of residential areas (classified according population density and level of development and as determined from 1990 satellite imagery), feedlots and *E. coli* counts measured per 100ml was produced to illustrate the impact of these activities on the bacteriological quality of the surface water. This map clearly shows that the major impact on the bacteriological quality of the water is from the informal and semi-formal/high density residential areas at Uitenhage and in the lower Chatty River. Those activities which influence on the bacteriological quality of the estuary are not as obvious because of factors, previously mentioned, which influence both the delivery and transport of faecal bacteria in the estuary. However, it can still be seen that potential sources are from informal/high density residential areas in the lower Chatty River and from the semi formal/high density residential area at Motherwell.

Finally, Map 20 is a map of the major industries, sewage treatment works, agricultural areas and the average phosphate and nitrate concentrations. This map was produced to portray the impact of these activities on the eutrophication of the catchment's surface waters. The map demonstrates that although agricultural and industrial activities influence the nutrient concentrations in Zwartkops River, the discharge from sewage treatment works is the major influencing factor on the eutrophic state of the Zwartkops River.

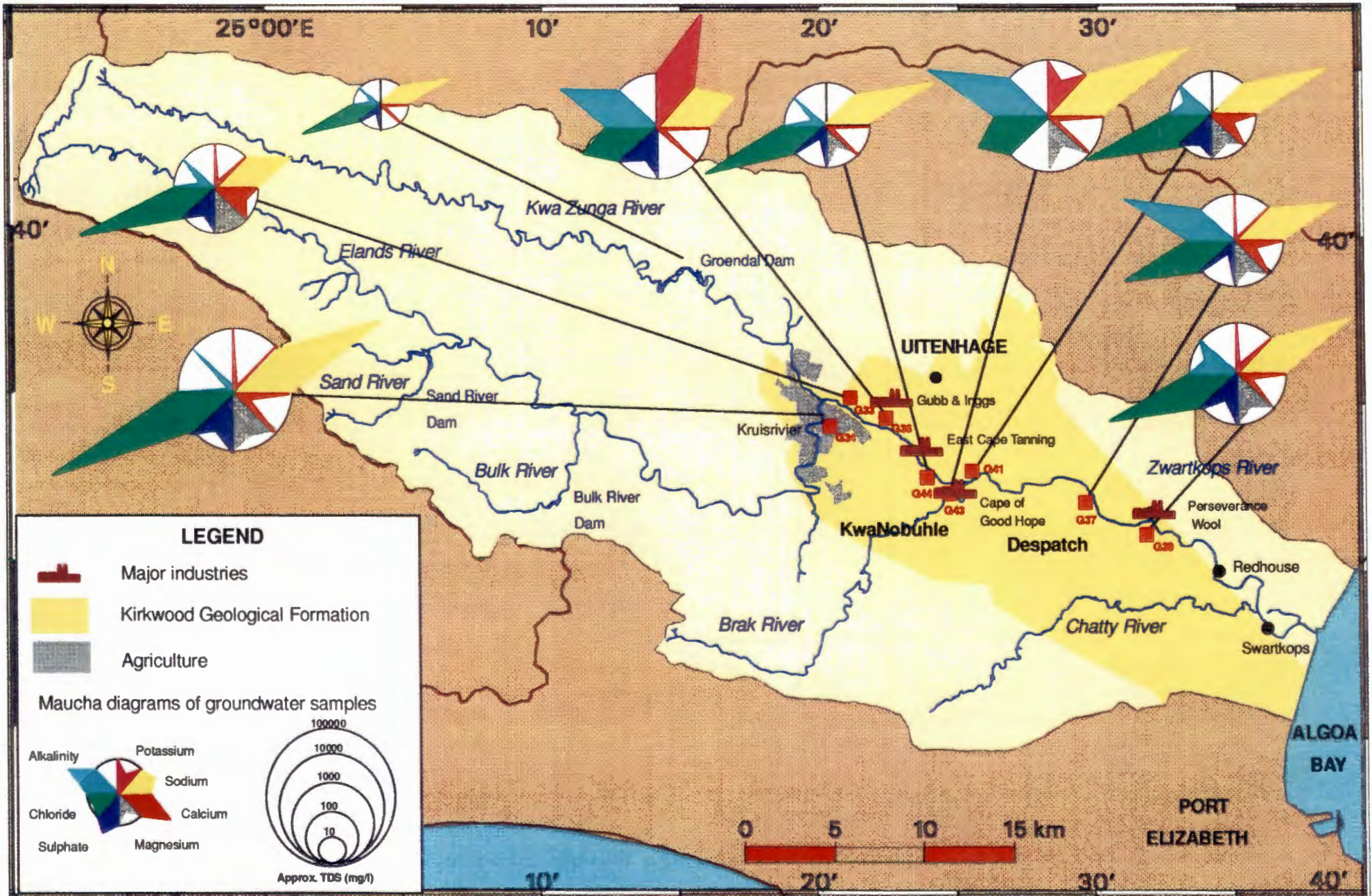
Table 25. Leopold matrix

Activities	Environmental Characteristics - Water Quality											
	Surface Water				Groundwater				Coastal Water			
	Salts	Bacter	Nutrient	Other	Salts	Bacter	Nutrient	Other	Salts	Bacter	Nutrient	Other
Residential												
• Formal (e.g. Uitenhage)		4/7	3/5			4/4	3/4			4/6	3/5	
• Semi-formal (e.g. Excelcior)		6/7	5/5			6/4	5/3			6/6	5/5	
• Informal (e.g. Parts of Ibhayl)		9/7	5/5			7/4	5/4			9/6	5/5	
Recreational		4/6								4/6		
Industrial												
• Wool processing	8/7		4/5		9/7		5/4					
• Tanning	6/7		3/5		7/7		4/4				3/5	
• Other (Motor industry)	3/7			Metals 4/3	2/7			Metals 3/4				4/3
Farming												
• Dryland agriculture	1/7				1/7							
• Irrigated agriculture	4/7		5/5		5/7		4/4					
• Livestock (intensive)		5/6	5/5			5/4	5/4					
Mariculture										2/6	1/5	

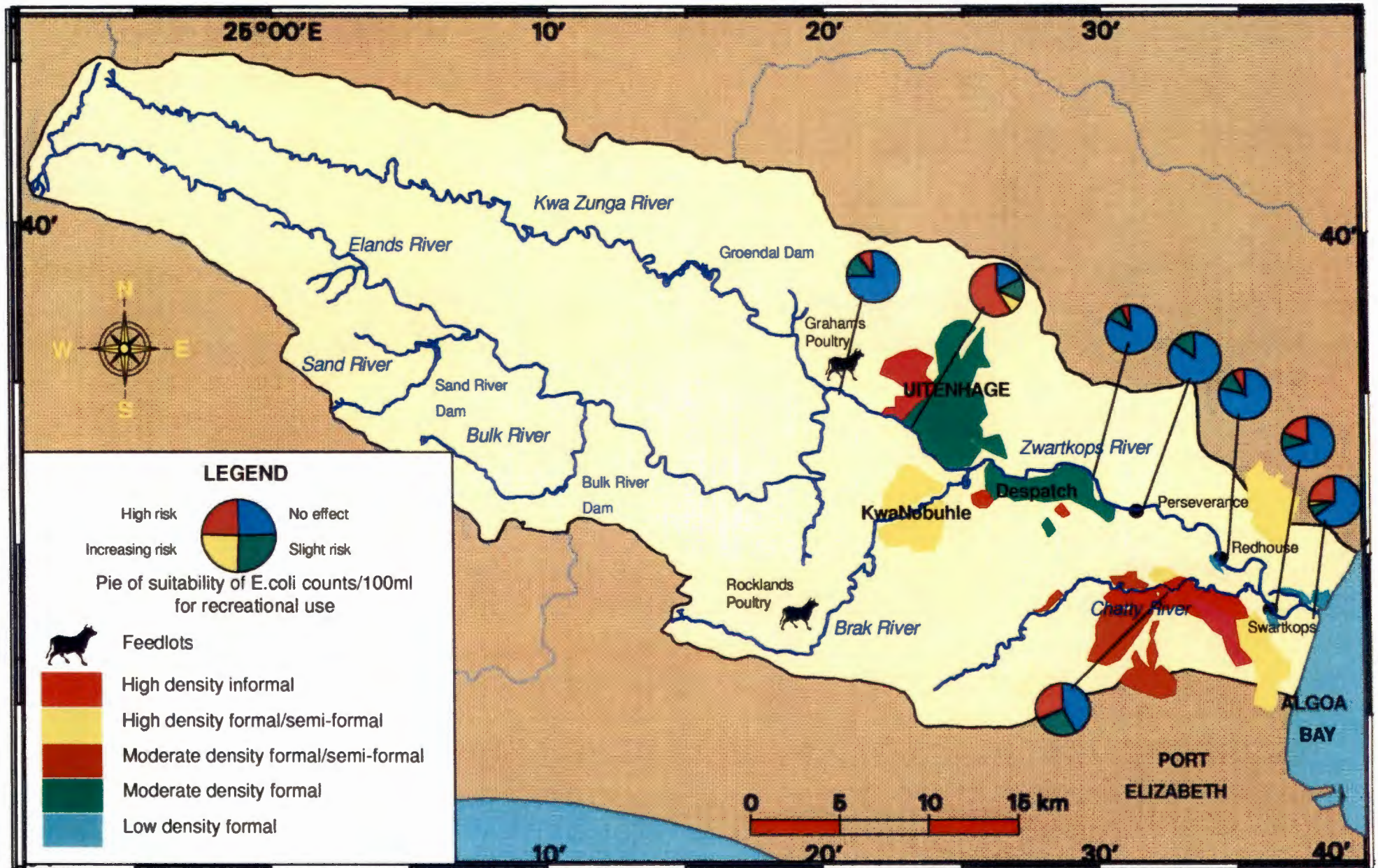
Table 25. Leopold matrix (Continued)

Activities	Environmental Characteristics - Water Quality											
	Surface Water				Groundwater				Coastal Water			
	Salts	Bacter	Nutrient	Other	Salts	Bacter	Nutrient	Other	Salts	Bacter	Nutrient	Other
Mining												
• Quarrying	2 7			Susp. solid 5 3								
• Salt production	5 7				1 7							
Forestry				Susp. solid 1 3								
Sewage Treatment	2 7	1 6	7 5	Metals 2 3	1 7	1 4	6 4	Metals 1 3	1 2	6 6	4 5	Metals 4 3
Solid Waste Disposal	4 7			Metals 3 7	4 7			3 7				
Stormwater Systems												
• Motherwell Canal		9 6	5 5	Metals 5 4						9 6	5 5	
• Kat Canal		9 6	6 5	Metals 5 4								
Water Supply Systems	1 7											
Nature Conservation	+2 7	+2 7	+2 7		+1 7							

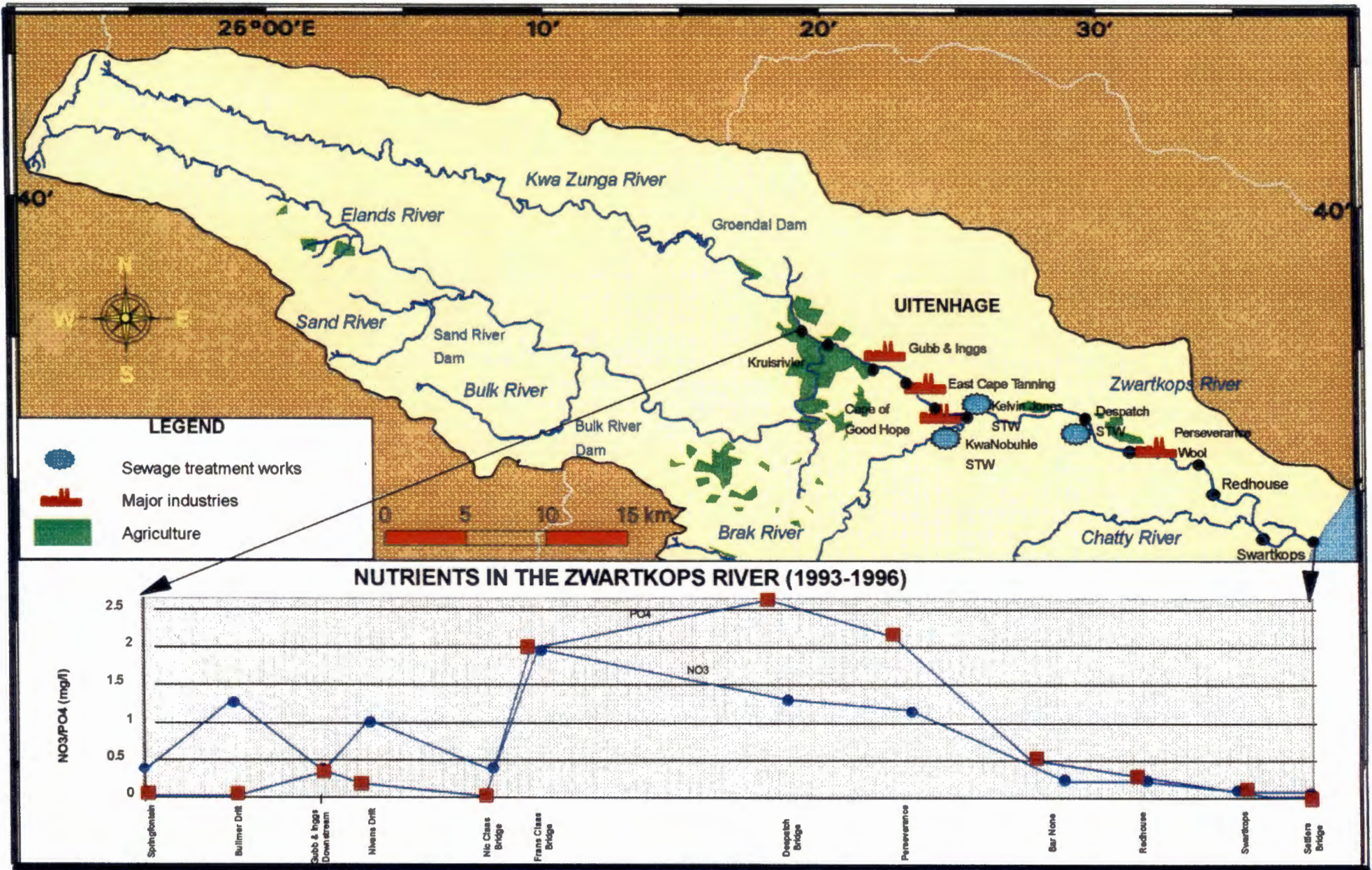
Where: Bacter = Bacteriological



Map 18. The combined impacts of geology, industrial activities and agricultural return flows on the major ions in the groundwater of the Zwartkops Catchment



Map 19. The combined impact of population density, level of urban development and intensive livestock farming practices on the microbiological quality of the surface water in the lower Zwartkops Catchment



Map 20. The combined impact of irrigated agriculture, major industrial activities and treated sewage discharges on the phosphate and nitrate concentrations in the Zwartkops River

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

The water quality issues within the catchment are primarily as a result of high salt concentrations and high bacteriological counts. In general, development has made water unsuitable for use in the lower Brak, lower Chatty and Zwartkops Sub-catchments, as well as in the coastal zone south of the Zwartkops River. The natural geology in the catchment has largely been responsible for the high salt concentrations in the lower Elands, upper Chatty and middle Brak Sub-catchments and has resulted in the water being unsuitable for use. Localised impacts on the salt concentrations present in the water resources in the catchment result from industrial activities and agricultural runoff.

Faecal pollution is of concern mostly in the estuary and coastal zone. The major sources of faecal contamination are from informal residential developments at Uitenhage, Motherwell and in the lower Chatty River. Other possible sources of faecal bacteria, especially in the estuary, are from urban stormwater runoff, seepage from conservancy tanks at Perseverance, Redhouse and Amsterdamhoek, leaking sewers and from the coastal zone. Sources of faecal bacteria in the coastal zone are from the Paapenkuils and Zwartkops Rivers, stormwater discharges and from the discharge of treated effluent from Fishwater Flats WRW.

The nutrient concentrations in the lower section of the catchment are of concern, in terms of the eutrophic status of the river which has led to the prolific growth of water hyacinth. Possible sources of nutrients are largely from treated sewage discharges. Other sources are runoff from urban, industrial and agricultural developments.

A more detailed investigation, and improved monitoring, is necessary to determine the major sources of nutrients and faecal bacteria in the Zwartkops Catchment. This will allow for these water quality issues to be prioritised and addressed in a management plan. The elevated salt concentrations which are as a result of natural marine geology, however, cannot be managed. An alternative source of water should be supplied to all water users the catchment, especially in the lower catchment where water quality is affected by these elevated salt concentrations.

The main aquatic ecosystem health issues within the catchment are due to flow, water quality, loss of habitat, barriers to migratory species and the presence of exotic or alien species. In the upper catchment, low flows in the river system as a result of dams and farming activities have reduced the integrity of the ecosystem health, while further downstream, urban and industrial developments and quarrying have reduced the water quality and hence, the habitat integrity.

This dissertation has shown that the environmental evaluation portion of the EIA process, as well as the methods and techniques used in EIAs, can be well adapted to deal with the cumulative impacts that usually occur from a number of activities occurring within a catchment. This portion of the process can also be well adapted to plan-making and the establishment of catchment management plans. Also evident from this dissertation is that water quality assessments in catchments, and hence the catchment management process as a whole, can benefit from this new approach, as well as the procedures and methods used in an environmental impact assessment. Particularly since these procedures and methods have evolved over nearly thirty years.

In addition, the recent recognition in the fundamental principles of the new water law of South Africa that water "*should be managed in an integrated manner, which is consistent with broader environmental management approaches*", and that water should be managed on a catchment level (DWAF, 1997:36), support this approach to using EIA to develop catchment management plans. The EIA process is particularly beneficial to catchment management as a result of its holistic nature, which ensures that all environmental, social and economic factors are taken into account, while ensuring that the public be included in the decision-making process. The techniques used in EIA, that is those tested in this assessment, have also proved useful in providing the water quality manager with the necessary information in a format which is of benefit to the decision maker.

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APPENDICES

APPENDIX A: WATER QUALITY CLASSIFICATION SYSTEM FOR SUITABILITY OF DRINKING WATER (Kempster, 1996:1)

Constituent	Class 0	Class I	Class II	Class III
Total dissolved salts (mg/l)	0 - 450	450 - 1000	1000 - 2450	>2450
Electrical conductivity (mS/m)	0 - 70	70 - 150	150 - 370	>370
Nitrate/nitrite (mg/l)	0 - 6	6 - 10	10 - 20	>20
Fluoride (mg/l)	0 - 1	1 - 1.5	1.5 - 3.5	>3.5
Sulphate (mg/l)	0 - 200	200 - 400	400 - 600	>600
Magnesium (mg/l)	0 - 30	30 - 70	70 - 100	>100
Sodium (mg/l)	0 - 100	100 - 200	200 - 400	>400
Chloride (mg/l)	0 - 100	100 - 200	200 - 600	>600
pH (pH units)	6 - 9	5 - 9.5	4-5 or 9.5-10	<4 or >10
Iron (mg/l)	0 - 0.1	0.1 - 0.2	0.2 - 2	>2
Manganese (mg/l)	0 - 0.05	0.05 - 0.1	0.1 - 1	>1
Zinc (mg/l)	0 - 3	3 - 5	5 - 10	>10
Arsenic (mg/l)	0 - 0.01	0.01 - 0.05	0.05 - 0.2	>0.2
Cadmium (mg/l)	0 - 0.005	0.005 - 0.01	0.01 - 0.02	>0.02
Faecal coliforms (counts/100ml)	0	0 - 1	1 - 10	>10

Additional water quality constituents, not included in classification but of concern in the Zwartkops catchment:

Constituent	Class 0	Class I	Class II	Class III
Potassium (mg/l)	0 - 50	50 - 100	100 - 400	>400
Ammonia (mg/l)	0 - 1	1 - 2	2 - 10	>10

APPENDIX B: SUMMARY OF MACROINVERTEBRATE ASSESSMENT
(Uys & Soxujwa, 1996:9)

Site	SASS Score	Taxa Score	Ave. Score per Taxon	Habitat Assessment Matrix	SASS as % of Reference	HAM as % of Reference
Upper Elands R.	137	25	5.5	103	100	100
Lower Elands R.	95	18	5.3	54	70	52
Sand R.	62	13	4.8	66	46	85
Bulk R.	123	20	6.2	113	90	109
Upper Brak R.	83	16	5.4	78	61	67
Lower Brak R.	56	13	4.3	93	41	80
KwaZunga R.	146	24	6.1	124	107	106
Groendal Dam	94	18	5.2	120	67	116
Springfontein	77	17	4.5	90	57	78
Bullmer Drift	136	21	6.5	116	100	100
Gubb & Inggs	75	18	4.2	95	55	82
Nivans Drift	86	19	4.5	104	74	90
Frans Claasen	81	17	4.8	113	60	97
Perseverance	28	7	4	105	21	95
Chatty River	45	9	5	78	33	29

APPENDIX C: SUMMARY OF FISH SURVEY CATCH METHODS AND NUMBERS

(Bok *et al*, 1996:2)

SITE	FISH SPECIES CAUGHT	METHOD & EFFORT	NUMBER OF FISH CAUGHT
KwaZunga, upstream of Groendal Dam	<i>Glossogobius callidus</i>	5 m minnow seine net - 6 m pull	61
	<i>Micropterus dolomieu</i> <i>Micropterus salmoides</i>	Observed while diving underwater in whole pool	7
KwaZunga, 4km below Groendal Dam	<i>Clarias gariepinus</i>	60 m gill net overnight	2
KwaZunga, Rooikrans picnic site	<i>Barbus pallidus</i>	60 m gill net overnight	0
	<i>Glossogobius callidus</i>	5 m minnow seine net - 6 m pull	35
Zwartkops, below Bullmer Drift	<i>Tilapia sparrmanii</i> <i>Oreochromis mossambicus</i>	60 m gill net overnight	5
Zwartkops, Nivans Drift	<i>Glossogobius callidus</i> <i>Oreochromis mossambicus</i> <i>Tilapia sparrmanii</i> <i>Cyprinus carpio</i>	6 m minnow seine net - 25 m pull	241
		- 10 m pull	64
Zwartkops, Frans Claasen Bridge	<i>Glossogobius callidus</i> <i>Oreochromis mossambicus</i> <i>Tilapia sparrmanii</i>	electric fish shocker - 100 m	52
Zwartkops, above Perseverance causeway	<i>Oreochromis mossambicus</i> <i>Myxus capensis</i> <i>Monodactylus falciformis</i>	60 m gill net overnight	145
Zwartkops, 200 m below Perseverance causeway	<i>Oreochromis mossambicus</i> <i>Myxus capensis</i> <i>Mugil cephalus</i> <i>Cyprinus carpio</i> <i>Micropterus dolomieu</i>	60 m gill net overnight	43
Elands, above Sand River	<i>Micropterus salmoides</i> <i>Pseudobarbus afer</i> <i>Barbus pallidus</i> <i>Sandelia capensis</i>	electric fish shocker - 60 m	40
Elands, 1 Km above KwaZunga confluence	<i>Micropterus salmoides</i> <i>Oreochromis mossambicus</i> <i>Glossogobius callidus</i> <i>Tilapia sparrmanii</i> <i>Cyprinus carpio</i>	60 m gill net overnight	3
		5m seine net - 5 m pull	120
Sand, below Sand River Dam	<i>Micropterus salmoides</i>	electric fish shocker - 50 m	11
Bulk, below Bulk River Dam	<i>Pseudobarbus afer</i> <i>Sandelia capensis</i>	electric fish shocker - 50 m	64
Brak, upper catchment	<i>Sandelia capensis</i>	electric fish shocker - 50 m	15
Brak, 50 m above Zwartkops confluence	<i>Glossogobius callidus</i>	6 m minnow seine net - 20 m pull	25
Chatty, upper catchment	<i>Glossogobius callidus</i> <i>Sandelia capensis</i> <i>Gambusia affinis</i>	electric fish shocker - 100 m	30

APPENDIX D: EXISTING MONITORING POINTS

Code	Site	Type of monitoring	Frequency	Responsibility
GD	Groendal Dam	Surface Water Quality: Some macro and trace metals, <i>E. coli</i>	Fortnightly or monthly, 6 monthly	UTLC
SF	Springfontein	Macro and trace metals	Monthly, trace metals 6 monthly	DWAF
A	Bullmer Drift	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	DWAF, (UTLC, G&I)
C	Below Gubb & Inggs	Macro and trace metals	Monthly, trace metals 6 monthly	DWAF, (G&I, UTLC)
D	Nivans Drift	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	DWAF (G&I, UTLC)
NCB	Nic Claassen Bridge	Some macro	Monthly	DWAF, UTLC
E	Frans Claassen Bridge	Macro and trace metals	Monthly, trace metals 6 monthly	DWAF, (UTLC, G&I)
F	Despatch Bridge	Macro and trace metals	Monthly, trace metals 6 monthly	DWAF (UTLC, G&I)
G	Perseverance Drift	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	DWAF (G&I, PETLC bact.)
H	Bar None	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	DWAF
I	Redhouse Yacht Club	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	DWAF, PETLC
-	Brickfields	Bacteriological	Weekly	bacteria
K	Swartkops Yacht Club	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	PETLC
L	Settlers Bridge	Macro & trace, bacteriological	Monthly, trace metals 6 monthly	DWAF, PETLC
-	Blue Hole	Bacteriological	Fortnightly	bacteria
CR	Veeplaas	Macro and bacteriological	Monthly	DWAF, PETLC
CRM	Chatty River Mouth	Macro and bacteriological	Monthly	bacteria
ER	Elands River	Macro	Monthly	PETLC, DH weekly
BR	Brak River (other points coincide with fish & invertebrate sampling points)	Macro and bacteriological Macro and trace metals	Monthly Once-off	DWAF DWA DWA DWA (UTLC some) DWA, IWR, ECNC
GP	Graham's Poultry	Source impacts on surface water quality: Macro and trace metals	Monthly, trace metals 6 monthly	DWAF
B	Gubb & Inggs (up & downstream)	Macro and trace metals	Monthly, trace metals 6 monthly	DWAF (UTLC, G&I some)
KC & KCK	Kat Canal (Kabah & mouth)	Macro and bacteriological	Monthly	DWAF, (UTLC, G&I some)
UECTD	East Cape Tanning (up & downstream)	Macro and trace metals	Monthly, trace metals 6 monthly	DWAF
ECT	Uitenhage stormwater canals	Some macro and trace metals	Monthly/weekly	UTLC (Tycon some weekly)
J	Motherwell Canal	Macro and bacteriological	Monthly/weekly	DWAF, PETLC bacteria weekly
-	KwaNobuhle STW	Macro and bacteriological	Monthly/weekly	DWAF, UTLC weekly
-	Uitenhage STW	Macro and bacteriological	Monthly/daily	DWAF, UTLC daily
-	Despatch STW	Macro and bacteriological	Monthly/quarterly	DWAF, DTLC
-	Fish Water Flats WRW	Macro, trace metals and bacteriological	Monthly/daily	quarterly DWA, PETLC daily
PR	Paapenkuis River	Coastal Water Quality: Bacteriological	Varies from daily to monthly according to holiday seasons	PETLC
SDP	South of Deal Party			
NDP	North of Deal Party			
SFWF	South Fish Water Flats			
NFWF	North Fish Water Flats			
SZR	South of Zwartkops River mouth			
NZR	North of Zwartkops River mouth			

Code	Site	Type of monitoring	Frequency	Responsibility
EL1 EL2 SA BU BR1 BR2 KZ1 Z1 Z2 Z3 Z4 Z5 Z6 Z7(a&b) CH1	Upper Elands River Lower Elands River Sand River Bulk River Upper Brak River Lower Brak River Upper KwaZunga River above Groendal Dam KwaZunga River below Groendal Dam Springfontein Bullmer Drift Gubb & Inggs Nivans Drift Frans Claasens Bridge Perseverance Drift Upper Chatty River	Fish, macroinvertebrates and surface water quality:	Once-off	IWR, ECNC, DWAF
M1H007-A01 - M1R001-A01 M1R002-A01 M1R003 M1H004-A01 M1H012-A01 - - - -	Groendal Dam - compensation flow, flow to treatment works and dam level Releases from Groendal Dam Releases from Bulk River Dam Releases from Sand River Dam Elands River at Longhill Nivans Drift KwaNobuhle STW Uitenhage STW Despatch STW Fish Water Flats WRW	Surface Flow:	Daily Daily Daily Daily Daily Continuous Continuous Daily Daily Daily Daily	UTLC UTLC PETLC PETLC DWAFF DWAFF UTLC UTLC DTLC PETLC
-	Kruisrivier (x2) Springfield Wincanton Mimosadale West (x2)	Groundwater levels:	Monthly Continuous Monthly Continuous/ Monthly	DWAF

Code	Site	Type of monitoring	Frequency	Responsibility
AK1 & 2 BF7 BF8 BF9 BF10 BF11 BF12 BF13 BF14 BF16 BF17 BF18 BF19 BF20 & 21 BF22 BF25 BF26 BF27 BF28 BF29 BF30 BF31 BN1 BN2 CD1 DH3 DT1 FK1 FK2 G11-6 GL2 GS2 KM1 KR50 LE1 ME1 MN1 & 2 MN3 & 4 PE1 RD1 RD2 RM1 SP1 TR1 UT1	Industex, Alexander Park, Uitenhage Hugo, Brakkefontein 'Uitkyk', Brakkefontein Leith, Brakkefontein Pridehuy - 'Klipskuil', Brakkefontein (67) Kock, Brakkefontein (67) Vos - 'Joyce', Brakkefontein Van der Merwe - 'Rapsie", Brakkefontein (39) Balfour, Brakkefontein Hurter, Brakkefontein (145+155) Sunderbank, Brakkefontein Dorfling, Brakkefontein Martin, Brakkefontein Charlewood, Rocklands Poultry, Brakkefontein Rose - 'La Rochelle', Brakkefontein (145) Mostert - 'Arbeidsgenot", Brakkefontein Leuscher- 'Von Wildenau', Brakkefontein (68) Liebenberg, Brakkefontein (102) Bezuidenhout 'Rocky Ridge', Brakkefontein Vermeulen, Brakkefontein Fourie - 'Windgat Vlake', Brakkefontein Little - 'Lamedos', Brakkefontein (204) Fatman, Boschfontein (390) Outspan International, Buffelsfontein (52) Scheepers - 'Cotswold', Elands River Valley Janse V Rensburg, Despatch Human - 'De Rust', Kruisrivier Harbron, Fonteinshoek (92) Janse V Vuuren, Fonteinshoek (36) Gubb & Inggs, Uitehage Uitenhage City Council, Groendal Reserve Thompson, Greenacres (Rooiland) Kemp, Kastaiing Boom Ferreira, Meldon (113) Janse V Vuuren, Langlaagte (51/61) Van Heerden, Marizane (97) Van Vuuren - Melkhoutboom, Elands River Scheepers - Melkhoutboom, Elands River Perseverance Wool Pullery, Mountain View Els, Rooiland (74) Swanepoel, Rooiland Landman, Ruimte, Kruisrivier Welgemoed, Sonop, Kruisrivier Potgieter, Totteridge Park Anderson, Uitkomst, Kruisrivier	Groundwater (from hydrocensus): Macro	Once-off	DWAF
G33 G34 G35 G36 G37 G38 G39 G40 G41 G42 G43 G44	Grahams Poultry Môreson Inggsville Gubb & Inggs Despatch Sewage Treatment Works Despatch 'chimney' (Below Despatch) Perseverance Wool Pullery Redhouse Kelvin Jones Sewage Treatment Works Cape of Good Hope Wool Pullery East Cape Tannery Nivans Drift	Groundwater (primary aquifer monitoring): Macro and trace metals	Quarterly	DWAF

APPENDIX E: WATER QUALITY DATA

**MONITORING OF PRIMARY AQUIFER
Macro analysis**

Borehole No.	SITE NAME	SAMPLE RUN *	E.C. (mS/m)	TDS (mg/L)	pH (Lab)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	F (mg/L)	Cl (mg/L)	NO3+NO2 as N (mg/L)	SO4 (mg/L)	PO4 as P (mg/L)	TAL as CaCO3 (mg/L)	Si (mg/L)	K (mg/L)	NH4 as N (mg/L)	Hardness (mg/L)	DOC (mg/L)	COD (mg/L)
SABS max Sea water			300 4400	2000 35000	5.5-9.5 8.2	400 10500	100 1350	400 400	1.5 1	600 19500	10 0.2	600 2650	0.2 0.01	650 120	18 6.4	800 400	2 0.5	300 6535	10 -	75 -
G40035	INGGSVILLE	1	90	421	7.1	119	18	9.4	<0.2	202	<0.1	46	<0.1	20	-	3	<0.1	97	4.2	16
		2	23	125	7.3	27	5	3	0.1	46	0.15	8	0.04	28	2.3	2.1	0.04	28	-	-
		3	26	121	7.3	32	5	3	0.1	54	0.19	6	0.019	16	2.5	2.5	0.04	28	-	-
G40034	MORESON	1	3650	25384	7.8	7386	1146	595	<0.2	13338	<0.5	3066	<0.1	608	-	139	0.6	6194	23	-
		2	3130	25683	7.6	7733	1198	404	0.1	11879	<0.04	3180	0.04	890	5.8	203	0.3	5922	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G40033	GRAHAMS POULTRY	1	385	2172	7.5	495	112	125	<0.2	1014	10.6	157	<0.1	181	-	38	<0.1	772	9	79
		2	442	2866	7.2	573	143	143	0.2	1471	2	325	0.05	129	4	45	0.1	944	-	-
		3	675	3588	7.5	817	185	192	0.2	2035	1.17	206	0.065	69	4.4	63.1	0.08	1239	-	-
G40036	GUBB&INGGS	1	820	7532	7.8	752	96	107	2	650	<0.1	650	9.6	2863	-	1476	97	661	377	1249
		2	816	8277	7.9	779	8	22	2.1	1152	0.83	748	268.4	2200	9.8	1993.4	50.26	88	-	-
		3	1026	8978	8.2	1003	116	99	2.6	650	8.72	809	0.035	3600	7.5	1749.4	92.26	731	-	-
G40044	NIVANSDRIFT	1	180	1056	7.2	252	37	40	<0.2	424	<0.1	62	<0.1	186	-	16	<0.1	252	10	40
		2	326	1859	7.4	474	72	51	0.2	839	0.04	129	0.15	216	3.1	29.6	0.04	423	-	-
		3	395	2500	7.6	706	88	59	0.3	1159	0.04	143	0.376	251	3.2	38.3	0.05	506	-	-
G40043	E.C.T.P.	1	4350	30597	7.5	9648	1019	427	1.6	16472	<0.1	1536	<0.1	1156	-	81	1.3	5245	31	-
		2	2870	22165	7.8	6974	569	225	1.1	11751	0.04	1340	0.04	978	6.4	110.2	0.98	2895	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G40042	C.G.H.P.	1	1260	13204	8	2426	336	183	1	1536	<0.1	282	<0.1	5840	-	1230	27	1835	192	3478
		2	1127	10264	8.4	2313	197	35	0.5	1496	0.31	38	78	4259	8.8	738.7	9.67	895	-	-
		3	1300	14614	8	3015	316	58	0.5	1627	0.1	645	0.578	6348	5	1208.7	0.46	1441	-	-
G40041	U.S.W.	1	540	3424	9.4	909	111	104	0.5	1304	<0.1	454	<0.1	433	-	14	0.5	715	17	79
		2	436	3066	7.5	793	98	86	0.5	1147	0.04	413	0.045	420	9.8	15.4	0.49	617	-	-
		3	459	3138	8.1	876	93	84	0.6	1154	0.04	426	0.005	399	10.7	16.4	0.36	591	-	-
G40038	CHIMNEY	1	920	6036	7.5	1610	210	175	<0.2	2582	2.2	621	0.5	648	-	44	1.3	1299	11	67
		2	874	6234	7.7	1658	227	170	0.3	2846	1.34	632	0.08	527	6.6	50.9	1.2	1356	-	-
		3	1101	6594	8.1	1877	211	168	0.3	3039	1.26	570	0.033	507	6.8	104.2	0.12	1285	-	-
G40037	D.S.W.	1	375	2618	7.4	430	59	58	<0.2	617	<0.1	37	35	952	-	65	155	387	20	103
		2	371	2746	7.5	439	55	51	0.2	650	0.04	48	32.5	958	16.7	60.8	135.9	353	-	-
		3	429	2685	7.5	485	47	46	0.3	631	0.09	55	36	878	17.3	64.9	135.5	308	-	-
G40039	P.W.P.	1	580	3614	7.7	1005	98	88	<0.2	1508	<0.1	296	<0.1	424	-	95	6	622	13	79
		2	513	3513	7.8	934	92	76	0.3	1523	0.04	276	0.11	422	4.4	89.2	6.18	567	-	-
		3	542	3667	8.2	1038	83	72	0.3	1639	0.04	232	0.17	416	4.5	95.6	0.37	520	-	-
G40040	REDHOUSE	1	5000	37144	7.8	10688	1361	961	2.3	18942	2.3	4383	<0.1	359	-	365	3.3	7983	22	-
		2	3900	30441	7.8	10967	1400	853	1	11938	0.46	4416	0.1	407	7.7	360	5.38	7873	-	-
		3	5550	42016	7.5	3015	5626	2783	0.9	24586	0.16	4167	0.033	280	6.1	1484	9.42	30024	-	-

* SAMPLE RUN 1: dates sampled = 95.05.23 to 95.05.24, dates analysed 95.06.06 to 95.06.12, sample preserved HgCl2, laboratory = CSIR Stellenbosch.

* SAMPLE RUN 2: dates sampled = 95.09.27 to 95.09.28, dates analysed = 96.02.16, sample unpreserved, laboratory = IWQS - Pretoria.

* SAMPLE RUN 3: dates sampled = 95.11.20 to 95.11.21, dates analysed = 96.02.16, sample unpreserved, laboratory = IWQS - Pretoria.

MONITORING OF PRIMARY AQUIFER
Trace metals

Borehole No.	SITE NAME	SAMPLE RUN *	Al (mg/L)	Ba (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Pb (mg/L)	Sr (mg/L)	V (mg/L)	Zn (mg/L)	As (mg/L)	Co (mg/L)	B (mg/L)	
SABS max			0.5	1	0.02	0.2	1	1	1	0.1	0.5	0.1	none	0.5	5	0.3	0.5	2	
Sea water			0.01	0.03	0.0001	0.00005	0.003	0.01	0.002	0.01	0.002	0.00003	8	0.002	0.01	0.003	0.0005	4.6	
G40035	IGGSVILI	1	0.33	<0.03	<0.005	<0.03	<0.03	0.5	0.05	<0.01	<0.03	<0.03	0.03	<0.03	<0.03	<0.005	<0.03	<0.1	
		2	0.076	0.007	<0.002	<0.003	<0.002	0.05	0.003	<0.005	<0.006	<0.015	0.038	<0.002	0.006	<0.05	-	-	
		3	<0.02	0.015	<0.002	<0.003	<0.002	0.008	<0.001	<0.005	<0.006	<0.015	0.045	<0.002	<0.004	<0.05	-	-	
G40034	FORESOI	1	0.81	0.09	0.03	<0.03	0.04	16.7	18.4	0.07	0.09	0.33	11.4	0.03	<0.03	<0.005	0.06	4	
		2	<0.02	0.034	<0.002	0.011	<0.002	<0.003	2.037	<0.005	<0.006	<0.015	7.105	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.039	<0.002	<0.003	<0.002	<0.003	3.041	<0.005	<0.006	<0.015	10.193	<0.002	<0.004	<0.05	-	-	
GRAHAM:																			
G40033	POULTR	1	0.62	0.23	<0.005	<0.03	<0.03	1.09	0.25	<0.01	<0.03	0.06	1.6	<0.03	<0.03	<0.005	<0.03	0.12	
		2	<0.02	0.307	<0.002	<0.003	<0.002	<0.003	<0.001	<0.005	<0.006	<0.015	1.827	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.546	<0.002	<0.003	<0.002	<0.003	<0.001	<0.005	<0.006	<0.015	2.431	<0.002	<0.004	<0.05	-	-	
G40036	IBB&ING	1	1.12	<0.03	0.007	0.04	<0.03	2.06	1.13	0.02	0.06	0.07	0.44	0.09	<0.03	0.626	<0.03	0.36	
		2	0.131	0.035	<0.002	0.034	<0.002	0.781	0.931	<0.005	0.032	<0.015	0.436	0.077	0.01	0.363	-	-	
		3	<0.02	<0.001	<0.002	0.027	<0.002	1.513	1.064	<0.005	0.015	<0.015	0.536	0.012	<0.004	<0.05	-	-	
G40044	JANSDRI	1	0.1	0.07	<0.005	<0.03	<0.03	1.48	0.638	0.011	<0.03	0.03	0.49	0.03	<0.03	<0.005	<0.03	0.25	
		2	<0.02	0.086	<0.002	<0.003	<0.002	<0.003	<0.001	<0.005	<0.006	<0.015	0.923	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.15	<0.002	<0.003	<0.002	<0.003	<0.001	<0.005	<0.006	<0.015	1.177	<0.002	<0.004	<0.05	-	-	
G40043	E.C.T.P.	1	4.43	0.08	0.034	0.04	0.05	2.02	2.88	0.08	0.14	0.35	9.07	0.05	<0.03	<0.005	0.08	4.42	
		2	<0.02	0.009	<0.002	<0.003	<0.002	<0.003	<0.001	<0.005	0.012	<0.015	4.869	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.041	<0.002	0.008	<0.002	<0.003	2.446	<0.005	0.043	<0.015	5.232	<0.002	<0.004	<0.05	-	-	
G40042	C.G.H.P.	1	0.36	1.07	0.021	0.03	0.04	8.09	3.48	0.06	0.19	0.21	3.34	0.1	<0.03	0.035	0.08	0.9	
		2	<0.02	0.269	<0.002	<0.003	<0.002	0.188	<0.001	<0.005	0.085	<0.015	2.058	0.075	<0.004	0.212	-	-	
		3	<0.02	0.717	<0.002	0.038	<0.002	3.575	3.557	<0.005	0.108	<0.015	4.253	0.142	<0.004	0.272	-	-	
G40041	U.S.W.	1	0.51	<0.03	0.007	<0.03	<0.03	6.54	0.88	0.03	0.05	0.1	1.16	<0.03	<0.03	0.02	<0.03	1.15	
		2	<0.02	0.005	<0.002	<0.003	<0.002	<0.003	0.037	<0.005	<0.006	<0.015	1.128	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.009	<0.002	<0.003	<0.002	<0.003	0.051	<0.005	<0.006	<0.015	1.059	<0.002	<0.004	<0.05	-	-	
G40038	CHIMNEY	1	0.69	0.09	0.011	<0.03	<0.03	0.36	0.93	0.03	0.04	0.12	2.28	<0.03	<0.03	0.006	<0.03	1.89	
		2	<0.02	0.091	<0.002	<0.003	<0.002	<0.003	0.616	<0.005	<0.006	<0.015	2.175	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.125	<0.002	<0.003	<0.002	<0.003	0.85	<0.005	<0.006	<0.015	3.2	<0.002	<0.004	<0.05	-	-	
G40037	D.S.W.	1	0.12	0.07	0.005	<0.03	<0.03	5.46	0.85	0.01	<0.03	0.03	0.38	<0.03	<0.03	0.013	<0.03	0.65	
		2	<0.02	0.004	<0.002	<0.003	<0.002	0.009	0.392	<0.005	<0.006	<0.015	0.328	<0.002	<0.004	<0.05	-	-	
		3	<0.02	<0.001	<0.002	<0.003	<0.002	<0.003	0.609	<0.005	<0.006	<0.015	0.517	<0.002	<0.004	<0.05	-	-	
G40039	P.W.P.	1	1.27	0.33	0.006	<0.03	<0.03	10.6	1.2	0.02	<0.03	0.08	1.05	<0.03	<0.03	0.008	<0.03	0.66	
		2	<0.02	0.19	<0.002	<0.003	<0.002	<0.003	<0.001	<0.005	<0.006	<0.015	0.795	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.308	<0.002	<0.003	<0.002	<0.003	1.003	<0.005	<0.006	<0.015	0.869	<0.002	<0.004	<0.05	-	-	
G40040	EDHOUSE	1	2.54	<0.03	0.041	<0.03	0.08	7.92	0.32	0.13	0.13	0.38	8.48	0.06	<0.03	<0.005	0.08	5.22	
		2	<0.02	0.019	<0.002	<0.003	<0.002	<0.003	<0.001	0.082	<0.006	<0.015	8.136	<0.002	<0.004	<0.05	-	-	
		3	<0.02	0.008	<0.002	<0.003	<0.002	<0.003	<0.001	0.042	<0.006	<0.015	11.084	<0.002	<0.004	<0.05	-	-	

* SAMPLE RUN 1: dates sampled = 95.05.23 to 95.05.24, dates analysed = 95.06.06 to 95.06.12, sample preserved HNO₃, laboratory = CSIR - Stellenbosch.
 * SAMPLE RUN 2: dates sampled = 95.09.27 to 95.09.28, dates analysed = 96.02.16, sample unpreserved, laboratory = IWQS - Pretoria.
 * SAMPLE RUN 3: dates sampled = 95.11.20 to 95.11.21, dates analysed = 96.02.16, sample unpreserved, laboratory = IWQS - Pretoria.

NCB - Nic Claassen Bridge																								
DATE	TEMP	DO	% SATUR	pH	DOC	OA	COD	NH4	NO3	F	TAL	Na	Mg	SI	PO4	SO4	Cl	K	Ce	EC	TDS	F. Coliform	*E. coli	
	*C	mg/l	RATION		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/m	mg/l	per 100 ml	per 100 ml	
1/18/94																								
2/25/94																								
3/23/94																								
4/8/94																								
5/17/94																								
6/30/94																								
7/29/94																								
8/12/94																								
9/22/94				8.2		5	51									151	763				293			
10/21/94				7.2		6.5	61									136	864				332			
11/25/94				8.2		5.4	72									200	1220				471			
12/9/94																								
1/20/95				7.4		2.5	20	0.3	0.3							12	90				39.3			
2/17/95				7.9		7.6	73	0.3	0.6						0.05	107	544				221			
3/23/95				7.6		6.6	61									90	490				200			
4/6/95				7		9.5	89	0.3	0.3						0.05	49	319				114			
5/26/95				7.6		3.9		0.3	0.4						0.05	71	162				105			
6/30/95				7.6		4.3	31	0.3	0.3						0.05	97	538				219			
31/07/95				8.1		9	52	0.3	0.3						0.05	80	1060				399			
30/08/95				8.5		4.9	46	0.3	0.3						0.05	219	1440	33			544			
28/09/95				8.4		7	53	0.3	0.3						0.09	229	1350	33			503			
23/10/95				7.9		5.9	66	0.3	0.3						0.21	244	1170	40			428			
21/11/95				8.3		8.7	71	0.3	0.3						0.21	314	1950	53			621			
12/4/95				8.9		6.8	51	0.3	0.3						0.06	244	1400	38			470			
18/01/96				8		9.4	86	0.3	0.3						0.05	234	1300	45			494			
14/02/96				8.1		7.8	68	0.3	0.3						0.06	110	830	46			315			
20/03/96				8.3		7	56	0.3	0.3						0.07	168	1270	55			488			
29/04/96																								
31/05/96																								
Mean				7.9556		6.544	59.235	0.3	0.329						0.081	151.9	931.1	42.88			347.57			
Standard Error				0.1138		0.464	4.275	2E-09	0.022						0.016	19.72	118.8	2.961			39.813			
Median				8.05		6.7	61	0.3	0.3						0.05	143.5	962	42.5			365.5			
Mode				7.6		7	51	0.3	0.3						0.05	244	#N/A	33			#N/A			
Standard Deviation				0.4829		1.97	17.626	6E-09	0.083						0.059	83.67	503.9	8.374			168.91			
Sample Variance				0.2332		3.879	310.69	3E-17	0.007						0.003	7001	3E+05	70.13			28532			
Kurtosis				-0.127		-0.49	0.5292	-2.36	10.56						2.71	-0.909	-0.567	-1.282			-0.9868			
Skewness				-0.236		-0.25	-0.442	1.124	3.205						2.012	0.173	0.003	0.258			-0.2997			
Range				1.9		7	69	0	0.9						0.16	302	1860	22			581.7			
Minimum				7		2.5	20	0.3	0.3						0.05	12	90	33			39.3			
Maximum				8.9		9.5	89	0.3	0.6						0.21	314	1950	55			621			
Sum				143.2		117.8	1007	4.2	4.6						1.05	2735	16760	343			8256.3			
Count				18		18	17	14	14						13	18	18	8			18			
Confidence Level(95.000%)				0.2231		0.91	8.3789	3E-09	0.043						0.032	38.65	232.8	5.903			78.033			

APPENDIX F: GLOSSARY OF ABBREVIATIONS

a annum

ARSC Algoa Regional Services Council

CSIR Council for Scientific and Industrial Research

d day

DA Department of Agriculture

DH Department of Health

DTLC Despatch Transitional Local Council

DSTW Despatch Sewage Treatment Works

DMEA Department of Mineral and Energy Affairs

DWAF Department of Water Affairs and Forestry

ECNC East Cape Nature Conservation

ECPA East Cape Provincial Administration

EMPR Environmental Management Programme Report

FWFWRW Fish Water Flats Water Reclamation Works

G General waste

G&I Gubb and Inggs

H Hazardous waste

ha hectare

ICR Institute for Coastal Research

KJSTW Kelvin Jones Sewage Treatment Works

km kilometre

m metre

MAP Mean Annual Precipitation

MAR Mean Annual Runoff

mg/l milligrams per litre

MI megalitre

mm millimetre

mS/m milli-Siemens per metre

PETLC Port Elizabeth Transitional Local Council

s second

SASS4 South African Scoring System Version 4

STW Sewage Treatment Works

spp. Species

TDS Total dissolved salts

TLC Transitional Local Council

UTLC Uitenhage Transitional Local Council

UPE University of Port Elizabeth

ZRWRMP Zwartkops River Water Resources Management Plan

APPENDIX G: PRIORITY LIST OF PROBLEMS IDENTIFIED BY THE PUBLIC

Priority	Problem	Sub-catchment
1	Informal settlements: Lack of reliable water supply; pollution of river; solid waste problems; danger from flooding; poverty and unemployment	Chatty & Zwartkops
2	Undesirable 1st World development: Expansion of Fishwater Flats WRW; proposed trunk route through wetlands; uncoordinated infrastructure development causes flooding	Lower Zwartkops
3	Polluted surface runoff/discharges: Motherwell, Markman and Kat Canals; seepage from effluent ponds; treated sewage discharges; industrial stormwater	Brak & Zwartkops
4	Alien vegetation: Water consumption by alien vegetation; riverine infestation, especially Bluegums and Hyacinth	Elands; KwaZunga & Upper Zwartkops
5	Legal issues: Dispute re releases from Groendal Dam; conflict between river users; lack of enforcement of marine legislation	KwaZunga & Lower Zwartkops
6	Solid waste: Litter and dumping; seepage from old waste sites	Elands, Brak, Chatty & Upper Zwartkops
7	Recreation: Poor water quality for recreation; better management of activities	Zwartkops
8	Toxic waste: Threat from pesticides; Waste Tech problems, stormwater pollution from industries to the Markman Canal	Elands and Lower Zwartkops
9	Attitude/Education: Negative attitude and disinterest towards improvement; poor communication	Elands, KwaZunga, Brak, Chatty & Upper Zwartkops
10	Environmental needs: No base flows released from dams for environment	Elands & KwaZunga
11	Poor water quality: Increases in salinity and general water quality	Elands, KwaZunga, Brak, Chatty & Zwartkops

Priority	Problem	Sub-catchment
12	Aesthetics: Unpleasant smells and lack of natural beauty	Zwartkops
13	Groundwater pollution: Pollution from poor sanitation practices; seepage from effluent ponds	Lower Brak & Zwartkops
14	Estuary dynamics: Sandbank development due to bridges, destruction of saltmarsh	Lower Zwartkops
15	Quarrying/erosion of river banks: Removal of river banks by quarrying; erosion due to poor farming practices; general erosion from removal of bank vegetation	Elands, KwaZunga & Zwartkops
16	Lack of hydrological data	Brak, Chatty & Zwartkops
17	Loss of fauna and flora: Loss of natural fish species; habitats of migrant birds threatened; threat from exotic fish	Elands & Zwartkops
18	Groundwater abstraction: Poor control of abstraction; lowering of the water table	Elands & Brak
19	Over abstraction/impoundments	Elands, KwaZunga, Brak, Upper Chatty and Upper Zwartkops