REPORT No. P 15000/00/0101

DEPARTMENT: WATER AFFAIRS AND FORESTRY

Directorate: Water Resources Planning

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT: VOLUME 2: APPENDICES
AUGUST 2002

COMPILED BY:

NINHAM SHAND
CONSULTING ENGINEERS

Title	**:**	**Fish to Tsitsikamma Water Management Area : Water Resources Situation Assessment - Main Report - Volume 2 of 2 : APPENDICES**
Authors	:	Various
Project Name	:	Water Resources Situation Assessment
DWAF Report No.	:	P 15000/00/0101
Status of Report	:	Final
First Issue	:	June 2002
Final Issue	:	August 2002

Approved for Study Team :

M. T. Shand

....

M J SHAND
Ninham Shand (Pty) Ltd

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate : Water Resources Planning

Approved for the Department of Water Affairs and Forestry by :

....

F A STOFFBERG
Chief Engineer
(Project Manager)

....

J A VAN ROOYEN
Director

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT

OVERVIEW

The water resources of South Africa are vital to the health and prosperity of its people, the sustenance of its natural heritage and to its economic development. Water is a national resource that belongs to all the people who should therefore have equal access to it, and although the resource is renewable, it is finite and distributed unevenly both spatially and temporally. The water also occurs in many forms that are all part of a unitary and inter-dependent cycle.

The National Government has overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial and sustainable use, the redistribution of water and international water matters. The protection of the quality of water resources is also necessary to ensure sustainability of the nation's water resources in the interests of all water users. This requires integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level where all persons can have representative participation.

This report is based on a desktop or reconnaissance level assessment of the available water resources and quality and also patterns of water requirements that existed during 1995 in the Fish to Tsitsikamma Water Management Area, which mostly occupies a portion of the Eastern Cape Province, with small portions falling within the Western Cape Province and the Northern Cape Province. The report does not address the water requirements beyond 1995 but does provide estimates of the utilisable potential of the water resources after so-called full development of these resources, as this can be envisaged at present. A separate national study has been conducted to consider future scenarios of land use and water requirements and the effects of water conservation and demand management measures on these requirements and to identify alternative water resource developments and water transfers that will reconcile these requirements with the supplies.

The main purpose of this report is to highlight the principal water related issues, to identify existing water shortages, to provide information that is necessary to formulate future strategies such as the national water resources strategy and catchment management strategies and to stimulate initial actions to ensure the best overall sustainable utilisation of the water, with minimal waste and harm to the aquatic ecosystems.

The National Water Act (No. 36 of 1998), requires that a national water resources strategy (NWRS) be established that sets out the policies, strategies, objectives, plans, guidelines and procedures and the institutional arrangements for the protection, use, development, conservation, management and control of water resources for the country as a whole, and establish and define the boundaries of water management areas taking into account catchment boundaries, socio-economic development patterns, efficiency considerations and communal interests. This strategy is binding on all authorities and institutions exercising powers or performing duties under the National Water Act.

The national water resources strategy will, *inter alia*, provide for at least the requirements of the Reserve, international rights and obligations, actions required to meet projected future water needs and water use of strategic importance. Furthermore, it will contain estimates of present and future water requirements, set out principles relating to water conservation and demand management, give the total quantity of water available within each water management area, state the surpluses or deficits, provide for inter-catchment water transfers required to balance the supply with the requirements and state the objectives in respect of water quality to be achieved through the classification system to be provided for the water resources.

A catchment management agency established in terms of the National Water Act (No. 36 of 1998), must progressively develop a catchment management strategy, objectives, plans, guidelines and procedures for the protection, use, development, conservation, management and control of water resources within its water management area. Such a strategy must not be in conflict with the national water resources strategy, must take into account the class of water resource and resource quality objectives, the requirements of the Reserve and any applicable international obligations, the geology, land use, climate, vegetation and waterworks within its water management area. The strategy shall contain water allocation plans, take account of any relevant national or regional plans prepared in terms of any other law; enable public participation and take into account the needs and expectations of existing and potential water users. This report provides the initial baseline data that can be used by the catchment management agency to develop its catchment management strategy, objectives, plans, guidelines and procedures for the protection, use, development, conservation, management and control of the water resources in its area of responsibility.

The national water resources strategy will be reviewed and published at five-yearly intervals, with Addenda being issued in the interim, when required. The strategy will give guidance to the Department of Water Affairs and Forestry in respect of the protection, use, development, conservation, management and control of water resources and will also serve as a very important means of communication with all the stakeholders. The overall responsibility for the compilation of the national water resources strategy rests with the Directorate: Strategic Planning of the Department of Water Affairs and Forestry, while the Directorate: Water Resources Planning is responsible for :

- Identification of water resources to meet particular requirements
- Identification of international rights and obligations
- Identification of water use of strategic importance
- Calculating water balances
- Developing plans to reconcile water requirements and resources.

A number of inter-related studies have therefore been included by the Directorate: Water Resources Planning of the Department of Water Affairs and Forestry in the national future scenario study that will supply the information required for formulating the strategies, as given above.

The main objective of this water resources situation assessment has been to determine the water requirements of all the user sectors (including those of the riverine and estuarine ecosystems) and the ability of the available water resources to supply these requirements. However, other aspects such as water quality, legal and institutional aspects, macro-economics, and existing infrastructure have also been addressed. This report outlines the 1995 water resources situation, using information obtained from previous study reports to identify the main water related issues of concern. The large body of information available in the Department of Water Affairs and Forestry and from other sources has also been collated and presented in this assessment. This has been collected on a catchment basis at the quaternary catchment level of resolution. The levels of confidence that can be attached to the data on land use, water requirements and surface water and groundwater resources have however, been found to vary considerably because of the desktop nature of the study. This has therefore also provided a basis for identifying where improvements need to be made to the data in future and to prioritise such studies. It is also important to note that where information on land and water use and sensitive ecosystems is not given, this could be due to the fact that it does not exist or because it has not been documented in a format or source that is readily accessible.

The larger inter-related studies that have supported this water resources situation assessment have been the following:

- Development of a computerised database

  Data collected in this water resources situation assessment has been used to populate the database of the Chief Directorate: Planning of the Department of Water Affairs and Forestry. The database design has mainly been based on the requirements of a water balance model that has been developed to compare the water requirements with the available water resources.

- Demographic study

  An important part in the development of the national water resources strategy is the future scenarios. Since water use is mainly driven by the requirements of the various socio-economic groupings of the population, a national demographic study was initiated. An important part of the study was an estimate of the base year (1995) population. The study has also associated the population with defined water user categories to facilitate estimating existing and future water requirements. These categories have *inter alia* been defined on the basis of reports on urban water supplies and questionnaires completed by local authorities.

- Macro-economic study

  Economic activity and its effects on the spatial distribution of the population and vice versa is an important determinant of water use. With the ever-increasing need for water for domestic use and protection of the water resources, water availability is already becoming a limiting factor in various regions of the country. The economic viability of continuing to supply water for existing sectors, such as irrigation and also of expanding such activities to satisfy socio-economic aspirations will need careful consideration. A national macro-economic study has therefore been undertaken to provide basic economic data for use in the demographic study and to provide macro-economic overviews for each water management area.

- Formulation and development of a water situation assessment model

  The primary function of the water situation assessment model is to reconcile water supply and water requirements by quantifying the surplus or deficit per catchment area. Water balances are compiled from the quaternary catchment level of resolution of the data, which can then be aggregated to suite any desired predetermined catchment boundaries. The water situation assessment model is nevertheless only a coarse planning tool and does not replace the detailed hydrological studies that are required for basin studies or project investigations.

- Water requirements for the ecological component of the Reserve

  The National Water Act (No. 36 of 1998) requires that water be provided for the Reserve, which is the quantity and quality of water required to satisfy basic human needs and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant resource. The ecological sensitivity and importance of the rivers in South Africa and the present ecological status class was therefore established at the quaternary catchment level of resolution, using available data and local knowledge.

At the same time the results of previous field assessments of the water requirements of the aquatic ecosystems at selected sites in South Africa were used in a separate study to develop a model for estimating the water required for the ecological component of the Reserve for various ecological management classes that correspond to those determined previously for the rivers throughout the country.

SYNOPSIS

1. INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act No. 36 of 1998 requires the Minister of Water Affairs and Forestry to establish a national water resource strategy for the protection, use, development, conservation, management and control of water resources. To enable the strategy to be established, information on the present and probable future situations regarding water requirements and water availability is required, that is, a national water resources situation assessment providing information on all the individual drainage basins in the country.

The Department of Water Affairs and Forestry (DWAF) has appointed consulting engineers to undertake Water Resources Situation Assessments for the purpose of gathering information and using it to reconcile the present water requirements of all the user sectors with the presently available water resources. The information produced by all the studies will be consolidated by DWAF into a national database which will be used to establish the National Water Resource Strategy. Scenarios of future water requirements and availability are being dealt with in a separate study. These scenarios will be taken up in the National Water Resource Strategy and will be reported on separately for each water management area.

As a component of the National Water Resource Strategy, the Minister of Water Affairs and Forestry has established water management areas and determined their boundaries.

The information gathered in the Water Resources Situation Assessments has been presented in the form of a separate report on each water management area (WMA). This report is in respect of the Fish to Tsitsikamma Water Management Area.

1.2 APPROACH TO THE STUDY

This study was carried out as a desktop investigation using data from reports and electronic databases, or supplied by associated studies, local authorities and DWAF. The study considered conditions as they were in the year 1995 and did not make projections of future conditions. Data at reconnaissance level of detail was collected on land-use, water requirements, water use, water related infrastructure, water resources and previous investigations of water supply development possibilities. Relevant data was used to calculate the yield of the water resources at development levels as they were in 1995, and the maximum yield that could be obtained from future development of these resources. The water balance (the relationship between water requirements and water availability) at selected points in each water management area was also calculated.

Information on urban water use and water related infrastructure was obtained from reports on urban water supplies and from questionnaires filled in by local authorities. The collected data on urban water use was supplied to consultants appointed to carry out a separate national demographic study, in relation to water requirements.

In that study, data from the 1996 census, and other sources, was used to derive demographic information for the whole country for the year 1995. In addition, the information on urban water use that was supplied by the water resources situation assessment studies, was analysed in the demographic study to derive typical unit water requirements. These were used, in conjunction with the demographic data, to estimate water requirements in 1995 for urban areas for which no recorded data was available.

Both the demographic data and the estimated water requirements in 1995, as supplied for the Fish to Tsitsikamma WMA by the national demographic study (DWAF, 2000b), are presented in this report. In addition to the separate studies on the water balance model and demography referred to above, separate studies were carried out to provide information on a national basis on :

- Macro-economic aspects
- Legal aspects of water resource management
- Institutional arrangements for water supply
- Effects of alien vegetation on runoff
- Groundwater resources
- Bacteriological contamination of water resources
- Water requirements for irrigation
- Ecological classification of rivers
- Water requirements for the ecological component of Reserve
- Effects of afforestation on runoff
- Storage-yield characteristics of rivers

Information from all the above studies, that is relevant to the Fish to Tsitsikamma Water Management Area, is included in the appropriate sections of this report. The main conclusions drawn from the information are summarised below, followed by a list of requirements for additional data and recommendations on the action needed to obtain the data.

2. CHARACTERISTICS OF THE WMA

The main characteristics of the Fish to Tsitsikamma WMA, as determined from the information gathered in this situation assessment, are listed below :

Physical Characteristics

- The Fish to Tsitsikamma WMA covers an area of 97 023 km^2 in which the mean annual precipitation ranges from 150 mm in the north-western interior, where the climate is semi-arid, and rainfall generally occurs in the period from March to May, to more than 1 100 mm along the coast in the south-west, where rainfall occurs throughout the year. Mean annual gross Symons Pan evaporation ranges from 2 300 mm to 1 500 mm.

- The geology of the WMA consists of Karoo sediments in the interior and sandstones, quartzites and conglomerates of the Cape Supergroup along the coast. Thus, water can be expected to have naturally elevated TDS concentrations in the interior and low concentrations along the coast.

- The small rivers of the coastal catchments are of high to very high ecological importance and sensitivity, and consequently have high ecological flow requirements. The Koonap River and Kat River and their tributaries are also of high ecological importance. Most of the other rivers are of moderate ecological importance and sensitivity and have correspondingly lower ecological flow requirements.

Development Status

- The population of the WMA in 1995 was approximately 1 623 000 people. Some 13% of the population lived in rural areas, and 87% of the total population lived in the towns of the WMA. About 64% of the population lives in the Algoa Coastal area, mainly within the boundaries of the Nelson Mandela Metropolitan Municipality.

- Much of the economic activity is concentrated in the south-western portion of the WMA, with the Port Elizabeth/Uitenhage area contributing 82% of the GGP in 1997. The GGP of the whole WMA was R21,8 billion in 1997, with the most important economic sectors, in terms of their contributions to GGP, being Manufacturing (28,3%), Trade (18,0%), and Government (16,6%). Transport and Manufacturing have comparative advantages relative to other WMAs.

Land-use

- Land-use is predominantly for rough grazing for livestock. Some 950 km2, or 1% of the surface area of the WMA is used for irrigated crops, but only about 700 km2 of land is irrigated in average years, with larger areas irrigated occasionally when rainfall and runoff is favourable in the semi-arid areas. Afforestation, mainly in the south-western coastal strip covers 417 km2, and 3 705 km2 of land consists of nature reserves. Alien vegetation other than the afforestation covered an equivalent condensed area of 940 km2.

- There were about 886 000 head of livestock in the WMA in 1995. Sheep and goats made up 61% of the livestock numbers, with sheep predominating.

Water Related Infrastructure

- Water related infrastructure is well developed, particularly in the southern half of the WMA and along the Great Fish River where most of the water requirements occur and where an average quantity of 560 million m3/a of water is imported from the Orange River by means of the Orange/Fish Transfer Scheme.

- Town bulk water supply schemes were generally adequate in 1995, but the requirements from many of them were approaching their capacities and supplies are likely to require augmentation soon.

- Many of the towns can be economically supplied with raw water imported from the Orange River, but some of the bigger towns where this is not the case, and where raw water supplies will require augmentation in the near future, are Adelaide, Fort Beaufort, Port Alfred, Kenton-on-Sea, Bushman's River Mouth, and Alexandria. The supply to Nelson Mandela Metropolitan Municipality could be augmented from the Orange River or from local sources.

Water Requirements

- Water requirements in 1995 were estimated to total 1 158 million m3/a, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. The major water user sector was agriculture, which required 911 million m3/a, or 79% of the total consumptive requirement (i.e. excluding the ecological Reserve). The next biggest water user was the urban and rural domestic sector, at 9% of the total consumptive requirement, followed by alien vegetation (7%) and afforestation (5%). The estimate of water use by alien vegetation is at a low level of confidence. With the requirements of the ecological Reserve added, and river channel losses of 112 million m3/a associated with the Orange/Fish Transfer Scheme, the total water requirement becomes 1 513 million m3/a.

- The equivalent water requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by alien vegetation and afforestation all included as impacts on yield, was 937 million m3/a. Adding Orange/Fish Transfer Scheme river channel losses of 112 million m3/a to this brings the total to 1 049 million m3/a. The estimates of the impacts on yield are at a low level of confidence.

- Allocations of water for irrigation from Government Water Supply Schemes total 915 million m3/a. Of this quantity, 722 million m3/a, or 79%, is allocated from the Orange/Fish Transfer Scheme. From the information gathered in this study, it appears that only about 63% of the allocation from the Orange/Fish Transfer Scheme is used, but this is in conflict with the information gathered in earlier studies and should be verified.

- On the basis of the above, water used for irrigation from Government Water Supply Schemes amounts to 651 million m3/a (excluding losses), and accounts for 86% of the average field edge irrigation water requirement of the WMA of 759 million m3/a. Therefore, only 14% of the irrigation water requirements in the WMA are provided from what were "private" sources prior to 1998. With the exception of the Kouga River catchment, information on the capacities of these sources and the quantities of water used from them is not well documented, but may be required in the future for specific areas where the need to further develop the water resources occurs.

Water Resources

- The natural MAR of the Fish to Tsitsikamma WMA was 2 154 million m3/a and the yield utilised from surface water resources in 1995 was 425 million m3/a at 1:50 year assurance. Some 50% of the utilised yield was from farm dams and run-of-river abstractions, and 43% from major dams. The balance of 7% was the impact of alien vegetation and afforestation on the yield. In addition, boreholes with an estimated yield of 40 million m3/a had been developed, bringing the total developed yield to 465 million m3/a at 1:50 year assurance.

- Natural water quality is good in some of the mountainous areas of the WMA, but in most other areas the base flows in the rivers are of high salinity, caused by the geological strata. For the same reason, only about 60% of the groundwater exploitation potential is estimated to be potable. The salinities of the base flows in many of the rivers are increased by irrigation return flows. In the Zwartkops River near Port Elizabeth, the impacts of urban development have resulted in high microbial pollution and elevated levels of nutrients in the water.

- The maximum potential utilisable yield of the WMA is estimated to be 943 million m3/a, which is 478 million m3/a more than the utilised yield in 1995. (The total exploitable groundwater resource that does not contribute to surface base flow is estimated to be 752 million m3/a, which appears to be a substantial over-estimate. The total potential surface water yield is estimated to be 654 million m3/a. However, the interaction between groundwater and surface water is not known, except for the estimates of base flow interaction. Therefore the maximum potential utilisable yield in each key area was assumed to be the greater of the maximum surface water potential, or the maximum potential groundwater yield not connected to surface water base flow. The values for the key areas were combined to obtain the estimated maximum water resource potential of 943 million m3/a. The adoption of the potential groundwater yield not connected to surface base flow rather than the full potential groundwater yield is conservative and is based on the assumption that a significant portion of the groundwater contribution to surface base flow is required for the ecological Reserve and is not, therefore, available for other water requirements.).

- Surface water resources could provide a maximum yield of 229 million m3/a additional to the surface water yield utilised in 1995, but the total potential yields in many areas could possibly not be economically developed. In some instances it might be more economical to develop groundwater resources to provide part of this.

Water Balance

- Comparison of the equivalent 1:50 year assurance water requirements of 937 million m3/a with the developed yield of 465 million m3/a shows a deficit of 472 million m3/a, but re-used return flows of 122 million m3/a reduce the deficit to 350 million m3/a. Imports of 560 million m3/a from the Orange River, which incur river channel losses of 112 million m3/a, result in an overall surplus of 98 million m3/a. There is considerable doubt about the validity of this surplus, as discussed below.

- The yield balance is at a low level of confidence because of uncertainty regarding the true run-of-river yields and the true impacts of the ecological Reserve, afforestation and alien vegetation on the 1:50 year yields of the various key areas. Reference to the deficient flow-duration-frequency curves in WR90 suggests that the total of the 1:50 year run-of-river yield in the WMA may be up to 125 million m3/a less than assumed for the yield balance. If this were the case, the yield balance would show a slight deficit in the Gamtoos River catchment and deficits in the Fish and Sundays River catchments which would need to be offset by increased imports from the Orange River. There would also be a significant deficit in the Koonap catchment. (The higher estimates of run-of-river yield have been retained in this report because they are the values used in the draft of the National Water Resource Strategy).

Costs of Water Resource Development

- The capital cost of developing the additional yield of 476 million m3/a was estimated to be R3 568 million at year 2000 prices including 14% VAT. However, the quality of groundwater and of surface water base flows in the WMA is variable, with high salinities in some areas. Therefore, the viability of developing the full potential yield may be affected by water quality as well as the high cost of constructing dams, and it is likely that only a small portion of this yield could be economically developed.

- On the basis of the data used for estimating the costs of development of the full potential yield of the water resources, the cost of developing groundwater resources is only half that of developing the same quantity of surface water yield. Therefore, it is surprising that only 5% of the potential groundwater yield had been developed by 1995. The reasons for this, which may be factors such as high distribution, operation and maintenance costs, which are not included in the cost estimates, should be determined.

3. CONCLUSIONS AND RECOMMENDATIONS

It is concluded from the above that there is insufficient reliable data to enable the water balance in the Fish to Tsitsikamma WMA to be determined with confidence. The available data on the following aspects is inadequate:

- The 1:50 year yields from farm dams and run-of-river yield for all areas of the WMA.
- The quantity of water from the Orange/Fish Transfer Scheme that is used for irrigation.
- The distribution, types and areas of crops irrigated from "private" sources and their water requirements.
- Ecological flow requirements of both rivers and estuaries and their impacts on the utlised yields of the water resources.
- The impacts of alien vegetation and afforestation on the yield of the water resources.
- The reasons for the limited utilisation of the groundwater resource in relation to its apparent total potential and low cost of development.

Although not apparent from the above, it was also found during the assessment that information is lacking on the following aspects:

- The capacities of the raw water supplies of some of the towns (this data should be obtained for information on urban water supply infrastructure to be comprehensive, but is not of high priority and should be available from the water services development plans prepared by the towns).
- The numbers and types of game in the WMA. (This is not of high priority because the numbers, and hence the water requirements, are likely to be small. Nevertheless, the information should be obtained for completeness of the data on the water requirements of livestock and game).
- Updated estimates of the yields of Beervlei, Commando Drift, and Kat River Dams, and the dams supplying Grahamstown at assurances of 1:50 years and at lower assurances typically used for irrigation, as these have not been recently determined.

Ideally, all the information referred to above should be available to facilitate the efficient management of the water resources of the Fish to Tsitsikamma WMA and the planning of their further development. However, a considerable amount of work will be required to obtain all the information, and it is unlikely that the task could be completed in a short time. Therefore, a phased approach is recommended, in which the required information is collected for particular areas as it becomes necessary to address water resources problems, or as the Reserve is implemented.

It is recommended that the run-of-river and farm dam yields in the Fish and Sundays River catchments be determined by using and modifying as necessary the system yield model that was developed for those rivers for the Orange River Development Project Re-planning Study to also take account of actual operating procedures.

With regard to the potential groundwater yields, the fact that groundwater has not been utilised to a greater extent casts some doubt on the reliability of the estimates of groundwater yield. It is recommended that the data be verified, starting with the Zwartkops Catchment, where the data shows the groundwater to be under-utilised, but a Government Subterranean Water Control Area was declared because the resource has appeared in the past to be stressed. The estimates of total potential yield given in this report should therefore be used with caution until the investigation confirms the assumed groundwater yields, or otherwise.

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DIAGRAMS

ABBREVIATIONS AND ACRONYMS

amsl	above mean sea level
AEMC	Suggested Ecological Management Class
CMA	Catchment Management Agency
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management Class
DESC	Default Ecological Sensitivity Class
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Class
GIS	Geographical Information System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act No. 36 of 1998)
PESC	Present Ecological Status Class
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TRC	Transitional Rural Council
WMA	Water Management Area
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model
ha	hectare
km^2	square kilometres
ℓ/c/d	litres per capita per day
m^3	cubic metre
Mℓ	Megalitres
Mℓ/d	Megalitres per day
%	percent

GLOSSARY OF TERMS

ASSURANCE OF SUPPLY	The reliability at which a specified quantity of water can be provided, usually expressed either as a percentage or as a risk. For example "98% reliability" means that, over a long period of time, the specified quantity of water can be supplied for 98% of the time, and less for the remaining 2%. Alternatively, this situation may be described as a "1 in 50 year risk of failure" meaning that, on average, the specified quantity of water will fail to be provided in 1 year in 50 years, or 2% of time.
BASIN	The area of land that is drained by a large river, or river system.
BIOTA	A collective term for all the organisms (plants, animals, fungi, bacteria) in an ecosystem.
CONDENSED AREA	The equivalent area of alien vegetation with a maximum concentration/density that represents the more sparsely distributed alien vegetation that occurs over a large area.
CATCHMENT	The area of land drained by a river. The term can be applied to a stream, a tributary of a larger river or a whole river system.
COMMERCIAL FARMING	Large scale farming, the products of which are normally sold for profit.
COMMERCIAL FORESTS	Forests that are cultivated for the commercial production of wood or paper products.
DAM	The wall across a valley that retains water, but also used in the colloquial sense to denote the lake behind the wall.
DEFICIT	Describes the situation where the availability of water at a particular assurance of supply is less than the unrestricted water requirement.
DEFAULT ECOLOGICAL MANAGEMENT CLASS	Default Ecological Management Class (A-D). A class indicating the ecological importance and sensitivity of an area, as it is likely to have been under natural (undeveloped) conditions, and the risks of disturbance that should be tolerated. Values range from ClassA (highly sensitive, no risks allowed) to ClassD (resilient systems, large risk allowed).
DRAINAGE REGION	The drainage regions referred to in this document are either single large river basins, or groups of contiguous catchments or smaller catchments with similar hydrological characteristics. They follow the division of the country into drainage regions as used by the Department of Water Affairs and Forestry.

ECOSYSTEM	A unit made up of all the living and non-living components of a particular area that interact and exchange materials with each other.
ECOSYSTEM HEALTH	An ecosystem is considered healthy if it is active and maintains its organisation and autonomy over time, and is resilient to stress. Ecosystem health is closely related to the idea of sustainability.
ECOLOGICAL IMPORTANCE	A measure of the extent to which a particular species, population or process contributes towards the healthy functioning of an ecosystem. Important aspects include habitat diversity, biodiversity, the presence of unique, rare or endangered biota or landscapes, connectivity, sensitivity and resilience. The functioning of the ecosystem refers to natural processes.
EDAPHIC	Pertaining to the influence of soil on organisms, OR Resulting from or influenced by factors inherent in soil rather than by climatic factors.
ENDANGERED SPECIES	Species in danger of extinction and whose survival is unlikely if the causal factors bringing about its endangered status continue operating. Included are species whose numbers have been reduced to a critically low level or whose habitat has been so drastically diminished and/or degraded that they are deemed to be in immediate danger of extinction.
ENDEMIC	Occurring within a specified locality; not introduced.
ENDOREIC	Portion of a hydrological catchment that does not contribute towards river flow in its own catchment (local) or to river flow in downstream catchments (global). In such catchments the water generally drains to pans where much of the water is lost through evaporation.
ENVIRONMENTALLY SENSITIVE AREA	A fragile ecosystem which will be maintained only by conscious attempts to protect it.
EPHEMERAL RIVERS	Rivers where no flow occurs for long periods of time.
FORMAL IRRIGATION SCHEME	The term applies to a scheme where water for irrigation purposes is stored in a dam controlled by DWAF or an Irrigation Board and supplied in pre-determined quotas to irrigators registered under the scheme.
HISTORICAL FLOW SEQUENCE	A record of river flow over a defined period and under a defined condition of catchment development in the past, calculated from a record of observed flow corrected for inaccuracies, or from records of observed rainfall, or a combination of the two.

HYDROLOGICAL YEAR	The twelve-month period from the beginning of October in one year to the end of September in the following year.
INVERTEBRATE	An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.
IRRIGATION QUOTA	The quantity of water, usually expressed as m^3/ha per year, or mm per year, allocated to land scheduled under the scheme. This is the quantity to which the owner of the land is entitled at the point at which he or she takes delivery of the water and does not include conveyance losses to that point.
LOTIC	Pertaining to fast running aquatic habitats such as fast flowing streams or rivers.
MEAN ANNUAL RUNOFF	Frequently abbreviated to MAR, this is the long-term mean annual flow calculated for a specified period of time, at a particular point along a river and for a particular catchment and catchment development condition. In this report, the MARs are based on the 70-year period October 1920 to September 1990 inclusive.
OPPORTUNISTIC IRRIGATION	Irrigation from run-of-river flow, farm dams, or compensation flows released from major dams. As storage is not provided to compensate for reduced water availability in dry years, areas irrigated generally have to be reduced in dry years.
PRESENT ECOLOGICAL STATUS CLASS	A class indicating the degree to which present conditions of an area have been modified from natural (undeveloped) conditions. Factors that are considered in the classification include the extent of flow modification, inundation, water quality, stream bed condition, riparian condition and proportion of exotic biota. Values range from ClassA (largely natural) to ClassF (critically modified).
QUATERNARY CATCHMENT	The basic unit of area resolution used in the WR90 series of reports published by the Water Research Commission and also in this report. The primary drainage regions are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been created to have similar mean annual runoffs : the greater the runoff volume the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example R30D, may be interpreted as follows : the letter R denotes Primary Drainage Region R, the number 3 denotes secondary catchment 3 of Primary Drainage Region R, the number 0 shows that the secondary catchment has not, in this case, been sub-divided into tertiary catchments, and the letter D shows that the quaternary catchment is the fourth in sequence downstream from the head of secondary catchment R30.

RARE	Species with small or restricted populations, which are not at present endangered or vulnerable, but which are at risk. These species are usually localised within restricted geographical areas or habitats, or are thinly scattered over a more extensive range. These may be species which are seldom recorded but may be more common than supposed, although there is evidence that their numbers are low.
RED DATA BOOK	A book that lists species that are threatened with extinction. The concept was initiated by the International Union for the Conservation of Nature, and has since become adopted by many countries. The "Red" stands for "Danger". The categories reflect the status of the species only within the area under review, and it is sometimes the case that species which are threatened in one region may have secure populations in other areas.
RELIABILITY OF SUPPLY	Synonymous with assurance of supply.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997) for people, who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource as indicated in the National Water Act (Act No. 36 of 1998).
RESERVOIR	The lake formed behind a dam wall. In this report the colloquial term dam is generally used for reservoir.
RESILIENCE	The ability of an ecosystem to maintain structure and patterns of behaviour in the face of disturbance or the ability to recover following disturbance.
RESOURCE QUALITY	The quality of all the aspects of a water resource including: (a) the quantity, pattern, timing, water level and assurance of instream flow; (b) the water quality, including the physical, chemical and biological characteristics of the water; (c) the character and condition of the instream and riparian habitat; and (d) the characteristics, condition and distribution of the aquatic biota.
RESOURCE QUALITY OBJECTIVE	Quantitative and verifiable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection.
RIVER SYSTEM	A network of rivers ranging from streams to major rivers and, in some cases, including rivers draining naturally separate basins that have been inter-connected by man-made transfer schemes.

SCHEDULED LAND	Irrigable land to which a water quota has been allocated.
SPATIO - TEMPORALLY ROBUST	Does not change significantly with time in relation to spatial distribution.
SUB-CATCHMENT	A sub-division of a catchment.
SUBSISTENCE FARMING	Small-scale farming where almost all produce is consumed by the farmer's household or within the local community.
SUGGESTED ECOLOGICAL MANAGEMENT CLASS	A class of water resource indicating the suggested management objectives of an area which could possibly be attained within 5 years. Values range from Class A (largely natural) to Class D (largely modified).
VADOSE ZONE	Relating to or resulting from water or solutions that are above the permanent groundwater level.
VULNERABLE	Species believed likely to move into the endangered category in the near future if the causal factors continue operating. Included are species of which all or most of the population are decreasing because of over-exploitation, extensive destruction of habitat, or other environmental disturbance. Species with populations which have been seriously depleted and whose ultimate security is not yet assured, and species with populations that are still abundant but are under threat from serious adverse factors throughout their range.
WATER IMPORTS	Water imported to one drainage basin or secondary sub-catchment from another.
WATER TRANSFERS	Water transferred from one drainage basin or secondary sub-catchment to another. Transfers in are synonymous with water imports.
YIELD	The maximum quantity of water obtainable on a sustainable basis from a dam in any hydrological year in a sequence of years and under specified conditions of catchment development and dam operation.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act No. 36 of 1998 requires the Minister of Water Affairs and Forestry to establish a national water resource strategy for the protection, use, development, conservation, management and control of water resources. To enable the strategy to be established, information on the present and probable future situations regarding water requirements and water availability is required, that is, a national water resources situation assessment providing information on all the individual drainage basins in the country.

The Department of Water Affairs and Forestry (DWAF) has appointed consulting engineers to undertake Water Resources Situation Assessments for the purpose of gathering information and using it to reconcile the present water requirements of all the user sectors with the presently available water resources. The information produced by all the studies will be consolidated by DWAF into a national database which will be used to establish the National Water Resource Strategy. Scenarios of future water requirements and availability are being dealt with in a separate study. These scenarios will be taken up in the National Water Resource Strategy and will be reported on separately for each water management area.

As a component of the National Water Resource Strategy, the Minister of Water Affairs and Forestry has established water management areas and determined their boundaries. The National Water Act provides for the delegation of water resource management from central government to the regional or catchment level by establishing catchment management agencies. It is intended that the documents produced in this study as well as in the subsequent scenario studies referred to above should, in addition to contributing to the establishment of the National Water Resource Strategy, provide information for collaborative planning of water resources development and utilisation by the central government and the future catchment management agencies.

In order to facilitate use by future catchment management agencies, the information has been presented in the form of a separate report on each water management area (WMA). This report is in respect of the Fish to Tsitsikamma Water Management Area, which mostly occupies a portion of the Eastern Cape Province, with small parts of the WMA falling within the Western Cape Province and the Northern Cape Province. A provincial water resources situation assessment can be derived by assembling the provincial data from each of those reports that describe the water management areas that occupy the province.

1.2 APPROACH TO THE STUDY

The study was carried out as a desktop investigation using data from reports and electronic databases, or supplied by associated studies, local authorities and DWAF. The study considered conditions as they were in the year 1995 and did not make projections of future conditions. Data at reconnaissance level of detail was collected on land-use, water requirements, water use, water related infrastructure, water resources and previous investigations of water supply development possibilities. Relevant data was used in a computerised water balance model, developed in a separate study (DWAF, 2000a) to calculate the yield of the water resources at development levels as they were in 1995, and the maximum yield that could be obtained from future development of these resources.

The water balance (the relationship between water requirements and water availability) at selected points in each water management area was also calculated.

Information on urban water use and water related infrastructure was obtained from reports on urban water supplies and from questionnaires filled in by local authorities. The collected data on urban water use was supplied to consultants appointed to carry out a separate national demographic study, in relation to water requirements.

In that study, data from the 1996 census, and other sources, was used to derive demographic information for the whole country for the year 1995. In addition, the information on urban water use, that was supplied by the water resources situation assessment studies, was analysed in the demographic study to derive typical unit water requirements. These were used, in conjunction with the demographic data, to estimate water requirements in 1995 for urban areas for which no recorded data was available.

Both the demographic data and the estimated water requirements in 1995, as supplied for the Fish to Tsitsikamma Water Management Area by the national demographic study (DWAF, 2000b), are presented in this report. In addition to the separate studies on the water balance model and demography referred to above, separate studies were carried out to provide information on a national basis on :

- Macro-economic aspects
- Legal aspects of water resource management
- Institutional arrangements for water supply
- Effects of alien vegetation on runoff
- Groundwater resources
- Bacteriological contamination of water resources
- Water requirements for irrigation
- Ecological classification of rivers
- Water requirements for the ecological component of Reserve
- Effects of afforestation on runoff
- Storage-yield characteristics of rivers

Information from all the above studies, that is relevant to the Fish to Tsitsikamma Water Management Area, is included in the appropriate sections of this report.

1.3 REPORT LAYOUT AND CONTENT

The findings of the study in respect of the Fish to Tsitsikamma Water Management Area are presented in the nine chapters that make up the main body of this report, and a number of appendices containing mainly statistics for the quaternary hydrological sub-catchments that make up the water management area. (The system used to divide the area into hydrological sub-catchments is explained in Section 2.1 of the report).

The chapter headings are:

Chapter 1: Introduction
Chapter 2: Physical Features
Chapter 3: Development Status
Chapter 4: Water Related Infrastructure
Chapter 5: Water Requirements
Chapter 6: Water Resources
Chapter 7: Water Balance

Chapters 2, 3 and 4 describe climatic and physical features, and land-uses that affect water resources or water supply. Chapter 5 describes the various water user sectors and their requirements. It includes information on water allocations, water conservation and demand management, and water losses and return flows. Chapter 6 describes the groundwater and surface water resources of the water management area, and Chapter 7 compares water requirements with the available resource. In Chapter 8, rough estimates are given of the cost of developing the portion of the total water resource that was not developed by 1995, and the conclusions and recommendations arising from the study are presented in Chapter 9.

CHAPTER 2: PHYSICAL FEATURES

2.1 THE STUDY AREA

The study area comprises the whole of the Fish to Tsitsikamma Water Management Area which is shown on Figure 2.1.1. It consists of three large drainage basins and the catchments of a number of smaller rivers that lie between the major drainage basins and the Indian Ocean. The major drainage basins are the Great Fish (Drainage Region Q), the Sundays (Drainage Region N), and the Groot/Gamtoos (Drainage Region L).

The Fish to Tsitsikamma WMA is bounded in the west by the Gouritz WMA, the Lower Orange and Upper Orange WMAs in the north, the Mzimvubu to Keiskamma WMA in the east, and the Indian Ocean in the south.

The topography is mountainous in the southern and eastern parts, while the rest of the area consists of the plains and hills of the Great Karoo (see Figure 2.1.2).

For purposes of assessing water requirements and the available water resources, the water management area has been divided into quaternary catchments (see Figure 2.1.3). These are the basic unit of area used in the report on the Surface Water Resources of South Africa, 1990 (Midgley *et al*, 1994), which is the main source of the hydrological data used in this study.

In this system, drainage regions throughout the country are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been selected to have similar runoffs: the greater the runoff volume, the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example L23C, may be interpreted as follows. The letter L denotes Drainage Region L (sometimes referred to as a primary catchment). The number 2 denotes secondary catchment 2 of Drainage Region L. The number 3 shows that the secondary catchment has, in this case, been sub-divided into tertiary catchments and that the tertiary catchment is the third in sequence downstream from the head of secondary catchment L2. The letter C shows that the quaternary catchment is the third in sequence downstream from the head of tertiary catchment L23.

The Fish to Tsitsikamma WMA consists of Drainage Regions L, M, N, P and Q and a portion of Drainage Region K. It contains a total of 202 quaternary catchments from these drainage regions.

In the description of features of the area that follows, references to quaternary catchments are shown in brackets to assist in locating the approximate positions of the features on Figure 2.1.3. Many of the features themselves are not shown on the figure because the scale of mapping is too small.

The total area of the WMA is some 97 000 km^2. For purposes of describing its physical features it may conveniently be sub-divided into the drainage areas referred to above.

- The Krom River drains a narrow valley (K90A, B, C, D and E) between the Suuranys Mountains to the interior and the Tsitsikamma Mountains towards the coast. On the other side of the Tsitsikamma Mountains a number of steep, deeply incised rivers (K80A to F) flow to the sea. To the east of the Krom River estuary (K90E), the Seekoei River flows to the sea across a fertile coastal plain (K90G).

- Drainage Region L is the basin of the Gamtoos River and its two major tributaries, the Groot River and the Kouga River. The catchment of the Groot River (L11, L12, L21, L22, L23, L30, L40, L50) lies entirely in the Karoo, where it covers an area of 29 560 km^2. The Groot River passes through narrow gorges in the Groot Winterhoek, Baviaanskloof, and Elandsberg mountain ranges (L70G) before its confluence with the Kouga River. The latter, with a catchment area of 4 053 km^2, rises in the Langkloof (L82A, B, C and D). The main tributary of the Kouga River is the Baviaanskloof River, which rises in the rugged mountains flanking the narrow Baviaanskloof Valley (L81A, B, C, D). The Groot and Kouga Rivers join to form the Gamtoos River (L90A) which drains the western slopes of the Elandsberg mountain range along its 90 km course to the sea (L90C).

- On the other side of the Elandsberg range, lies the Elands River (M10B) which is one of the two main tributaries of the Zwartkops River (M10C and D) which has a catchment area of 2 630 km^2 and flows to the sea through the ecologically important Zwartkops Estuary (M10D). The other main tributary of the Zwartkops River is the Kwa Zunga which also rises in a mountainous area (M10A).

- The Sundays River Basin (Drainage Region N) covers an area of some 21 250 km^2, most of which is situated in the Great Karoo, where the topography consists of arid plains interspersed with steep, rocky hills.

- The coastal catchments of the Albany district (Drainage Region P) are situated in an area of about 5 300 km^2 between the basins of the Sundays and the Great Fish Rivers and the sea. This is an area of steep, bush covered hills with deeply incised river valleys. The main rivers are the Kariega (P30A, B, C), the Bushman's (P10A to G), and the Kowie (P40A, B, C).

- The Great Fish River Basin (Drainage Region Q) covers an area of 30 000 km^2 of varied topography. Much of the upper part of the basin is an arid area where numerous small, and frequently dry, tributaries originate along the edge of the interior plateau (Q11, 12, 14). The main tributary in the north-eastern part of the basin is the Tarka River (Q41, Q42, Q43, Q44) which rises on the northern slopes of the Winterberg Mountains (Q44A, A41A, D). The main tributary in the west of the basin is the Little Fish River, which, with a catchment area of 2 838 km^2, drains the arid area to the south-west of Cradock.

  The Koonap River, with a catchment area of 3 334 km^2, rises on the southern slopes of the Winterberg (Q92A, B, C) and flows through mountainous terrain to join the lower reaches of the Fish River (Q92G).

  The Kat River catchment, with mean annual precipitation ranging from 800 mm in the mountains along its eastern edge (Q94A, B) to 480 mm in the vicinity of the Fish River (Q94F) is the wettest part of the Great Fish River Basin. The area of the catchment is 1 715 km^2 and the floor of the main valley is fertile and fairly wide.

  Only minor tributaries join the Great Fish River downstream of its confluence with the Kat River, where it flows for about 100 km through deeply incised meanders in hilly terrain (Q93A, B, C) to its estuary (Q93D).

For purposes of describing the characteristics of the WMA, it was divided into a number of key areas. These are either the catchments of the main rivers within the WMA, or groupings of several minor catchments. The key areas are listed in Table 2.1.1, where reasons for selecting them are also included.

TABLE 2.1.1: KEY AREAS WITHIN THE FISH TO TSITSIKAMMA WMA

CATCHMENT					REASON FOR SELECTION
PRIMARY		SECONDARY		TERTIARY/ QUATERNARY	
No.	Description	No.	Area	No.	
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom	K90A to D	Catchment of Impofu Dam
		K8, K9 (part)	Tsitsikamma Coast	K80A to F K90E to G	High rainfall coastal strip
L	Groot/Gamtoos	L1, L2	Upper Groot	L11, L12, L21, L22, L23	Catchment of Beervlei Dam
		L3 to L7	Lower Groot	L30 - L70	Groot River Catchment downstream of Beervlei Dam
		L8	Kouga	L81, L82	Catchment of Kouga Dam
		L9	Gamtoos	L90A to C	Gamtoos River irrigation scheme area
M	Algoa Coast	M1 M2 M3	Zwartkops Port Elizabeth Coega	M10A to D M20A, B M30A, B	Nelson Mandela Municipal Area
N	Sundays	N1 (Part)	Upper Sundays	N11, N12	Catchment of Van Rynevelds Pass Dam
		N1, N2, N3	Middle Sundays	N13, N14 N21 - 24 N30	Catchment of Darlington Dam
		N4	Lower Sundays	N40	Lower Sundays Irrigation Scheme area
P	Albany Coastal Catchments	P1, P2 P3, P4	Bushmans Kowie/Kariega	P10, P20 P30, P40	Catchment of Bushmans River Catchments of Kowie and Kariega Rivers
Q	Great Fish	Q1 (Part)	Upper Fish	Q11, Q12, Q13A	Catchment of Grassridge Dam
		Q4	Tarka	Q41, Q42, Q22 Q43 Q44A, B	Catchment of Lake Arthur
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish	Q13B, C Q14, Q21 Q30 Q44C Q50A	Incremental catchment of Elandsdrift Weir
		Q8 (Part)	Upper Little Fish	Q80A to E	Catchment of De Mistkraal Weir
		Q5 - Q9 (Part)	Middle Fish	Q50B, C, Q60, Q70 Q80F, G,	Part of Fish River Irrigation Scheme area
		Q9 (Part)	Koonap	Q92	Koonap River Catchment
		Q9 (Part)	Kat	Q94	Kat River Catchment
		Q9 (Part)	Lower Fish	Q91A to C Q93A to D	Main stem of lower Fish River

2.2 CLIMATE

2.2.1 Temperature

The mean annual temperature ranges between 15ºC in the west to 20ºC in the east, with an average of 16,1ºC for the WMA as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. The following Table summarises temperature data for the WMA for these two months (Schulze *et al*, 1997).

TABLE 2.2.1: TEMPERATURE DATA

MONTH	TEMPERATURE	AVERAGE (°C)	RANGE (°C)
January	Mean temperature	21,0	10 - 24,8
	Maximum temperature	27,8	17,2 - 32,7
	Minimum temperature	14,1	2,8 - 19,7
	Diurnal range	13,7	6,3 - 18,7
July	Mean temperature	10,6	-0,3 - 16,8
	Maximum temperature	17,7	8,2 - 22,3
	Minimum temperature	3,5	-8,8 - 11,6
	Diurnal range	14,2	9,8 - 19,8

Frost occurs in the inland areas in winter, typically over the period from mid-May to late August and snowfalls occur on the mountains in the winter.

2.2.2 Rainfall

Rainfall in the Fish to Tsitsikamma WMA generally occurs very late in summer (March to May) in the northern, north-western, north-eastern and central parts of the WMA, and throughout the year in the coastal region, where the peak rainfall months are December and January.

There is a great variation of rainfall throughout the WMA. The mean annual precipitation (MAP) along the coastal region ranges from a low of 434 mm in the east to a high of 1 100 mm in the west, and varies from 200 mm to 500 mm in the central plateau. It varies between 300 mm and 400 mm in the northern escarpment regions, and between 150 mm and 400 mm in the western interior. The distribution of rainfall is shown on Figure 2.2.1.

2.2.3 Humidity and Evaporation

The relative humidity in the WMA is higher in summer than in winter. It is generally highest in February (the daily mean ranges from 56,1% in the north to 82,7% in the south) and lowest in July (the daily mean ranges from 51,4% in the north to 72,3% in the south).

Average potential mean annual gross evaporation (MAE) (as measured by Symons-pan) for the WMA ranges from 1 500 mm in the east to a high of 2 300 mm in the dry western parts. The highest Symons-pan evaporation is in January (range from 120 mm to 367 mm) and the lowest evaporation is in June (range from 65 mm to 116 mm).

The gross irrigation requirement (based on rainfall and A-pan evaporation) ranges from 800 mm per annum in the dry western parts to 2100 mm per annum in the eastern and central plateau regions. The minimum monthly requirement is in June (ranging from 0 mm to 100 mm) and the maximum monthly requirement is in January (ranging from 30 mm to 280 mm). Mean annual gross Symons-pan evaporation is shown on Figure 2.2.2.

2.3 GEOLOGY

The geology of the Fish to Tsitsikamma WMA is shown on Figure 2.3.1. The coastal strip consists of sandstones and shales of the Cape Supergroup, while the interior consists entirely of sedimentary rocks of the Karoo Supergroup with numerous dolerite intrusions. The mountain ranges to the west of Port Elizabeth, in which the Langkloof (L82A to J) and Baviaanskloof (L81A to H) are situated consist of heavily folded rocks of the Table Mountain Group. The mountains of the catchment of the Zwartkops River immediately to the north (M10A, B) of Port Elizabeth are formed by strata of the same group.

The mountainous terrain inland of these ranges which extends in a broad band from the western to the eastern boundary of the WMA, consists of sandstones and shales of the Witteberg Group.

To both the west and east of Port Elizabeth, between the mountain ranges of Table Mountain Group strata and the sea, there are areas of mudstones, sandstones, shales and conglomerates of the Uitenhage Group. These are overlain in parts by sand or limestone deposits.

The strata of the Karoo Supergroup consist of a strip of shales and sandstones of the Ecca Group along the northern edge of the coastal mountainous belt, followed further inland by mudstones and sandstones of the Beaufort Group.

The rocks of the Karoo Supergroup are of marine origin and, consequently, cause groundwater generally to be of high salinity. The same applies to the strata of the Uitenhage Group in the coastal belt, but groundwater extracted from the rocks of the Cape Supergroup is generally of low salinity. The quality of water in the rivers during periods of low flow is similar to that of the groundwater in their catchments.

The Fish to Tsitsikamma WMA is not rich in minerals and mining operations consist mainly of quarrying for building materials. The main quarrying operations are for kaolin for brickmaking from weathered shales of the Witteberg Group in the vicinity of Grahamstown (P10A, P40A).

2.4 SOILS

Figure 2.4.1 shows a generalised soils map of the WMA based on some sixteen broad soil groupings. The figure was obtained from the report on the Water Resources of South Africa, 1990 (Midgley *et al*, 1994). The 16 groupings were derived by the Department of Agricultural Engineering of the University of Natal using a national base map which was divided into 82 soil types. These soil types were then analysed according to features most likely to influence hydrological response, viz. depth, texture and slope.

The following soil types occur in the Fish to Tsitsikamma Water Management Area:

- Moderately deep to deep clayey loams in undulating terrain along the south-western edge of the WMA (K80A to E), on the floor of the Langkloof Valley (L82A to D), along the coast in the south-east, and in the upper portion of the Fish River Basin.
- Moderate to deep sandy loams on the steep slopes of the mountains in the south-western portion of the WMA.
- Moderate to deep sandy loams on the steep slopes of the hills and mountains formed from rocks of the Witteberg Group (L70E, F, N40A to D, P10A to D, Q93B, D).

- Moderately deep to deep clayey loams on the flat floor of the lower Sundays River Valley (N40C to F).
- Shallow sandy loams in undulating terrain in the north-western corner of the WMA (L11A, B, D and L21F).
- Predominantly moderately deep to deep sandy soil in undulating terrain in the rest of the WMA, which comprises most of the area inland of the coastal mountain belt, and the coastal area in and adjacent to Port Elizabeth.

2.5 NATURAL VEGETATION

2.5.1 Introduction

Some 20 000 different plant species occur throughout South Africa. These are, however, not randomly distributed within the region but are organised into distinct communities, largely dependent on the prevailing climatic (especially rainfall) and soil conditions. For the purposes of identifying and managing the heterogenous arrangement of vegetation within South Africa it is necessary to be able to recognise relatively homogenous vegetation groups or types. Furthermore, for the recognised groups to be meaningful, it is essential that they are readily apparent and spatio-temporally robust.

Acocks (1988) introduced the concept of "Veld Type", which he defined as: "*a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities"*. Acocks (1988) identified a total of 70 veld types in South Africa (see Table 2.5.1.1), including 75 variations. These 70 veld types fall into 11 broad categories, ranging from various forest types to sclerophyllous (Fynbos) types (Table 2.5.1.1). These "simplified" Acocks veld type categories are used for the purposes of this report, and accordingly the description of the natural vegetation types occurring within the Water Management Area (WMA) is rather broad.

2.5.2 Natural Vegetation Types within the Fish-Tsitsikamma WMA

The Fish-Tsitsikamma WMA is located within the Eastern Cape, and the vegetation within this province is dominated by Coastal Tropical Forest Types, Karoo and Karroid Types, False Karoo Types, Temperate and Transitional Forest and Scrub Types, Pure Grassveld Types and False Sclerophyllous Bush Types. In addition to the aforementioned veld types, the Fish-Tsitsikamma WMA also contains limited areas of Tropical Bush and Savanna Types, False Bushveld Types and False Grassland Types. The veld types occurring within the Fish-Tsitsikamma WMA are described in more detail below and illustrated in Figure 2.5.2.1.

Coastal Tropical Forest

A relatively broad band of Coastal Tropical Forest occurs adjacent to the coastline in the south of the Fish-Tsitsikamma WMA. This veld type is typically confined to the coastal area or immediate vicinity, and includes areas of forest, thornveld and bushveld. There is considerable turnover in species composition between forest patches and therefore different forest patches typically comprise different species compositions. Rainfall is typically higher than that for Temperate and Transitional Forest and Scrub, ranging from 900 to 1500 mm per annum. Coastal Tropical Forest occurs at any altitude from sea level to 450 m above mean sea level (MSL). This veld type exhibits a long history of anthropogenic effects, especially grazing by livestock.

Tropical Bush and Savanna

An isolated patch of this veld type occurs towards the east of the Fish-Tsitsikamma WMA, within Quaternary Catchments Q80C and Q80D. This veld type includes areas of savanna, grassland and thornveld. Tropical Bush and Savanna typically occurs on shallow soils at elevations from 150 m to over 1000 m MSL. Rainfall is low to moderate, typically ranging from 250 to 750 mm per annum.

TABLE 2.5.1.1: A LIST OF THE DETAILED AND SIMPLIFIED ACOCKS VELD TYPES (Acocks, 1988)

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Coastal Forest and Thornveld	1	**Coastal Tropical Forest**
Alexandria Forest	2	
Pondoland Coastal Plateau Sourveld	3	
Knysna Forest	4	
'Ngongoni Veld	5	
Zululand Thornveld	6	
Eastern Province Thornveld	7	
North-eastern Mountain Sourveld	8	**Inland Tropical Forest**
Lowveld Sour Bushveld	9	
Lowveld	10	**Tropical Bush and Savanna**
Arid Lowveld	11	
Springbok Flats Turf Thornveld	12	
Other Turf Thornveld	13	
Arid Sweet Bushveld	14	
Mopani Veld	15	
Kalahari Thornveld	16	
Kalahari Thornveld invaded by Karoo	17	
Mixed Bushveld	18	
Sourish Mixed Bushveld	19	
Sour Bushveld	20	
False Thornveld of Eastern Cape	21	**False Bushveld**
Invasion of Grassveld by Acacia karoo	22	
Valley Bushveld	23	**Karoo and Karroid**
Noorsveld	24	
Succulent Mountain Scrub	25	
Karroid Broken Veld	26	
Central Upper Karoo	27	
Western Mountain Karoo	28	
Arid Karoo	29	
Central Lower Karoo	30	
Succulent Karoo	31	
Orange River Broken Veld	32	
Namaqualand Broken Veld	33	
Strandveld	34	
False Arid karoo	35	**False Karoo**
False Upper Karoo	36	
False Karroid Broken Veld	37	
False Central Lower Karoo	38	
False Succulent Karoo	39	
False Orange River Broken Karoo	40	
Pan Turf Veld invaded by Karoo	41	
Karroid Merxmuellera Mountain Veld replaced by Karoo	42	
Mountain Renosterveld	43	
Highveld Sourveld and Dohne Sourveld	44	**Temperate and Transitional Forest and Scrub**
Natal Mist Belt 'Ngongoni Veld	45	
Coastal Renosterveld	46	
Coastal Fynbos	47	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Cymbopogon – Themeda Veld	48	**Pure Grassveld**
Transitional Cymbopogon – Themeda Veld	49	
Dry Cymbopogon – Themeda Veld	50	
Pan Turf Veld	51	
Themeda Veld or Turf Highveld	52	
Patchy Highveld to Cymbopogon – Themeda Veld	53	
Turf Highveld to Highland Sourveld Transition	54	
Bakenveld to Turf Highveld Transition	55	
Highland Sourveld to Cymbopogon – Themeda Veld	56	
North-eastern Sandy Highveld	57	
Themeda – Festuca Alpine Veld	58	
Stormberg Plateau Sweet Veld	59	
Karroid Merxmuellera Mountain Veld	60	
Bankenveld	61	**False Grassveld**
Bankenveld to Sour Sandveld Transition	62	
Piet Retief Sourveld	63	
Northern Tall Grassveld	64	
Southern Tall Grassveld	65	
Natal Sour Sandveld	66	
Pietersburg Plateau False Grassveld	67	
Eastern Province Grassveld	68	
Fynbos	69	**Sclerophyllous Bush**
False Fynbos	70	**False Sclerophyllous Bush**

False Bushveld
Moderate size patches of the False Bushveld veld type start to appear towards the eastern boundary of the Fish-Tsitsikamma WMA, and continue into the adjacent Mzimvubu-Keiskamma WMA. This veld type has a very localised distribution within South Africa, and is restricted to the Eastern Cape. False Bushveld is typically dominated by the thorn, *Acacia karoo*, and is characterised as a thorn-bushclump veld which is invading grassveld. Rainfall is moderate, ranging from 400 to 650 mm per annum.

Karoo and Karroid Bushveld
This veld type is dominant along the western boundary of the Fish-Tsitsikamma WMA, where it covers some 50 to 60% of the WMA. The flora is characteristically low, typically less than 1 m in height, and includes scrub, bushes, dwarf trees and a few grasses. Rainfall within this vegetation type typically ranges between 150 mm and 500 mm per annum, but reaches a maximum of up to 900 mm per annum in some of the river valleys. Karoo and Karroid Bushveld occurs at any altitude from sea level to 1700 m amsl.

False Karoo
This is also a dominant veld type within this WMA, occurring widely throughout the area, particularly within the northern and eastern portions of the Fish-Tsitsikamma WMA. Similar to Karoo and Karroid veld type, the False Karoo veld type is typified by low vegetation, but in contrast contains more grassy elements. The areas occupied by this veld type are typically very arid and in parts may receive less than 100 mm of rainfall per annum. This veld type generally occurs below 1200 m amsl.

Temperate and Transitional Forest and Scrub
A large patch of this vegetation type occurs towards the eastern boundary of the Fish-Tsitsikamma WMA. As the name implies, this veld type is typical of relatively temperate habitats. This general veld type includes areas of forest, grassland and fynbos. Temperate and Transitional Forest and Scrub occurs from sea level to up to 1350 m. Rainfall is typically high, ranging from 650 to 1150 mm per annum, although in may be somewhat lower within the coastal renosterveld and fynbos elements of this veld type, where it typically ranges between 300 to 500 mm per annum.

Pure Grassveld
Broad bands of this veld type occur along the northern boundary, also extending into the central portions, of this WMA. This type represents the true grassveld, and occurs on the upper plateau and the mountain tops, at altitudes ranging from 1050 to over 3050 m MSL, in regions which are too dry and/or experience frost too regularly for the development of any kind of forest. Rainfall typically ranges from 400 to 750 mm per annum. Much of this veld type has been impacted by farming activities.

False Grassveld
Two isolated patches of this veld type occur towards the east of the Fish-Tsitsikamma WMA. False Grassveld occurs on either sandy of stoney soils at altitudes ranging between 800 to 1750 m MSL. Rainfall ranges between 550 to 1150 mm per annum, typically falling in summer. Much of this veld type has been impacted by farming activities.

False Sclerophyllous Bush
This veld type occurs in a broad band towards the south of the Fish-Tsitsikamma WMA. False Schlerophyllous Bush is typically indistinguishable from true Fynbos. It is usually dominated by Asteracous elements (daisies). As for Sclerophyllous Bush, the areas occupied by the False Sclerophyllous Bush veld type are typically fairly mesic, receiving in excess of 500 mm, and up to 1500 mm, of rainfall per annum.

2.6 ECOLOGICALLY SENSITIVE SITES

2.6.1 Sensitive Ecosystems

The conservation of living resources is essential for sustaining development by: maintaining the essential ecological processes and life support systems, preserving genetic diversity and ensuring that utilisation of species and ecosystems is sustainable. However, for conservation to succeed it should be underpinned by two basis principles, namely the need to plan resource management (including exploitation) on the basis of an accurate inventory and the need to implement proactive protective measures to ensure that resources do not become exhausted. Accordingly, a vital component of ensuring sustainable conservation practices is the identification of conservation worthy habitats or sensitive ecosystems.

In terms of section 2(1) of the Environment Conservation Act (No. 73 of 1989), South Africa's schedule of protected areas was published in the Government Gazette 15726 in May 1994 (Notice 449 of 1994). This classification identifies the following sensitive or protected areas: Scientific and Wilderness Areas, National Parks and Equivalent Reserves, Natural Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas and Protected Land/Seascapes, based on their location and the functions they fulfill.

South Africa has also recognised the importance of its wetlands as sensitive ecosystems which require conservation, and accordingly has become a signatory to the international *Convention on Wetlands of International Importance especially as Waterfowl Habitat* or RAMSAR Convention. In terms of this convention signatories undertake to include wetland conservation considerations in their national land-use planning, and as far as possible to ensure the wise use of wetlands within their territory.

Before moving on to discuss ecosystems of concern to the study area it would be prudent to give some consideration to the definition of aquatic ecosystems, especially with respect to the National Water Act (No. 36 of 1998). In general terms, an ecosystem may be defined as a community of organisms and their physical environment interacting as an ecological unit. Hence, aquatic ecosystems encompass the aquatic community and water resources necessary to sustain its ecological integrity. Within the National Water Act, the water resource requirements of aquatic ecosystems are recognised and protected by the introduction of the concept of an ecological reserve *viz.* the water required to protect the aquatic ecosystem of the water resources. The Reserve refers to both the quantity and quality of the resource. Accordingly, development must take cognisance not only of the sensitivity of the receiving ecosystem but also of the resource requirements or ecological reserve of the aquatic communities it supports.

2.6.2 River Classification

The water resources of South Africa are to be protected in terms of the National Water Act (No. 36 of 1998). This will be accomplished by classifying each water resource, setting the resource quality objectives and determining the Reserve. This process had not yet been completed and therefore it was necessary to determine the present condition or present ecological status class (PESC) of the water resources so as to estimate the quantities of water required to maintain them in this condition for the purpose of the 1995 water resources situation assessment.

The water resources situation assessment has been performed at the quaternary catchment scale of resolution as described in Section 2.1. However, the delineation of these quaternary catchments was not based on ecological principles. In order to provide some ecological basis for the estimates of water requirements to maintain a particular class of river it was decided to base estimates of water requirements on an index of the ecological importance and sensitivity class (EISC) of the rivers in the quaternary catchment of concern. The ecological importance and sensitivity class of the rivers was used to derive the default ecological management class (DEMC), which relates to a default ecological status class (DESC). The default ecological status class and the present ecological status class (PESC) have been used to arrive at a suggested future ecological management class (AEMC) to be considered for the water resources. The default ecological status class would normally be assigned to a water resource on the basis of ecological sensitivity and importance. This methodology is based on the assumption that the ecological importance and sensitivity of a river would generally be closely associated with its default ecological management class and that its current ecological status and potential to recover from past ecological damage will determine the possibility of restoring it to a particular ecological management class.

This section describes the procedures and methods adopted to estimate the various status and management classes of the rivers that will be used to estimate the corresponding quantities of water required for that component of the Reserve that is necessary to protect the aquatic ecosystems according to the designated class.

The procedure that has been followed to determine the various classifications is illustrated in Diagram 2.6.2.1. The descriptions of the various ecological importance and sensitivity classes (EISC), default ecological management classes (DEMC), default ecological status classes (DESC), present ecological status classes (PESC) and the suggested future ecological management class (AEMC) are given in Diagram 2.6.2.2.

Individual assessors familiar with the ecology of a particular area or a comparable area were engaged in discussions and workshops during which a number of biotic and habitat determinants, considered important for the determination of ecological importance and sensitivity, were quantified or scored. The procedure that was followed was considered to be suitable for the situation where the delineation of the quaternary catchment units was not based on ecological considerations. The approach may however, have a low ecological sensitivity because of the absence of an ecological typing framework. The median of the scores assigned by the assessors was calculated to derive the ecological importance and sensitivity class. The assessors were then required to compare this with their overall estimation of the ecological importance and sensitivity class of the mainstem river of the quaternary catchment of concern near its outlet.

The assessors were required to record and be able to substantiate their assessments to a reasonable degree for possible review in future.

The ecological importance and sensitivity classes were either assessed during meetings or at a workshop held during 1998. This was followed by a second workshop during 1999 that was primarily concerned with the assessment of the present ecological status class, the potential to improve the ecological status class and the suggested future management class. The second workshop however, also involved an overall review of the ecological importance and sensitivity assessments determined during the original workshop.

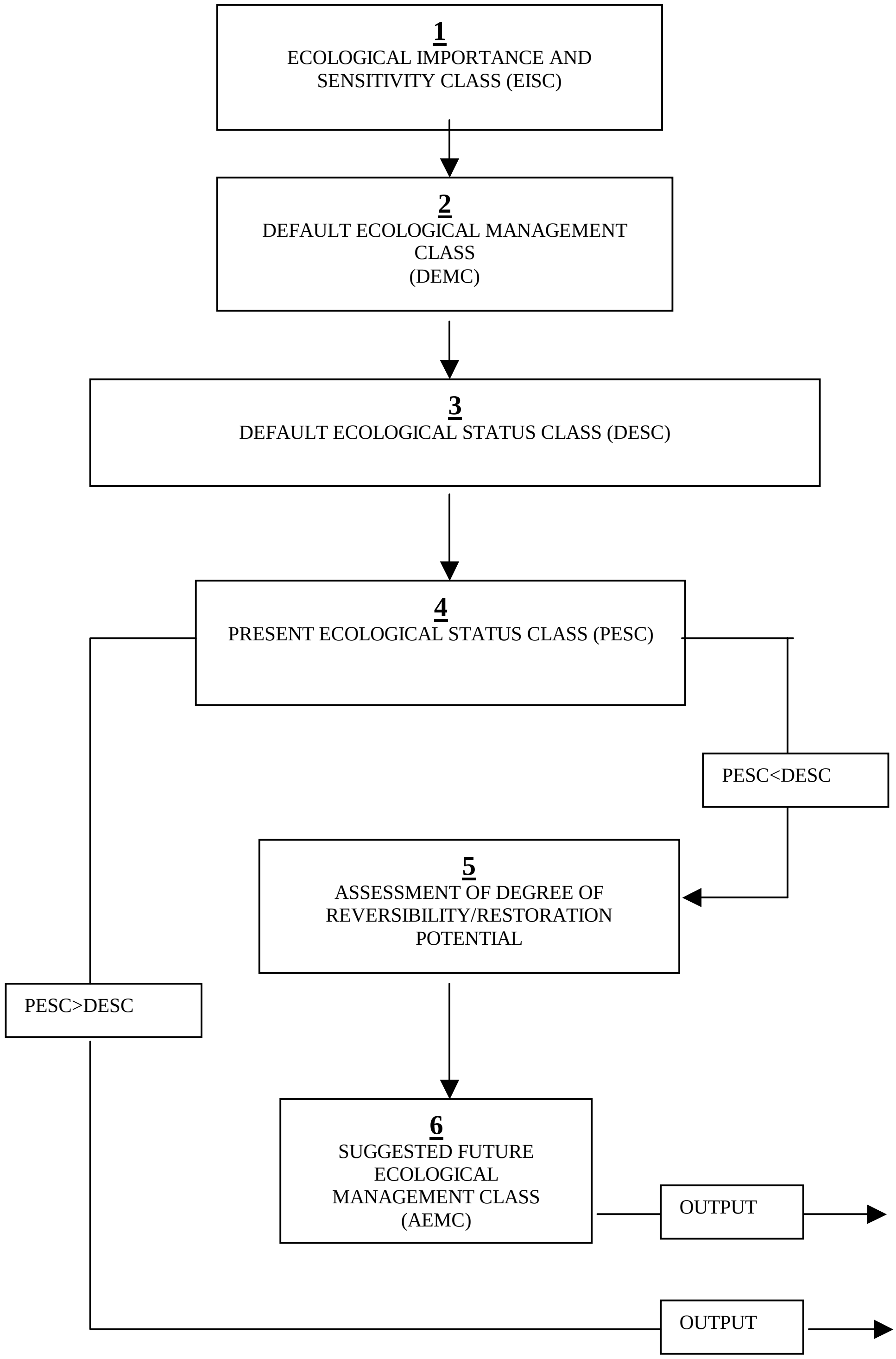

Diagram 2.6.2.1: Procedure followed to determine the river classifications

EISC		DEMC and DESC
Very high	→ No human induced hazards	→ Class A: Unmodified natural
High	→ Small risk allowed	→ Class B: Largely natural
Moderate	→ Moderate risk allowed	→ Class C: Moderately modified
Low/marginal	→ Large risk allowed	→ Class D: Largely modified

PESC	PESC: SUGGESTED ATTAINABLE IMPROVEMENT Acceptable range of AEMC:
Class A: Unmodified natural	Class A: Unmodified natural
Class B: Largely natural	Class B: Largely natural
Class C: Moderately modified	Class C: Moderately modified
Class D: Largely modified	Class D: Largely modified
Class E: Seriously modified	Class E: Seriously modified
Class F: Critically modified	Class F: Critically modified

→: indicates relationship.
▶: indicates possible direction of desirable change.

Diagram 2.6.2.2: Descriptions of EISC, DEMC DESC, PESC and AEMC

The procedure that was adopted to classify the rivers was qualified in the following respects:

- Only lotic systems (i.e. streams and rivers and associated habitats such as lotic wetlands) can be classified and the procedure is not meant to be applied to lakes, pans, impoundments or estuaries. Although several of the components considered in this assessment may be generally applicable, the application of the procedure to systems other than rivers and streams was not attempted.

- Where a quaternary catchment contained an estuary, this procedure was only applied to the riverine part of the catchment.

- Only the mainstem river in a quaternary catchment was considered in the assessment and therefore the management class must not be applied to any tributary streams in the quaternary catchment. These tributaries and their associated water requirements do however, become relevant when a water resources situation assessment is conducted at a sub-quaternary level.

- In cases where a dam wall was present at or relatively close to the outlet of a quaternary catchment, the assessments for that quaternary catchment were based on the river upstream of the dam (i.e. upstream of the backwater effect of the dam).

- In cases where degradation has occurred along certain sections of the mainstem of a quaternary catchment, but where there are still substantial less disturbed sections, the classification was based on those less disturbed areas. The intention of this was to ensure that the ecological component of the Reserve would provide for these less disturbed sections as if they were situated at the outlet of the quaternary catchment, where the ecological component of the Reserve will be estimated for the water resources situation assessments.

- The classifications were fundamentally considered from an instream and riparian zone perspective. Although the catchment in itself plays a major role in the condition and functioning of the rivers and streams in the catchment, the purpose of this procedure was not to provide an overall assessment of the condition of each catchment.

- The riparian zone has broadly been regarded as that part of the river bordering on the river channel. Usually characteristic plant species and/or vegetation structure provided an indication of the extent of the riparian zone.

The specific aspects that were considered when classifying the rivers are described below.

Ecological Importance and Sensitivity Class (EISC)
The following ecological aspects were considered for the estimation of the ecological importance and sensitivity class:

- The presence of rare and endangered species, unique species (i.e. endemic or isolated populations) and communities, species intolerant to changes in flow regime or water quality and also species diversity were taken into account for both the instream and riparian components of the river.

- Habitat diversity was also considered. This included specific habitats and river reaches with a high diversity of habitat types such as pools, riffles, runs, rapids, waterfalls and riparian forests.

- The importance of the Particular river or stretch of river in providing connectivity between different sections of the river, i.e. whether it provides a migration route or corridor for species.

- The presence of conservation or relatively natural areas along the river section serving as an indication of ecological importance and sensitivity.

- The ecological sensitivity (or fragility) of the system to environmental changes. Both the biotic and abiotic components were included.

The ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and broader scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its resilience or capability to recover from a disturbance that has occurred.

The present ecological status was not considered when determining the ecological importance and sensitivity *per se.* The ecological importance and sensitivity that has been established for the water resources situation assessments is a general and unrefined estimate. It is strongly biased towards the potential importance and sensitivity of the mainstem river of the quaternary catchment under close to unimpaired conditions.

Present Ecological Status Class (PESC)
Habitat integrity i.e. ecological integrity, condition and change from the natural condition, was regarded as a broad preliminary indicator of present ecological status for the purpose of the water resources situation assessments.

The above attributes that were used to estimate the present ecological status were each scored, from which the mean was calculated. This mean was used to assign a present ecological status class to the mainstem river in the vicinity of the outlet of the quaternary catchment.

Suggested Future Ecological Management Class (AEMC)
The potential to improve the ecological conditions was assessed only in terms of the present flow regime. Degradation of the system purely because of non-flow related changes was ignored.

The practicality of improving an existing modified ecological system to arrive at the suggested future ecological management class was assessed on the basis of the changes that have occurred, by comparing the difference between the present ecological status class and the default ecological status. For the purpose of these water resources situation assessments restoration was accepted to be the "…re-establishment of the structure and function of an ecosystem, including its natural diversity". Generally, structure is the native or natural species diversity of the ecosystem, while function is its productivity in terms of growth of plant biomass as the basis for food webs and the functions of hydrology, trophic structure and transport. Restoration is to reverse the decline of the health of a degraded ecosystem towards its historic structure. In contrast, reclamation and rehabilitation are usually more local and site-specific, while habitat creation refers to the establishment of new habitat, without regard to historical conditions.

The water resources situation assessment is, *inter alia*, concerned with the quantity of water, and therefore particular emphasis was placed on flow modification. Where the impact on the biota and the habitats of the estimated present flow modification was less than can be inferred from the present ecological status, this was taken into account and specifically highlighted (emphasised or flagged). It is obvious that such a state of affairs needs more specific attention. This situation arose only in a limited number of cases and has been indicated in the assessment of both the present ecological status class and the suggested future ecological management class, but needs more specific attention in future.

2.6.3 Aquatic Ecosystems of Concern to the Study

It is important to recognise that within the context of the current report, sensitive ecosystems refer specifically to ecosystems which are sensitive with respect to possible changes in water quantity and quality. Other sensitive ecosystems, specifically protected areas, are discussed in Section 2.6.4 below.

The Fish to Tsitsikamma WMA derives its name from the Fish River, which is the most easterly river within the WMA, and the Tsitsikamma River, located on the western boundary of this WMA. Other major rivers within this WMA include the Brak, Bushmans, Gamtoos, Groot, Kouga, Salt, Sundays and Vlekpoort rivers.

The ecological significance/ conservation importance of the river systems falling within the Fish-Tsitsikamma WMA, as exemplified by their Ecological Importance and Sensitivity Classes (EISC), is summarised in terms of associated ecological management or status classes in Figures 2.6.3.1 to 2.6.3.3. These show, respectively for each quaternary catchment, the default ecological management class, the present ecological status class, and the suggested future ecological management class. As outlined in Section 2.6.2, the EISC of a river is an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system=s ability to resist disturbance and its capability to recover from disturbance once it has occurred. The EISC leads to the DEMC shown on Figure 2.6.3.1. As evident from Figure 2.6.3.1, the river reaches within the Fish-Tsitsikamma WMA exhibit the full range of EISCs from "very high" to"low", and associated DEMCs ranging from Class A : unmodified natural, to Class D : largely modified. Many of the river reaches exhibiting a DEMC of Class A or Class B (K80A-F, K90A-C, K90E-G, L50A, L70A-G, L81A-D, L82A-H, L82J, M10A, N40A, P10A-D, P30A, P30B, P40A-D, Q60A, Q60B, Q92A-G, Q94A-F) occur within conservation areas, and any future human manipulation of these reaches would require very strong motivation. The remaining river reaches within the Fish-Tsitsikamma WMA have become modified to various degrees, largely due to anthropogenic activities, and thus exhibit an EISC of "moderate" to "low", corresponding to DEMCs of Class C : moderately modified and Class D : largely modified. The PESCs derived from the EISCs and DEMCs are shown on Figure 2.6.3.2. These were used to determine the ecological flow requirements described in Section 5.2.

This overview of the ecological significance and conservation importance of the river systems within the Fish-Tsitsikamma WMA is of necessity superficial. However, the assessment of the EISC and Default Ecological Management Class for the various Quaternary Catchments (outlined in Section 2.6.2) involved the consideration of a range of ecological determinants, including: rare and endangered biota, unique biota, intolerant biota, species richness, diversity of habitats types or features, refuge value of habitat types, sensitivity to flow changes, sensitivity to water quality changes, migration route/ corridor for instream and riparian biota and presence of conservation or natural areas. This information is summarised within DWAF's EcoInfo database (DWAF, 1999a), and accordingly this database should be consulted as a matter of course at the onset of any water utilisation and development projects, to provide insight into the ecological sensitivity of the environment which is likely to be impacted by the proposed project, particularly with respect to sensitive habitats and rare and endangered species.

The ecological sensitivity of aquatic systems other than rivers, including lakes, wetlands and groundwater systems, has to date not been assessed within the Fish-Tsitsikamma WMA. Similarly, the estuarine systems are generally not well studied, but could be ecologically important and sensitive to reduced flows and changes in water quality, especially salinity. Accordingly, it is imperative that if any future development of the water resources in the Fish-Tsitsikamma WMA is considered, a comprehensive study of these other aquatic systems, to ascertain the environmental acceptability of the development, is undertaken.

2.6.4 Natural Heritage Sites, Proclaimed Game and Nature Reserves and Wilderness Areas

As previously alluded to, the sensitive ecosystems outlined above only include those relevant to aquatic ecosystems. However, in addition to these ecosystems the Fish-Tsitsikamma WMA contains other protected areas which may be impacted directly or indirectly upon by development activities associated with water resources. These protected areas include Natural Heritage Sites as well as those areas listed in Section 2.6.1, *viz.* Scientific and Wilderness Areas, National Parks and Equivalent Reserves, Natural Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas and Protected Land/Seascapes.

Table 2.6.1 contains a list of the protected areas within the Fish-Tsitsikamma WMA. All water resource development and utilisation should take cognisance of these sites and it is the developer's responsible to identify the exact proximity of activities to any of these sites, and to ensure that activities do not threaten the integrity of these sites. This consideration is particularly pertinent where water resource development activities impact on the supply of water resources to these areas and hence their long-term ecological sustainability.

TABLE 2.6.1: PROTECTED NATURAL AREAS AND NATURAL HERITAGE SITES WITHIN THE FISH-TSITSIKAMMA WMA

AREA NAME	CATEGORY	GRID REFERENCE
Addo Elephant National Park	National Parks and Equivalent Reserves	33º 55'S 25º 50'E
Alexandria State Forest	Habitat and Wildlife Management Areas	33º 42'S 26º 25'E
Andries Vosloo Koedoe Nature Reserve	Habitat and Wildlife Management Areas	33º 08'S 26º 43'E
Auckland Nature Reserve	Habitat and Wildlife Management Areas	33º 36'S 26º 55'E
Barville Park	South African Natural Heritage Sites	33º 33'S 26º 45'E
Baviaanskloof Wilderness Area	Habitat and Wildlife Management Areas	33º 40'S 24º 15'E
Beggars Bush Nature Reserve	Habitat and Wildlife Management Areas	33º 17'S 26º 41'E
Bloukrans Coastal Forest	Habitat and Wildlife Management Areas	33º 58'S 23º 35'E
Bloukrans Main Forest	Habitat and Wildlife Management Areas	33º 56'S 23º 36'E
Blouleliesbos Main Forest	Habitat and Wildlife Management Areas	34º 01'S 24º 03'E
Boosmansbos Wilderness Area	Habitat and Wildlife Management Areas	33º 43'S 24º 55'E
Cape St. Francis Nature Reserve	Habitat and Wildlife Management Areas	34º 11'S 24º 51'E
Cockscomb State Forest	Habitat and Wildlife Management Areas	33º 42'S 24º 30'E
Commando Drift Nature Reserve	Habitat and Wildlife Management Areas	32º 07'S 26º 02'E
Cycad Nature Reserve	Habitat and Wildlife Management Areas	33º 31'S 26º 35'E
De Vasselot Nature Reserve	Habitat and Wildlife Management Areas	34º 00'S 23º 32'E
Elmhurst	South African Natural Heritage Sites	33º 34'S 26º 47'E
Faraway	South African Natural Heritage Sites	33º 20'S 26º 29'E
Finella Falls	South African Natural Heritage Sites	32º 22'S 26º 21'E
Formosa Nature Reserve	Habitat and Wildlife Management Areas	33º 55'S 24º 00'E
Fort Fordyce Nature Reserve	Habitat and Wildlife Management Areas	32º 41'S 26º 30'E
Glendower	South African Natural Heritage Sites	33º 35'S 26º 46'E
Glen Avon Falls	South African Natural Heritage Sites	32º 41'S 25º 39'E
Great Fish River Nature Reserve	Habitat and Wildlife Management Areas	33º 29'S 27º 06'E
Groendal Wilderness Area	Habitat and Wildlife Management Areas	33º 43'S 25º 18'E
Hluleka Wildlife and Marine Reserve	Habitat and Wildlife Management Areas	33º 52'S 26º 17'E
Kabeljousrivier Nature Reserve	Habitat and Wildlife Management Areas	34º 00'S 25º 56'E
Kap Rivier Nature Reserve	Habitat and Wildlife Management Areas	33º 28'S 27º 05'E
Kareedouwberg	South African Natural Heritage Sites	33º 58'S 24º 15'E
Karoo National Park	National Parks and Equivalent Reserves	32º 18'S 22º 27'E

AREA NAME	CATEGORY	GRID REFERENCE
Karoo Nature Reserve	Habitat and Wildlife Management Areas	32º 15'S 24º 30'E
Kasouga Farm	South African Natural Heritage Sites	33º 37'S 26º 45'E
Klasies River Caves	South African Natural Heritage Sites	34º 06'S 24º 24'E
Kowie Nature Reserve	Habitat and Wildlife Management Areas	33º 34'S 26º 51'E
Krom Rivier State Forest	Habitat and Wildlife Management Areas	33º 58'S 24º 15'E
Kromrivierspoort	South African Natural Heritage Sites	34º 02'S 24º 30'E
Kruisementfonetin	South African Natural Heritage Sites	32º 59'S 25º 19'E
Loeriebos Nature Reserve	Habitat and Wildlife Management Areas	33º 48'S 25º 06'E
Longmore State Forest	Habitat and Wildlife Management Areas	33º 59'S 25º 10'E
Lottering Main Forest	Habitat and Wildlife Management Areas	33º 57'S 23º 42'E
Lottering Coastal Forest	Habitat and Wildlife Management Areas	33º 59'S 23º 44'E
Mananga Cycad Colony	South African Natural Heritage Sites	31º 52'S 25º 56'E
Mountain Zebra National Park	National Parks and Equivalent Reserves	32º 14'S 25º 27'E
Mpofu Nature Reserve	Habitat and Wildlife Management Areas	32º 39'S 26º 36'E
Mtethomusha Game Reserve	Sustainable Use Area	31º 15'S 25º 25'E
Olivewoods	South African Natural Heritage Sites	32º 43'S 25º 44'E
Otterford State Forest	Habitat and Wildlife Management Areas	33º 48'S 24º 58'E
Plaatbos Nature Reserve	Habitat and Wildlife Management Areas	33º 58'S 23º 55'E
Seekoeirivier Nature Reserve	Habitat and Wildlife Management Areas	34º 05'S 24º 54'E
Silaka Wildlife Reserve	Habitat and Wildlife Management Areas	33º 43'S 25º 46'E
Stinkhoutberg Nature Reserve	Habitat and Wildlife Management Areas	33º 43' S 24º 55'E
Stormsrivier Coastal Forest	Habitat and Wildlife Management Areas	34º 01'S 23º 51'E
Stormsrivier Main Forest	Sustainable Use Area	33º 58'S 23º 51'E
Sunshine Coast Nature Reserve	Habitat and Wildlife Management Areas	33º 38'S 26º 48'E
Swan Island Nature Reserve	Habitat and Wildlife Management Areas	34º 06'S 24º 54'E
The Island Nature Reserve	Habitat and Wildlife Management Areas	33º 58'S 25º 22'E
Thomas Baines Nature Reserve	Habitat and Wildlife Management Areas	33º 24'S 26º 30'E
Thyspunt	South African Natural Heritage Sites	34º 12'S 24º 45'E
Tootabi Nature Reserve	Habitat and Wildlife Management Areas	33º 24'S 26º 30'E
Tsitsikamma National Park	National Parks and Equivalent Reserves	34º 00'S 23º 04'E
Tsolwana Game Park	Habitat and Wildlife Management Areas	32º 11'S 25º 18'E
Van Stadensberg	South African Natural Heritage Sites	33º 49'S 25º 11'E
Waters Meeting Nature Reserve	Habitat and Wildlife Management Areas	33º 25'S 26º 55'E
Witelsbos Main Forest	Habitat and Wildlife Management Areas	33º 59'S 24º 06'E
Woody Cape Nature Reserve	Habitat and Wildlife Management Areas	33º 43'S 26º 17'E

The aforementioned list of protected areas should be regarded as dynamic, since other protected areas are likely to be identified within this WMA in the future. Accordingly, it is the developer's responsibility to ensure that they are familiar with the most recent status of protected areas.

2.7 CULTURAL AND HISTORICAL SITES

Development of water supplies and services can have a negative impact on the archaeological and cultural heritage by way of development of dams, pipelines, canals, water services infrastructure and enterprises following on the provisions of water.

The National Monuments Act (No. 28 of 1969) provides for the protection and conservation of cultural resources including all archaeological sites. In addition, the Environment Conservation Act (No. 73 of 1989) provides for the integration of cultural resources into environmental management processes.

Any given development may have an impact on archaeological or cultural heritage sites. It is essential therefore that potential impacts of any water supply and services related development should be assessed at the earliest possible phase of project planning.

Permission for the development to proceed is granted by the National Monuments Council once it is satisfied that steps have been taken to safeguard archaeological or cultural heritage sites, or that they have been adequately recorded and/or sampled.

The purpose of this section is to highlight the need to take cognisance of any cultural or historical sites which may be present within the Fish-Tsitsikamma WMA and accordingly could influence the further development and utilisation of water resources within this WMA. Cultural and historical sites can be broadly defined as natural or manmade areas that are associated with human activity and history, and which carry social, cultural, religious, spiritual or historic significance. Furthermore, sites of palaeontological significance contain fossilised human or animal remains. The National Heritage Resources Act (No. 25 of 1999) provides automatic protection for palaeontological, archaeological and historical sites and materials older than 60 years, and a permit is required before any alterations can be made to such artefacts.

No general listing of the sites of palaeontological, archaeological and historical significance within the Fish-Tsitsikamma WMA is available. The South African Heritage Resources Agency (formerly the National Monuments Council) does possess a database of National Monuments within each province, but this is only of limited use since it only lists National Monuments (as declared within the Government Gazette), and the vast majority of these occur within urban areas which are unlikely to be impacted upon by water utilisation and development projects. Accordingly, it is the responsibility of the developer to liaise with the South African Heritage Resources Agency and South African Museum to establish whether they are aware of any sites of cultural/ historical/ archaeological interest within any area earmarked for development. Moreover, it is the developer's responsibility to ensure that the development area is surveyed for archaeological sites or artefacts, and that necessary steps are taken to conserve them if they are present. To this end, the developer should be familiar with the relevant sections of the National Heritage Resources Act and any other relevant legislation (*e.g.* National Parks Act (No. 57 of 1975)), and should consult with the South African Heritage Resources Agency upon discovering sites or artefacts of palaeontological, archaeological or historical significance.

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

The early development of water related infrastructure in the Fish to Tsitsikamma WMA was in the form of small water supply schemes implemented by local authorities for town water supplies and by individual farmers, or groups of farmers for the irrigation of crops.

In 1912 the Union Irrigation Department, which was the forerunner of the Department of Water Affairs and Forestry, was created. This led to the construction during the next fifteen years of a number of large dams to regulate the erratic flow of water in the rivers to provide a more reliable supply for the large scale irrigation of crops. Most of the bigger dams in the interior of the WMA were constructed during this period. Thus, Darlington Dam was completed in 1922, both Lake Arthur and Grassridge Dam in 1924, and Vanrynevelds Pass Dam in 1925.

For the next thirty years the construction of dams for irrigation relied on private enterprise and took the form of numerous small farm dams in the less arid parts of the WMA. It was not until 1956 that another large state owned dam, in the form of Commando Drift Dam, was completed to provide water for irrigation. This was followed by the completion of Beervlei Dam on the Groot River tributary of the Gamtoos River in 1957 and Kouga Dam on the other main tributary of the Gamtoos in 1964. Beervlei Dam was built primarily as a flood control structure to protect irrigated lands along the banks of the Groot and Gamtoos Rivers, but it also stores water for irrigation.

The start of construction of the Orange River Project in 1966 was the beginning of a twenty year period in which major infrastructure was developed in the WMA to convey water from the Orange River to large areas of irrigated lands, as well as to many towns, in the Fish and Sundays River basins. This infrastructure is described in Chapter 4.

In those parts of the WMA that are not served by large state owned dams, the numbers of small, privately owned farm dams constructed have increased steadily, with more than 290 registered in 1995 in terms of Dam Safety legislation (i.e. capacity more than 50 000 m^3 and wall height more than 5 m). Of these, 14% were constructed before 1950, a further 34% between 1950 and 1975, and 56% between 1975 and 1995. The oldest currently registered farm dam was constructed near Graaff Reinet in 1861.

Some of the dams constructed for town water supplies are also amongst the older dams in the WMA. Grahamstown's Milner Dam dates back to 1898, and Port Elizabeth's Sand River Dam to 1905. As the water requirements of Port Elizabeth and Grahamstown, the two biggest urban centres in the WMA, grew, additional, and generally bigger dams were built at intervals. The result is that today the Port Elizabeth/Uitenhage urban complex, now falling under the Nelson Mandela Metropolitan Municipality, obtains its water from nine local dams and the Orange-Fish Transfer Scheme, and Grahamstown obtains its water from four local dams and the Orange-Fish Transfer Scheme.

3.2 DEMOGRAPHY

3.2.1 Introduction

A national study (Schlemmer *et al*, 2001) to develop water use projections to the year 2025 was undertaken for the Department of Water Affairs and Forestry by a team of specialists, in order to support the development of the National Water Resource Strategy.

This included the development of baseline 1995 population estimates. The work commenced well before the results of the 1996 census became available, and a number of sources were used to develop the baseline data set. The database developed was subsequently reconciled with the results of the census in areas where the census had provided superior information.

The study focused on so-called functional urban centres having or likely to have reticulated water supply systems in the future. In a number of instances areas on the fringe of urban centres and classified as rural in the 1996 census were incorporated with the functional urban centres defined in the study, and urban populations identified in this study therefore differed from the urban populations enumerated in the census. The regional weighting of census counts to compensate for undercounts was also identified as a factor distorting some urban populations in smaller centres reported in the census.

3.2.2 Methodology

Functional urban areas were identified within magisterial districts. Estimates were made of the 1995 population in these centres, while the populations outside of these urban areas were grouped together as a so-called rural remainder. The urban populations were further categorised in order to provide a basis for developing estimates of urban water use for the entire country (see Section 5.3).

A number of sources and approaches were used to obtain baseline population data for the year 1995. These included projections and estimates made by the following institutions:

- The Development Bank of Southern Africa.
- The Demographic Information Bureau.
- The Bureau for Market Research.
- Local authority estimates, where available.

The data from the above sources were compared with extrapolations and estimates based on the following:

- Household counts from the sampling database held by one of the participating consultants.
- Previous census results from 1970 onwards, including former homeland censuses.
- Estimates obtained from very large surveys such as that of the SAARF.
- The database of villages of the Directorate: Water Services of the Department of Water Affairs and Forestry.

Discrepancies were reconciled on the basis of local knowledge and special enquiries directed at local authorities. The results of the 1996 census became available after this had been completed, and was used as an additional check on the database. Where discrepancies were significant these were investigated, and the database was revised where the 1996 census provided improved information.

As an overall check the population distribution database for 1995 that was developed as part of this study was projected for one year on the basis of a ruling population growth rate of 1,9%. An effective population of 42 379 000 persons in 1996 was arrived at in this way, which is only 1% above the 1996 census population of 41 945 000 persons.

A reasonable estimate of the distribution of the rural population was made, using the census results for the rural population as a guideline, to develop a spatially distributed database.

3.2.3 Historical Population Growth Rate

Accurate historical population data for the WMA as a whole is not readily available. The reason for this is that the main sources of data are the national population censuses for which published data are available in terms of magisterial districts. As the boundaries of the latter do not coincide with the boundaries of the WMA, the population of the WMA can only be roughly estimated. Nevertheless, this information can be used to obtain an indication of trends in population growth.

It appears from data extracted from population censuses and published by the Development Bank of Southern Africa (DBSA, 1991), that the average growth rate of the population in the area between 1980 and 1990 was about 2,6% per annum.

In general, urban populations increased and rural populations decreased. The exception was the arid areas in the western interior of the WMA (Pearston, Jansenville, Aberdeen, Steytlerville and Willowmore) where both urban and rural populations decreased, to give decreases in total populations of between 0,4% and 2,5% per annum. While overall population growth in the Port Elizabeth, Uitenhage and Humansdorp area was in excess of 2,6% per annum, it was between 0,5% and 2,5% in the other areas, excluding those referred to above where populations decreased.

3.2.4 Population Size and Distribution in 1995

In 1995, approximately 1 623 000 people lived in the WMA. About 1 413 000 (87%) of these lived in urban or peri-urban areas, and the remaining 13% in rural areas. The distribution of the population is shown in Table 3.2.4.1 and on Figure 3.2.4.1, where it can be seen that the population is concentrated in the Algoa Coast area (64%).

3.3 MACRO-ECONOMICS

3.3.1 Introduction

The purpose of this section is to provide an economic overview of the salient features of the Fish to Tsitsikamma Water Management Area (WMA) in terms of the following aspects:

- The present economic development of the Fish to Tsitsikamma WMA on a sectoral basis, taking into account the context of economic development in South Africa.
- The comparative advantages of the Fish to Tsitsikamma WMA.

Selected graphs are included to illustrate the text and additional supporting information is given in Appendix B.1.

TABLE 3.2.4.1: POPULATION IN 1995

CATCHMENT						POPULATION IN 1995		
PRIMARY		SECONDARY/TERTIARY		TERTIARY/QUATERNARY		URBAN	RURAL	TOTAL
No.	Description	No.	Description	No.	Description			
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	2 250	1 100	3 350
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	34 700	12 362	47 062
		TOTAL IN KROM/TSITSIKAMMA				**36 950**	**13 462**	**50 412**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12, L21, L22, L23	Western Cape Northern Cape Eastern Cape	0 0 4 600	5 146 390 300	5 146 390 4 900
		Sub-total : Upper Groot Catchment				4 600	5 836	10 436
		L3 to L7	Lower Groot	L30 - L70	All Eastern Cape	13 600	4 041	17 641
		L8	Kouga	L81, L82	Western Cape Eastern Cape	1 950 5 650	2 450 9 312	4 400 14 962
		Sub-total : Kouga Catchment				7 600	11 762	19 362
		L9	Gamtoos	L90A to C	All Eastern Cape	14 550	9 229	23 779
		Total in Groot/Gamtoos Basin in Northern Cape				0	390	390
		Total in Groot/Gamtoos Basin in Western Cape				1 950	7 596	9 546
		Total in Groot/Gamtoos Basin in Eastern Cape				38 400	22 882	61 282
		TOTAL IN GROOT/GAMTOOS BASIN				**40 350**	**30 868**	**71 218**
M	Algoa Coast	M1 M2 M3	Zwartkops Port Elizabeth Coega	M10A to D M20A, B M30A, B	All Eastern Cape	**1 015 900**	**21 784**	**1 037 684**
N	Sundays	N1 (Part)	Upper Sundays (Vanrynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0 1 450	68 1 900	68 3 350
		Sub-total : Upper Sundays				1 450	1 968	3 418
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21 - 24 N30	All Eastern Cape	48 450	6 840	55 290
		N4	Lower Sundays	N40	All Eastern Cape	16 700	21 064	37 764
		TOTAL IN SUNDAYS BASIN				**66 600**	**29 872**	**96 472**
P	Albany Coastal Catchments	P1, P2	Bushmans	P10, P20	All Eastern Cape	26 100	14 445	40 545
		P3, P4	Kowie/Kariega	P30, P40	All Eastern Cape	82 800	12 459	95 259
		TOTAL IN ALBANY COASTAL CATCHMENTS				**108 900**	**26 904**	**135 804**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12 Q13A	All Eastern Cape	10 750	3 748	14 498
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	5 400	4 380	9 780
		Q1 (Part) Q2 to 4, Q5 (Part)	Upper Middle Fish (Elandsdrift Weir)	Q14, Q21, Q22 Q13B, C, Q30, Q50A, Q44C	All Eastern Cape	46 000	9 648	55 648
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	16 500	2 162	18 662
		Q5 - Q8 (Part)	Middle Fish	Q50B, C, Q60, Q70, Q80F, G	All Eastern Cape	5 200	6 676	11 876
		Q9 (Part)	Koonap	Q92	All Eastern Cape	21 700	7 332	29 032
		Q9 (Part)	Kat	Q94	All Eastern Cape	26 050	31 443	57 493
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	15 050	22 443	37 493
		TOTAL IN GREAT FISH BASIN				**146 650**	**87 832**	**234 482**
TOTAL IN WMA IN NORTHERN CAPE						0	390	390
TOTAL IN WMA IN WESTERN CAPE						1 950	7 664	9 614
TOTAL IN WMA IN EASTERN CAPE						1 411 150	201 567	1 612 717
TOTAL IN WMA						**1 413 100**	**209 621**	**1 622 721**

3.3.2 Data Sources

The information presented has been derived from a database of macroeconomic indicators that was prepared by Urban-Econ: Development Economists from a number of sources, including the Development Bank of Southern Africa. Appendix B.2 contextualises each WMA economy in terms of its significance to the national economy, as derived from the national economic database. Only gross geographic product (GGP) and labour data are analysed. A brief description of the database of macro-economic indicators and associated economic information system is given in Appendix B4.

Gross geographic product is the total value of all final goods and services produced within the economy in a geographic area for a given period. GGP is the most commonly used measure of total domestic activity in an area and is also the basis for the national account. Changes in the local economy can therefore be expressed as an increase in GGP. Base GGP data for 1972, 1975, 1978, 1981, 1984, 1988, 1991, 1993 and 1994 were obtained from Statistics South Africa. Data for unknown years between 1972 and 1994 were interpolated using a compound growth formula. The interpolated data was balanced with national account figures. Data for 1995 to 1997 is based on weighted least squares estimates of the long-term trend, taking into account the change in electricity consumed. The projected data was balanced with national account figures. The major limitation of GGP figures is that activities in the informal sector are largely unmeasured.

The **labour** distribution provides information on the sectoral distribution of formal economic activities, as do the GGP figures, but in addition, information is provided on the extent of informal activities, as well as dependency. Dependency may be assessed from unemployment figures, as well as by determining the proportion of the total population that is economically active. *Total economically active* population consists of those employed in the formal and informal sectors, and the unemployed. *Formally employed* includes employers, employees and self-employed who are registered taxpayers. *Unemployment figures* include people who are actively looking for work, but are not in any type of paid employment, either formal or informal. *Active in informal sector* includes people who are employers, employees or self-employed in unregistered economic activities, i.e. businesses not registered as such. The labour data was obtained directly from the Development Bank of Southern Africa (DBSA). The DBSA has utilised the 1980 and 1991 population censuses as the basis but has also updated the figures utilising the 1995 October Household Surveys of Statistics South Africa (CSS statistical release P0317 for South Africa as a whole and P3017.1 to P0317.9 for the nine provinces).

The GGP and labour statistics are disaggregated into the following major economic sectors:

- Agriculture
- Mining
- Manufacturing
- Electricity
- Construction
- Trade
- Transportation
- Finance
- Government and Social Services (Community Services).

Separate GDP figures for government and social services are available. However, in the labour market these figures are combined into the community services sector. The nature and composition of each sector are described in **Appendix B.3**.

3.3.3 Methodology

Each sector of the economy was dealt with in an appropriate way to reflect a reasonable approximation of the spatial distribution of production and labour:

Agriculture
The digitised geographic layer of WMAs was merged with the Magisterial District (MD) boundaries, and the surface area for each of the newly generated polygons was determined. The proportion of the surface area of each MD, which falls within each WMA, was calculated, and that proportion was used to allocate the part of a GGP figure that falls on each side of a WMA-boundary.

Trade and Community Services
To take account of the subdivision of local authority areas by MD or WMA boundaries, the number of enumerator areas (EAs) falling within each subdivision of a local authority area, as a proportion of the total number of EAs in a local authority area, was determined. This proportion was applied to the latest population figure (1996 census) of each local authority area. As EAs are of approximately equal population size, these proportions were used to calculate the approximate population for that part of a local authority area which falls within each MD, as they are subdivided by WMA boundaries. The population of each MD segment, as a proportion of the total MD population, was used to calculate the proportion of a GGP figure which should be allocated to each segment of a MD, so that theses figures could be totalled up within the WMA boundaries.

Other Sectors
Historical factors such as the relocation of certain segments of the population to non-productive areas had to be taken into account when allocating the GGP figure to the WMAs. Subsequently, for all the sectors apart from those discussed above, only the Caucasian population was used to perform the calculations as described above. Economic activities in these sectors are less dependent on population *per se*, but are dependent on the same factors which affect the kind of population distribution that is not distorted by government intervention or other external factors. The Caucasian population has typically not been influenced by the latter factors, and its distribution is therefore a better guide for determining the distribution of economic activities in these sectors.

3.3.4 Status of Economic Development

The GGP of the Fish to Tsitsikamma WMA was R21,8bn in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are shown below:

- Port Elizabeth 69,1%
- Uitenhage 12,9%
- Albany 3,8%
- Other 14,2%

Economic Profile
The composition of the Fish to Tsitsikamma WMA economy is shown in Diagram 3.3.4.1. The most important sectors in terms of contribution to GGP are shown below:

- Manufacturing 28,3%
- Trade 18,0%
- Government 16,6%
- Finance 13,8%
- Transport 10,8%
- Other 12,5%

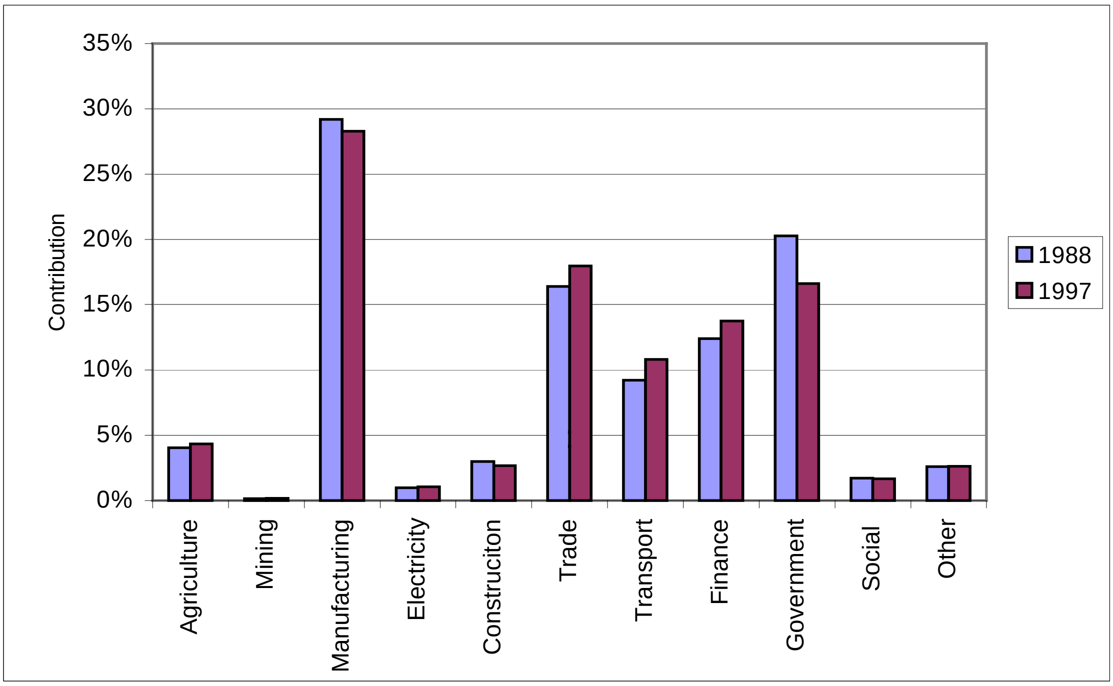

Diagram 3.3.4.1: Contribution by sector to economy of Fish to Tsitsikamma Water Management Area, 1988 and 1997 (%)

The Fish to Tsitsikamma WMA includes the fourth largest metropolitan area in the country, namely the Port Elizabeth-Uitenhage metropolis. This is the hub of motor vehicle manufacturing in the country, and the largest exporter of mohair in the world.

The automotive industry is an important industry in the Fish to Tsitsikamma WMA. For example, the Delta Motor Corporation is established in Port Elizabeth and Volkswagen is situated in Uitenhage. Several component manufacturers are also clustered around these industries, e.g. tyre, automotive glass and lighting manufacturers.

Port Elizabeth is a large centre for trade and this is bolstered further by the fact that it is an import and export harbour. Tourism is an established sector in towns like Grahamstown, where the annual arts festival takes place and Graaff Reinet, where historical buildings have been restored. On the coast tourism is also active, as the area between Natures Valley and Cape St Francis offers some of the country's most scenic coastline and rain forests. Tourism is also established in towns like Cradock, a historical settler town, and the nearby Mountain Zebra National Park. Some of the world's best surfing is available in the Jeffrey's Bay/Cape St Francis area.

Agriculture in the WMA is characterised by large farms with an average farm size of 1 551 ha. Farms near Port Elizabeth have an average size of about 400 ha and those in the hinterland about 3200 ha. Livestock farms are typically slightly larger (1647 ha) than mixed farms (1564 ha), but about four times the size of orchards and field crop farms.

The main production areas for mohair in the world are in the Western Region District, namely in the districts of Jansenville, Somerset East, Aberdeen, Willowmore, Albany and Graaff- Reinet. After the collapse of the Texan mohair industry, the Eastern Cape as a whole produces almost 60% of the world's mohair, and of this, the majority is produced in the Western Region District.

After the Free State the Eastern Cape produces the country's second biggest amount of wool, most of it in the Fish to Tsitsikamma WMA. Port Elizabeth is the only auction site for wool in the country.

Most cultivated land in the hinterland is irrigated because the rainfall is too low to rely on rain.

A great deal of citrus is grown in the Fish to Tsitsikamma WMA, especially the Sundays River Valley in the Kirkwood district, and the Gamtoos River Valley in the Hankey district. The area produces almost 50% of the country's export navel oranges. The Sundays and Gamtoos rivers also have large irrigation schemes. Most vegetables grown in the province are produced in the Gamtoos valley. Pineapples, chicory and wheat are grown in the coastal areas, pineapples being grown especially in the Bathurst area. These parts of the Eastern Cape, along with those in the Mzimvubu to Keiskamma WMA, are considered as some of the world's best pineapple-growing areas.

Major timber-growing areas occur on the Outeniqua Coast.

The strength of the transport sector could to a large extent be attributed to the Port Elizabeth harbour and airport. The airport currently handles approximately 800 000 passengers per year.

Economic Growth
The average annual growth in production by sector is shown in Diagram 3.3.4.2. The following sectors recorded the highest average annual growth rates between 1987 and 1997:

- Trade : 2,7%
- Finance : 2,1%
- Construction : 2,0%
- Manufacturing : 0,6%

The trade and tourism industry could continue this positive growth trend, with possibilities of development identified. For example, in the Valley of Desolation, nearby Graaff Reinet, plans are advanced for the establishment of a giant conservancy, which will rival the Kruger National Park in terms of size and diversity of game, with the added benefit of being malaria free. A casino has been developed in Port Elizabeth.

Further growth could be expected in the construction sector due to the housing projects initiated in the Western Region of the Eastern Cape, since 1998. Approximately 30 506 residential units must be built. In the Stormberg District, approximately 12 573 units will be built.

Although the manufacturing sector is the main economic sector in this WMA it only recorded a growth rate of 0,6% per annum. One of the possible reasons is the oversupply of automotive components in the world market. Another factor that contributed to this low growth rate is the collapse of the mohair industry centred in Port Elizabeth.

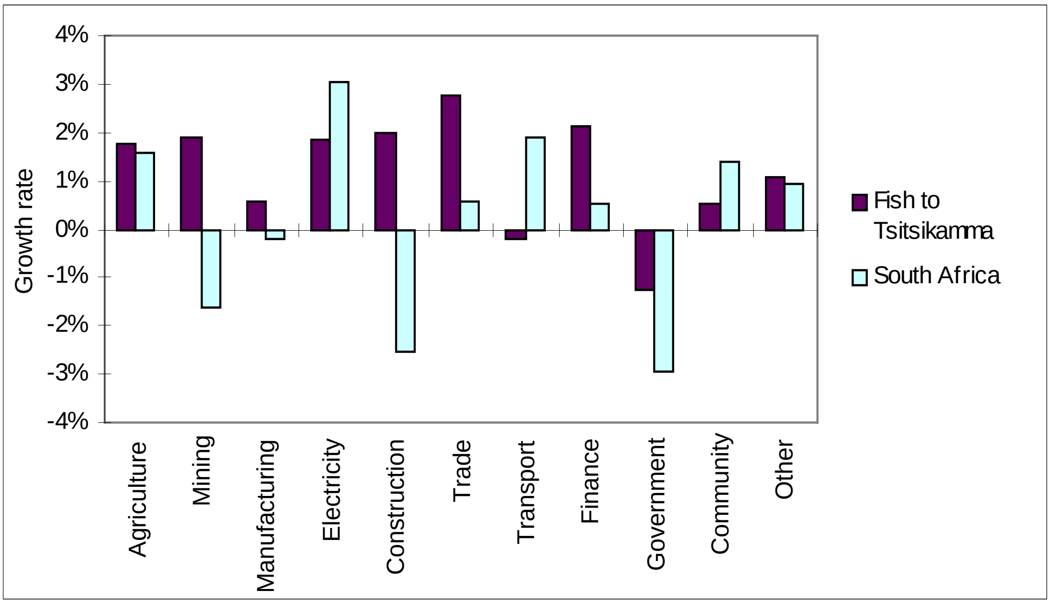

Diagram 3.3.4.2: Average annual economic growth by sector of Fish to Tsitsikamma Water Management Area and South Africa, 1988-1997

Labour

Of the total labour force of 680 000 in 1994, 39,4% were unemployed, which is higher than the national average of 29,3%. Forty five percent (44,6%) are active in the formal economy. Forty four percent (44,2%) of the formally employed labour force work for government. The second largest percentage, 21,4%, is involved in manufacturing activities, and 12% in trade.

Employment growth was recorded in the financial services (0,5% per annum); and the government sector (1,8% per annum). All the other economic sectors recorded negative annual growth rates.

3.3.5 Comparative Advantages

A geographic area is said to have a comparative advantage in the production of certain goods and services if it can produce them at a lower cost per unit than another region while maintaining the same quality. When this is the case, production of such goods tend to become relatively more concentrated in the region which has the comparative advantage. The location quotient is a measure of the relative concentration of economic activities in a region as compared with another region, or as compared with a larger region of which it forms part. A location quotient for an economic sector with a value of more than one implies that the sector contributes a larger percentage to a sub-region's GGP than that sector contributes to the larger area of which the sub-region forms part. The location quotient can, however, not be equated with comparative advantage, and provides only an indication.

Sectors in the Fish to Tsitsikamma WMA with location quotient values of greater than one are as follows:

- Manufacturing : 1,2
- Trade : 1,1
- Transport : 1,4
- Government : 1,1
- Other : 1,3

Diagram 3.3.5.1 shows the location quotients for Fish to Tsitsikamma WMA. The Figure shows that, based on the location quotients for 1997, the Fish to Tsitsikamma WMA economy is relatively more competitive than the remainder of South Africa in the following economic activities:

- Transport
- Manufacturing
- Trade
- Government
- "Other"

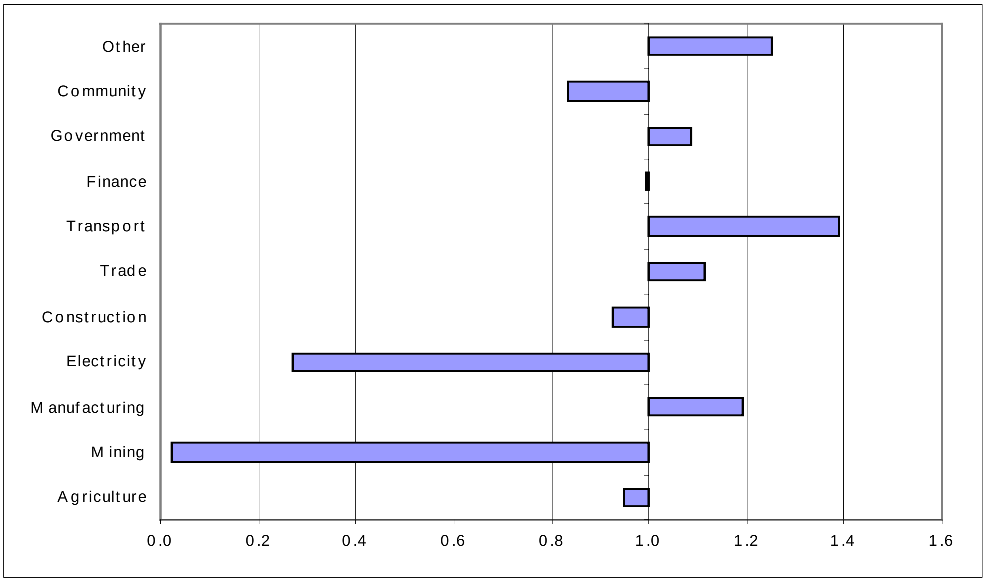

Diagram 3.3.5.1: Fish to Tsitsikamma Gross Geographic Product location quotient by sector, 1997

The comparative advantage of the manufacturing sector can largely be attributed to the presence of the automotive and related industries in the Port Elizabeth and Uitenhage area.

The comparative advantage of the trade and tourism industry is the result of the importance of Port Elizabeth as a trade centre and the tourism attractions of surrounding areas such as the Jeffrey's Bay, Graaff Reinet, Cradock and Grahamstown.

3.4 LEGAL ASPECTS AND INSTITUTIONAL ARRANGEMENTS FOR WATER SUPPLY

3.4.1 Past History

The history of settlement in southern Africa is linked to the availability and supply of fresh water. From early times South African water law was based on the needs of white settlers who in colonising the land promulgated a water law in which domestic and agriculture needs and later industrial needs played the major role (*res publica)* and the government had the function to regulate the use of water (*dominus fluminis*).

Initially Roman and Roman Dutch law had a strong influence in the shaping of South African water law and water running in rivers was regarded as common property. This changed in the latter half of the 19th century, after the occupation of the Cape by the British. The judges trained by the British introduced the principle that owners of property riparian to a river became entitled to water from that river.

The first codification of water law in South Africa was in the Irrigation and Conservation of Waters Act of 1912. The emphasis was still on irrigation and carried down the riparian principle. This Act was repealed by the Water Act of 1956, which also placed a major emphasis on the use of water for irrigation, although other water uses, such as domestic, urban and industrial, also received recognition.

This remained the situation until the National Water Act (Act No. 36 of 1998) (NWA) was assented to by the President on 20 August 1998. As from 1 October 1999 the whole of the NWA came into full effect and is now the only Act dealing with water law.

3.4.2 National Water Act

The NWA does away with and introduces some far-reaching concepts. These concepts have both economic and social features. The former to address water management by conservation and pricing strategy and the latter by ensuring that past discriminatory principles are not continued in the NWA. The most important of these can be summarised as follows:

- The riparian principle is done away with. The nation's water resources become common property, belonging to the nation as a whole. Therefore the previous concept of private ownership in water is done away with;
- The national government, through the Minister of Water Affairs and Forestry, becomes responsible as the public trustee of all water resources to ensure that water resources are protected and water allocated equitably and used beneficially in the public interest. Therefore the NWA reflects the constitutional right of access to sufficient water (Section 27 of the Constitution);
- All right to use water derives from the NWA;
- Water must be available for the Reserve. The Reserve is a new concept and consists of two legs, namely the quantity and quality of water required to satisfy basic human needs as prescribed by the Water Services Act (Act No 108 of 1997) for people who now or will in future require water and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. Thus environmental considerations are anchored in the NWA;
- Setting out in the purposes of the Act that institutions which have appropriate community, racial and gender representation must be developed to give effect to the NWA;

- Shifts the emphasis from the traditional "supply management" approach towards "demand management", that is conservation of the nation's water resources by lessening the demand and providing for an innovative pricing system.
- Providing for extensive public participation. Virtually no decision can be made without public participation;
- The abolishment of the Water Courts and introducing a Water Tribunal where administrative final decisions can be appealed to; and
- Recognition of international obligations.

3.4.3 Strategies

The NWA makes provision for establishment of two water management strategies. These are the National Water Resource Strategy and the Catchment Management Strategy. The National Water Resource Strategy is binding on the Minister of the Department of Water Affairs and Forestry, other organs of State and all water management institutions for anything contained therein, while the catchment management strategy is binding on the relevant catchment management agency and is more on a local level.

Water resource management will in future be based on the management strategies and the classification system for the protection of water resources provided for in the NWA. The contents of the National Water Resource Strategy are wide and included therein are the principles relating to water conservation and water demand management; the objectives in respect of water quality to be achieved through the classification system, as well as having to establish the future water needs. The National Water Resource Strategy will also provide for international rights and obligations.

3.4.4 Environmental Protection

Chapter 3 of the NWA deals with protection of the water resources.

The Minister must classify the nation's water resources and then determine the class and resource quality objectives for each class. This will establish clear goals for resource protection and at the same time provide for a balance between the need to protect and sustain one's water resources and the need to develop and use them on the other hand.

An important function is for the Minister to determine the Reserve, which as stated above, is closely linked to the Water Services Act (Act No. 108 of 1997).

Section 19 of the NWA provides *inter alia* that any person who is in control of land over which pollution is taking place or who causes pollution or potential pollution to take place, must take the necessary steps to prevent this from continuing. Should this not be done, the Minister shall have the right to take the necessary steps to recover the cost from the responsible person.

3.4.5 Recognition of Entitlements

The NWA abolishes the historical distinction between public and private water. There is no ownership in water and all water is subject to a licensing system, except for the following:

- Water use that is set out under Schedule 1 of the NWA;
- General authorisations issued under section 39 of the NWA; and

- Existing lawful use recognised under the NWA until such time as the person is required to apply for a licence.

The statutory difference between water resources within an area proclaimed as a government water control area in terms of the Water Act of 1956 and areas outside a government water control area has now been done away with. In actual fact the whole of the country is a government water control area.

3.4.6 Licensing

Whereas the Water Act of 1956 divided water into different categories, in the NWA all water has the same status. Section 21 of the NWA sets out what is regarded as water use. These include, amongst other uses, taking water from a water resource, storage of water, diverting water, discharging waste into a watercourse, disposing of waste in a manner that may detrimentally impact on a water resource and recreational use.

Two new concepts of water use are created. The first is that the Minister can declare any activity to be a stream flow reduction activity, if that activity reduces the availability of water. Afforestation has already been declared a stream flow reduction activity. The second new concept is that the Minister can declare any activity to be a controlled activity if that activity impacts on a water resource. Activities such as irrigation on any land with waste, recharging of an aquifer are examples of activities that are already controlled activities.

All water use requires a licence unless it falls into a Schedule 1 use (this deals with the *de minimus* use, such as water for reasonable domestic use, small gardening and animal watering (excluding feedlots); or was permissible as an existing lawful use (water use permitted under previous laws and which were exercised during the period of two years before the date that Section 32 came into effect; namely 1 October 1998); and under a general authorisation.

An important innovation is that a licence can only be for a maximum period of 40 years and is subject to a review period, which may not be at intervals of more than five years. A licence can be increased at each review period but not for more than the review period. This is known as the "revolving licence".

If a person who has an existing lawful use applies for a licence under Section 43 of the NWA (compulsory licensing), and the application has been refused or has been granted for a lesser amount which results in severe economic prejudice, the applicant may claim compensation. Compensation cannot be claimed if the reduction is to provide for the Reserve, rectify a previous over-allocation or a previous unfair allocation.

Compensation must be claimed from the Water Tribunal.

The Minister has the right to attach conditions to any licence as well as to make regulations on various topics set out in section 26 of the NWA.

3.4.7 Other Legislation

It is important to note that although the Water Services Act (Act No. 108 of 1997) deals with water services, the actual water use is controlled under the NWA.

The NWA is aligned with other laws in order to prevent, for example, duplication of applications, unnecessary expenses and where possible, a "one stop" can be issued. Specific examples are as follows:

- Environment assessments in terms of the Environmental Conservation Act of 1989 can be taken into account by the responsible authority when issuing a licence;
- If a licence is issued under other acts that meet the purpose of the NWA, the responsible authority can dispense with the issuing of a licence for water under the NWA; and
- Provisions in the Constitution of the Republic of South Africa must be complied with.

Further, there is a close connection between the Water Services Act (Act No. 108 of 1997) and the NWA.

The Abolition of Racially Based Land Measures Act repealed laws that previously restricted black persons from owning or occupying land. These acts had the effect of preventing black persons from having any water rights or under certain circumstances, limited water entitlements.

Notwithstanding the NWA there are other acts to which a water user and indeed the State must comply.

These Acts are the following:

Physical Planning Act (Act No. 125 of 1991)
Under this act no land use, development or subdivision may be permitted unless in accordance with an approved plan.

Development Facilitation Act (Act No. 67 of 1995)
This act prescribes the set of principles with which all development projects and all land use and land use planning should comply, and which will serve as guidelines for the administration of land use and development schemes.

Restitution of Land Rights (Act No. 22 of 1994)
This act is aimed at the restitution of land to those who have been deprived thereof in terms of discriminatory laws. Claims are lodged with the Land Claims Commission. It is because of this act that when a transfer of water entitlements is approved in terms of the NWA an indemnity is required from the transferor that a claim was not lodged against the land in terms of the Restitution of Land Rights Act.

Environmental Conservation Act (Act No. 73 of 1989)
This act provides for the effective protection and control of the environment. It makes provision for the declaration of an environmental conservation policy.

In terms of this act the state has a responsibility to act as trustee of the natural environment and to consider all activities which may have an influence on the environment.

Activities, which may have a detrimental effect on the environment, have been published in terms of Section 21 of this act. To undertake any of these activities, authorisation is required, which can only be obtained from the Minister of Environmental Affairs and Tourism after the prescribed procedure has been complied with. The construction of various forms of water works (dams, water diversions, water transfer schemes, etc.) are subject to the new process.

Through a consultative process a White Paper for Sustainable Coastal Development in South Africa was prepared. In terms thereof it is the joint responsibility of the Departments of Water Affairs and Forestry and of Environmental Affairs and Tourism to protect the in-shore marine environment.

In terms of this act the Department of Environmental Affairs and Tourism is responsible for issuing waste permits under this act and has published a Government Notice 1986 of 24 August 1990 relating to the identification of waste. This government notice needs drastic amendment to bring it in line with the NWA.

In May 2000 the Department of Environmental Affairs and Tourism published a White Paper on Integrated Pollution and Waste Management for South Africa. Aspects included water pollution; diffuse water pollution, marine pollution; and land pollution.

National Environmental Management Act (Act No. 107 of 1998)

This act lays a new foundation for environmental management. The act includes 20 principles that serve as a general framework within which environmental management and implementation plans must be formulated and guide any other law concerned with the protection or management of the environment. Environment is defined as the natural environment and the physical chemical, aesthetic and cultural properties of it that influence human well being.

To give effect to these principles this act creates the National Environmental Forum and the Committee for Environmental Co-ordination and defines the procedure for the establishment of a Coastal Management Subcommittee of the Committee for Environmental Co-ordination in order to achieve better inter-governmental co-ordination of coastal management.

This act provides for the drawing up of environmental implementation plans by certain scheduled national Government Departments and the Provinces. In addition, environmental management plans are to drawn up by certain national Departments. The two sets of plans do not have to be drawn up by the private sector and may be consolidated. The purpose of the plans is set out in detail and must co-ordinate and harmonise environmental policies, plans, decisions of the three spheres to prevent duplication; give effect to co-operative governance and enable monitoring the achievement.

Chapter 7 of this act relates to environmental damage, duty of care, emergencies and remediation.

Conservation of Agriculture Resources Act (Act No. 43 of 1983)

This act is to provide for control over the utilisation of the natural agricultural resources in order to promote the conservation of the soil; the water resources and vegetation and the combating of weeds and invader plants. Except for weeds and invader plants, this act does not apply to land in an urban area.

3.4.8 Institutions Created Under the National Water Act

The NWA creates various institutions, some of which are listed below.

The first are Catchment Management Agencies (CMA) and one CMA will be established in each of the Water Management Areas that have been promulgated by Government Notice 1160 of 1 October 1999 (19 in total). These will have various functions either delegated or assigned to them, thus bringing the management of water resources to the regional or catchment level. A CMA will operate via a board along the lines set out in Schedule 4 to the NWA. The composition of the board is recommended by an Advisory Committee that is established by the Minister and has the important task to recommend to the Minister proposed members who are racially, gender and community representative.

A second institution is that of Water User Associations (WUA) that will operate on a restricted local level and are in effect cooperative associations of individual water uses who wish to undertake related water activities for a mutual benefit. Irrigation Boards established under the Water Act of 1956 had until 29 February 2000 to transform into a WUA. All WUAs must have a constitution based on the lines set out in Schedule 5 to the NWA, which must be approved by the Minister. The policy of the Department of Water Affairs and Forestry is that these must also as far as possible be racially, gender and community representative.

A third institution is a body to implement international agreements. This can only be established by the Minister in consultation with the Cabinet.

A fourth body that the Minister can establish is Advisory Committees. These committees may be established for a particular purpose but can also have powers delegated to it by the Minister.

Lastly the NWA establishes a Water Tribunal where appeals against administrative decisions by the Department of Water Affairs and Forestry and CMA's can be heard. The question of compensation for loss of entitlements to use water is also to be heard in this Tribunal. Appeals on questions of law from the Tribunal are heard in the High Court.

3.4.9 Institutions Responsible for Community Water Supplies

The Water Services Act, No. 108 of 1997, deals with the provision of water supply services and sanitation services in a manner consistent with the broader goals of water resource management. The institutional structure provided for in the Act includes, in addition to the National Government, represented by the Department of Water Affairs and Forestry, the following bodies:

(i) Water Services Authorities, which are municipalities, including district or rural councils, that are responsible for ensuring access to water services.

(ii) Water Boards, which may be established by the Minister of Water Affairs and Forestry, after due consultation with stakeholders, for the primary purpose of providing water services to other water services institutions.

(iii) Water Services Committees, which may be established by the Minister of Water Affairs and Forestry to provide water services to communities within their own service areas where the Water Services Authorities having jurisdiction in the areas in question are unable to provide water services effectively.

(iv) The Provincial Government, which may take over the functions of a Water Services Committee or a Water Board, if requested to do so by the Minister of Water Affairs and Forestry.

(v) Advisory Committees, which may be appointed by the Minister of Water Affairs and Forestry to provide advice on matters falling within the scope of the Act.

The municipalities are the Water Services Authorities responsible for water services in the WMA. The municipalities were restructured in the year 2000. As this report deals with the period prior to that, mainly the institutional arrangements prior to the re-structuring are reported on here.

The Fish to Tsitsikamma WMA was fortunate in that most of the transitional local councils had the resources and the technical skills to be Water Services Authorities. Therefore, they became the Water Service Authorities responsible for the water and sanitation services of their own towns and the surrounding areas. The areas of jurisdiction of the transitional local councils are shown on Figure 3.4.9.1.

The areas that did not fall within the jurisdiction of the transitional local councils fell under the transitional regional councils that are also shown on Figure 3.4.9.1. These areas are generally nature reserves or privately owned farmland where the owners of the land are responsible for their own water supplies. In these areas, neither the transitional rural councils nor the district councils were Water Services Authorities.

In the south-eastern corner of the WMA, between the Great Fish River and the eastern boundary of the WMA, where there are areas of tribal land that were part of the former Republic of Ciskei. When the Ciskei was re-incorporated into South Africa, DWAF took over the responsibility for community water supplies in these areas, and was the Water Services Authority until the year 2001, when the responsibility passed to the new Amatole District Municipality. The boundaries of the supply area of the Amatola Water Board, which provides water services mainly in the Mzimvubu to Keiskamma WMA, have recently been extended to include this area.

3.5 LAND-USE

3.5.1 Introduction

Analysis of satellite images of the area (CSIR, 1999) has shown that land use is predominantly for rough grazing for livestock, with some 88 000 km^2, or 90% of the surface area of the WMA being used for this purpose. It is estimated (Department of Agriculture, 1994) that there were 866 000 head of livestock in the WMA in 1995, of which 61% were sheep or goats, and 36% were cattle. The satellite images show that 2 273 km^2, or 2% of the surface area of the WMA is used for Dryland cultivation of crops, but this is probably an over-estimate because the satellite images do not distinguish areas of uncultivated land within large blocks of cultivated land.

Irrigated lands occupy about 948 km^2, or 1% of the area of the WMA, and it is estimated that about 74% of the land developed for irrigation is actually irrigated in average years. Afforestation occupies 417 km^2, or 0,4% of the total area. Nature reserves cover about 3 705 km^2 (4% of the surface area of the WMA), and urban areas and rural villages together occupy 404 km^2, which is less than 0,4% of the surface area of the WMA.

The condensed area of alien vegetation is equivalent to approximately 1% of the area of the WMA.

Statistics on the main categories of land use are shown in Table 3.5.1.1 for the key areas, and the distribution of those categories of land use that are directly associated with water requirements is shown per key area on Figure 3.5.1.1.

Land use per province and per district council area is shown in Table 3.5.1.2.

3.5.2 Irrigation

Irrigated Areas

Estimates of irrigated areas and the types of crops grown under irrigation are shown for each key area in Table 3.5.2.1 and a map depicting the extent of irrigated land in each key area is shown on Figure 3.5.1.1. It is emphasised that the level of confidence in the reliability of the data is low because accurate data on areas of irrigation is not readily available.

The sources of data were the following:

- *The Surface Water Resources of South Africa 1990* (Midgley *et al*, 1994) for the Tsitsikamma Coast (K80A to K80F), part of the catchment of Beervlei Dam (L11A to L11F), the Coega Catchment (M30A, B) and the Port Elizabeth area (M20A, B).

- *The Algoa System Analysis* (DWAF, 1994a) for the catchments of Impofu and Churchill Dams (K90A to K90D), the Langkloof area (L81, L82), and the Gamtoos River valley (L90A to L90C).

- A report prepared for the Algoa Regional Services Council (Van Wyk and Louw, 1991) for part of the Tsitsikamma Coast (K90E to K90G).

- A report prepared on a catchment management strategy for the Zwartkops River (DWAF, 2001) for the Zwartkops River catchment (M10A to M10D).

- A report with the title *Marketing Potential for Irrigation Crops in Region D: Final Report* (Kassier *et al*, 1988) for most of the Groot River catchment (L12 to L70).

- A report with the title *Evaluation of Agricultural Developments: Reconnaissance Phase Draft Report* (DWAF, 1995) prepared as part of the Orange River Development Project Replanning Study. The information in this report was used for the Sundays River catchment, for the main stem of the Great Fish River, for the Little Fish River (Q80) and for the catchment of the Koonap River (Q92).

- *A report on the Kat River Basin Study* (HKS, 1990) for the Kat River catchment (Q94).

- *The Ciskei National Water Development Plan* (HKS, 1991) for the Kat River catchment (Q94) and the Lower Fish River (Q93C, D).

- The South African National Land-cover Database (CSIR, 1999) for the distribution of irrigated land between quaternary catchments along the Fish and Sundays Rivers.

TABLE 3.5.1.1: LAND USE BY KEY AREAS

CATCHMENT						LAND USE IN 1995									
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		IRRIGATION (1) (km²)	DRYLAND SUGAR CANE (km²)	OTHER (2) DRY LAND CROPS (km²)	AFFORES-TATION(3) (km²)	INDIGENOUS FORESTS (3) (km²)	ALIEN (4) VEGETATION (km²)	NATURE (5) RESERVES (km²)	URBAN/ RES(6) AREAS (km²)	ROUGH(7) GRAZING AND OTHER (km²)	TOTAL(8) AREA (km²)
No.	Description	No.	Description	No.	Description										
K	Krom/ Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	6,90	0	197	0,55	1,44	32,52	84,50	1,38	521,71	846
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F, K90E to G	All Eastern Cape	11,46	0	656	183,53	27,36	116,72	151,48	17,28	754,17	1918
		TOTAL IN KROM/TSITSIKAMMA (All Eastern Cape)				**18,36**	**0**	**853**	**184,08**	**28,80**	**149,24**	**235,98**	**18,66**	**1275,88**	**2764**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12, L21, L22, L23	Western Cape Northern Cape Eastern Cape	15,00 5,00 5,90	0 0 0	30 2 3	0,00 0,00 0,00	0,00 0,00 0,00	1,50 0,70 0,12	0,00 0,00 0,00	1,20 0,00 1,02	12211,30 3305,30 5025,96	12259 3313 5035
		L3 to L7	Lower Groot	L30 - L70	All Eastern Cape	12,60	0	32	0,00	0,00	34,39	350,10	3,74	8522,17	8955
		L8	Kouga	L81, L82	Western Cape Eastern Cape	12,00 48,02	0 0	15 105	0,00 1,82	0,00 0,00	37,40 258,93	200,00 1231,90	0,00 6,29	247,60 1889,04	512 3541
		L9	Gamtoos	L90A to C	All Eastern Cape	56,00	0	117	88,46	0,00	9,84	102,25	2,91	824,53	1201
		Total in Groot/Gamtoos Basin in Northern Cape				5,00	0	2	0,00	0,00	0,70	0,00	0,00	3305,30	3313
		Total in Groot/Gamtoos Basin in Western Cape				27,00	0	45	0,00	0,00	38,90	200,00	1,20	10658,90	12771
		Total in Groot/Gamtoos Basin in Eastern Cape				122,50	0	256	90,28	0,00	303,28	1 684,25	13,96	18061,73	18732
		TOTAL IN GROOT/GAMTOOS BASIN				**154,50**	**0**	**303**	**90,28**	**0,00**	**342,88**	**1884,25**	**15,16**	**32025,93**	**34816**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**14,50**	**0**	**305**	**60,55**	**0,00**	**113,57**	**289,91**	**240,17**	**1606,30**	**2630**
N	Sundays	N1 (Part)	Upper Sundays (Vanrynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 22,50	0 0	0 0	0,00 0,00	0,00 0,00	0,00 3,54	0,00 64,48	0,00 0,98	251,00 3330,50	251 3422
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21 - 24, N30	All Eastern Cape	145,20	0	91	0,00	0,00	20,74	107,59	11,54	12798,93	13175
		N4	Lower Sundays	N40	All Eastern Cape	126,00	0	207	0,00	0,00	11,05	552,09	7,41	3496,45	4400
		TOTAL IN SUNDAYS BASIN				**293,76**	**0**	**298**	**0,00**	**0,00**	**35,33**	**724,16**	**19,93**	**19876,82**	**21248**
P	Albany Coastal Catchments	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**13,23**	**0**	**377**	**6,28**	**0,00**	**228,93**	**278,20**	**34,43**	**4383,93**	**5322**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12 Q13A	All Eastern Cape	54,70	0	0	0,00	0,00	0,18	0,00	4,23	4264,89	4324
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	21,50	0	21	0,00	0,00	0,14	58,19	2,44	4394,73	4498
		Q1 (Part) Q2 to 4, Q5 (Part)	Upper Middle Fish (Elandsdrift Weir)	Q14, Q21, Q22 Q13B, C, Q30, Q50A, Q44C	All Eastern Cape	159,40	0	0	0,00	0,00	18,64	71,59	12,58	7782,79	8045
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	45,70	0	0	0,00	0,00	1,57	4,04	4,98	1814,71	1871
		Q5 - Q8 (Part)	Middle Fish	Q50B, C, Q60, Q70, Q80F, G	All Eastern Cape	109,30	0	1	0,00	0,00	3,49	0,04	1,15	3230,02	3345
		Q9 (Part)	Koonap	Q92	All Eastern Cape	27,08	0	35	3,07	4,27	1,24	7,30	5,56	3254,75	3334
		Q9 (Part)	Kat	Q94	All Eastern Cape	18,68	0	36	73,32	32,32 (9) (3)	21,78	19,19	18,94	1531,96	1715
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	17,63	0	33	0,00	0,00	22,45	172,30	25,52	2840,10	3111
		TOTAL IN GREAT FISH BASIN				**454,0**	**0**	**126**	**76,39**	**36,59 (9) (3)**	**69,49**	**332,65**	**75,40**	**29081,48**	**30243**
TOTAL IN WMA IN NORTHERN CAPE						5,0	0	2	0,00	0,00	0,70	0,00	0,00	3305,30	3313
TOTAL IN WMA IN WESTERN CAPE						27,00	0	45	0,00	0,00	38,90	200,00	1,20	12709,90	13022
TOTAL IN WMA IN EASTERN CAPE						916,35	0	2 215	417,58	65,39 (9) (3)	899,84	3545,15	402,55	72235,14	80688
TOTAL IN WMA						**948,35**	**0**	**2 262**	**417,58**	**65,39 (9) (3)**	**939,44**	**3745,15**	**403,75**	**88250,34**	**97023**

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1. From CSIR land-use maps (CSIR, 1999) in conjunction with listed areas obtained from DWAF Eastern Cape Regional Office. Values are the estimated maximum land areas irrigated.
2. Total cultivated areas from CSIR 1999 less irrigated areas derived as explained in Note 1.
3. From *A Handy Reference Manual on the Impacts of Timber Plantations on Runoff in South Africa* (CSIR, 1995). An area of 9 km² of indigenous forest falls within nature reserves and is not again included in the "Total Area" column.
4. WRC, 1998.
5. Measured off DWAF GIS coverage of nature reserve boundaries.
6. Built up areas from CSIR land-use maps (CSIR, 1999). Areas include rural villages in tribal areas as well as towns and smallholdings.
7. Remaining land after all other land-uses in this table had been allocated.
8. WSAM database.

NOTE : Values are reported to two decimal places for purposes of cross-checking with other values in this report. This does not mean that the values are accurate to this level.

TABLE 3.5.1.2: LAND USE BY PROVINCE AND DISTRICT COUNCIL AREA

TYPES OF LAND USE	AREAS IN EASTERN CAPE PROVINCE					AREAS IN NORTHERN CAPE PROVINCE	AREAS IN WESTERN CAPE PROVINCE			TOTAL AREA [8] (km^2)
	AMATOLA DISTRICT COUNCIL (km^2)	DRAKENSBERG DISTRICT COUNCIL (km^2)	STORMBERG DISTRICT COUNCIL (km^2)	WESTERN REGION DISTRICT COUNCIL (km^2)	TOTAL FOR EASTERN CAPE (km^2)	BO KAROO DISTRICT COUNCIL (km^2)	KLEIN KAROO DISTRICT COUNCIL (km^2)	CENTRAL KAROO DISTRICT COUNCIL (km^2)	TOTAL FOR WESTERN CAPE (km^2)	
Irrigation [1]	157	9	251	499	916	5	12	15	27	948
Dryland Sugar Cane	0	0	0	0	0	0	0	0	0	0
Other Dryland Crops [2]	57	15	100	2 043	2 215	2	36	9	45	2 262
Afforestation [3]	76	0	0	342	418	0	0	0	0	418
Indigenous Forest [3]	37 (9) [3]	0	0	28	65 (9) [3]	0	0	0	0	65 (9) [3]
Nature Reserves [5]	148	0	130	3 267	3 545	0	200	0	200	3 745
Alien Vegetation [4]	28	0	19	853	900	1	37	1	38	939
Urban Areas [6]	48	2	17	336	403	0	0	1	1	404
Other [7]	6 544	1 389	15 199	49 103	72 235	3 305	223	12 488	12 711	88 251
TOTAL AREA [8]	**7 086**	**1 415**	15 716	**56 471**	**80 688**	**3 313**	**508**	**12 514**	**13 022**	**97 023**

1. From CSIR land-use maps (CSIR, 1999) in conjunction with listed areas obtained from DWAF Eastern Cape Regional Office. Values are the estimated maximum land areas irrigated.
2. Total cultivated areas from CSIR 1999 less irrigated areas derived as explained in Note 1.
3. From *A Handy Reference Manual on the Impacts of Timber Plantations on Runoff in South Africa* (CSIR, 1995). An area of 9 km^2 of indigenous forest falls within nature reserves and is not again included in the "Total Area" column.
4. WRC, 1998.
5. Measured off DWAF GIS coverage of nature reserve boundaries.
6. Built up areas from CSIR land-use maps (CSIR, 1999). Areas include rural villages in tribal areas as well as towns and smallholdings.
7. Remaining land after all other land-uses in this table had been allocated.
8. WSAM database.

NOTE : Values are reported to two decimal places for purposes of cross-checking with other values in this report. This does not mean that the values are accurate to this level.

TABLE 3.5.2.1: IRRIGATION LAND USE

CATCHMENT						TOTAL [1] IRRIGATED LAND AREA (km^2)	TOTAL AREA OF CROPS (km^2)	LAND AREA IRRIGATED IN AVERAGE YEARS (km^2) [2]								
PRIMARY		SECONDARY		TERTIARY/QUATERNARY				LUCERNE	MAIZE	VEGE-TABLES	PASTURE	CITRUS	WHEAT	DECID. FRUIT	OTHER CROPS	TOTAL
No.	Description	No.	Description	No.	Description											
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	6,9	6,9	-	-	0,2	5,7	-	-	1,0	-	6,9
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	11,5	11,5	-	-	-	-	-	-	-	11,5	11,5
		TOTAL IN KROM/TSITSIKAMMA				**18,4**	**18,4**	**-**	**-**	**0,2**	**5,7**	**-**	**-**	**1,0**	**11,5**	**18,4**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	15,0 5,0 5,9	15,0 5,0 5,9	5,8 1,9 2,3	- - -	- - -	- - -	- - -	- - -	- - -	0,6 0,2 0,3	6,4 2,1 2,6
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	12,6	14,5	10,0	-	-	-	-	-		2,6	12,6
		L8	Kouga	L81, L82	Western Cape Eastern Cape	12,0 48,0	12,0 48,0	- -	- -	- -	- 10,0	- -	- -	12,0 29,4	- 8,6	12,0 48,0
		L9	Gamtoos	L90A to C	All Eastern Cape	56,0	74,6	7,0	-	33,6	-	12,3	-	-	3,1	56,0
		Total in Groot/Gamtoos Basin in Northern Cape				**5,0**	**5,0**	**1,9**	**-**	**-**	**-**	**-**	**-**	**-**	**0,2**	**2,1**
		Total in Groot/Gamtoos Basin in Western Cape				**27,0**	**27,0**	**5,8**	**-**	**-**	**-**	**-**	**-**	**12,0**	**0,6**	**18,4**
		Total in Groot/Gamtoos Basin in Eastern Cape				**122,5**	**143,0**	**19,3**	**-**	**33,6**	**10,0**	**12,3**	**-**	**29,4**	**14,6**	**119,2**
		TOTAL IN GROOT/GAMTOOS BASIN				**154,5**	**175,0**	**27,0**	**-**	**33,6**	**10,0**	**12,3**	**-**	**41,4**	**15,4**	**139,7**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	14,5	14,5	1,1	-	11,6	1,8	-	-	-	-	14,5
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld's Pass Dam)	N11, N12	Western Cape Eastern Cape	0,0 22,5	0,0 22,5	- 8,0	-	- -	- -	- -	- -	- -	- 1,0	0,0 9,0
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	145,2	145,2	40,0	7,0	2,3	-	3,9	-	-	1,1	54,3
		N4	Lower Sundays	N40	All Eastern Cape	126,0	126,0	25,0	-	25,0	-	76,0	-	-	-	126,0
		TOTAL IN SUNDAYS BASIN				**293,7**	**293,7**	**73,0**	**7,0**	**27,3**	**-**	**79,9**	**-**	**-**	**2,1**	**189,3**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	13,2	13,2	-	-	-	-	-	-	-	6,6	6,6
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	54,7	63,3	23,6	4,0	-	6,0	-	6,0	-	-	39,6
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	21,5	23,0	9,6	2,0	2,0	-	-	2,0	-	-	15,6
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir)	Q14, Q21, Q22, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	159,4	175,7	65,3	14,0	-	18,0	-	18,0	-	-	115,3
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	45,7	48,5	20,1	3,0	-	5,0	-	5,0	-	-	33,1
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	109,3	120,1	47,1	8,0	-	12,0	-	12,0	-	-	79,1
		Q9 (Part)	Koonap	Q92	All Eastern Cape	27,1	27,1	18,0	-	-	-	-	-	-	1,6	19,6
		Q9 (Part)	Kat	Q94	All Eastern Cape	18,7	18,7	2,0	-	-	-	11,5	-	-	-	13,5
		Q9 (Part)	Lower Fish	Q91A to C Q93A to D	All Eastern Cape	17,6	17,6	10,1	2,5	0,5	-	-	-	-	-	13,1
		TOTAL IN GREAT FISH BASIN				**454,0**	**494,0**	**197,6**	**31,5**	**2,5**	**41,0**	**11,5**	**43,0**	**-**	**1,6**	**328,7**
TOTAL IN WMA IN NORTHERN CAPE						**5,0**	**5,0**	**1,9**	**-**	**-**	**-**	**-**	**-**	**-**	**0,2**	**2,1**
TOTAL IN WMA IN WESTERN CAPE						**27,0**	**27,0**	**5,8**	**-**	**-**	**-**	**-**	**-**	**12,0**	**0,6**	**18,4**
TOTAL IN WMA IN EASTERN CAPE						**916,3**	**976,8**	**291,0**	**38,5**	**75,2**	**58,5**	**103,7**	**43,0**	**30,4**	**36,4**	**676,7**
TOTAL IN WMA						**948,3**	**1008,8**	**298,7**	**38,5**	**75,2**	**58,5**	**103,7**	**43,0**	**42,4**	**37,2**	**697,2**

1. Maximum areas irrigated when sufficient water is available.
2. Estimates of average areas of land irrigated were made in consultation with officials of the DWAF Eastern Cape Regional Office. The estimates are at a low level of confidence.

In most of the references the information on areas of irrigated land were not provided for individual quaternary catchments. Therefore, for the purposes of this study, areas were allocated to quaternary catchments in the ratios of the length of the main river course in each quaternary catchment to the sum of the lengths of the main river courses in the area under consideration. The exceptions to this procedure were those quaternary catchments for which specific data were available, and the catchments along the Fish and the Sundays River where water imported from the Orange River is used.

In the case of the Fish and Sundays River quaternary catchments supplied from the Orange River, the areas of land scheduled in individual irrigation districts were obtained from the DWAF Eastern Cape Regional Office in Cradock and allocated to quaternary catchments in proportion to the areas of irrigated land shown on the CSIR land-use maps (CSIR, 1999).

In consultation with officials of the DWAF Eastern Cape Regional Office in Cradock, some minor adjustments were made to the areas obtained from the sources described above to obtain the maximum irrigated areas shown in the column headed "Total Irrigated Land Area" in Table 3.5.2.1. These values are estimates of the maximum areas irrigated when sufficient water is available in the rivers and dams. Owing to the high annual variability of rainfall over most of the Fish to Tsitsikamma WMA, the volume of water required to irrigate the total area of land developed for irrigation is not available every year.

The section of Table 3.5.2.1 headed "Land Area Irrigated in Average Years" shows estimates, made in consultation with officials of the DWAF Regional Office in Cradock, of the average areas of land irrigated in each key area in the "Total" column on the right hand edge of the table. The other columns show the approximate areas of different types of crops grown. These values were derived using information on crop mixes contained in the references referred to above, and should be regarded as being only indicative of the true situation.

In the Groot/Gamtoos River Basin double cropping occurs on about 20 km^2 of irrigated land and on about 40 km^2 of land in the Fish River Basin. The column in Table 3.5.2.1 headed "Total Area of Crops" gives an indication of the maximum areas of crops grown when double cropping is allowed for. It has been assumed that in the Fish River Basin all the double cropping occurs on land irrigated with water imported from the Orange River and that the distribution of double cropping is in the same pattern as the area of irrigated land. The distribution of different types of crops assumes that, where double cropping occurs, crops of the same category are grown, so that no piece of land is used to produce two different categories of crops in one year. This may not be the case in practice.

It can be deduced from Table 3.5.2.1 that the area of land irrigated in average years is about 74% of the total area that is irrigated when there is sufficient water. In some areas, such as the Upper Sundays River catchment, less than 50% of the total area is irrigated on average, whereas the area irrigated remains constant from year to year in other areas such as the Gamtoos River valley. The reasons for these differences are discussed below, where irrigation practices in the different key areas are described.

Irrigation Methods

Irrigation methods vary widely throughout the WMA. Flood irrigation is widely used for Lucerne and pastures, while more sophisticated methods are generally used for high value crops such as citrus orchards.

Descriptions of irrigation practices in the various areas of the WMA follow.

The Fish River Basin

The Fish River Basin covers an area of some 30 000 km^2 within which there is considerable variation in climate and topography and, consequently, in irrigation practices. Therefore, for purposes of describing irrigation practices, it has been divided into the Upper Fish Catchment, the Tarka River Catchment, the upper Middle Fish Catchment, the Upper Little Fish Catchment, the Middle Fish Catchment, the Lower Fish Catchment, the Koonap River Catchment, and the Kat River Catchment.

With the exception of the last two catchments mentioned, they all receive water from the Orange River via the Orange-Fish Transfer Scheme, which is described in Chapter 4. Irrigation in the Koonap and Kat River catchments relies on water from local sources.

In the areas that receive water from the Orange River, approximately 350 km^2 of land is scheduled under the Orange-Fish Transfer Scheme. However, according to officials of the DWAF Eastern Cape Regional Office in Cradock, only about 200 km^2 is irrigated every year. In determining the average irrigated areas shown in Table 3.5.2.1, it has been assumed that 30% of the rest of the scheduled area is irrigated each year, on average, and that this pattern applies throughout the area. These assumptions need to be verified to improve the level of confidence in information on irrigation land-use and the estimates of water requirements derived from the land-use data. (Investigations carried out for the Orange River Development Project Replanning Study (DWAF, 1995) concluded that more than the scheduled area of land was irrigated upstream of Elandsdrift Weir and slightly less downstream, giving a total irrigated area of some 370 km^2 as opposed to the average of 295,6 km^2 shown in Table 3.5.2.1 for the Great Fish River Basin excluding the Koonap and Kat key areas).

- **The Upper Fish Catchment**

  The catchment of the upper portion of the Great Fish River is, for purposes of this discussion, considered to be the area upstream of Grassridge Dam (tertiary catchments Q11 and Q12 and quaternary catchment Q13A). It covers an area of 4 324 km^2. Mean annual rainfall is between 300 mm and 400 mm except along the north-eastern edge, where it increases to between 400 and 500 mm.

  The geological strata comprise mudstones and sandstones of the Karoo Group, intruded by dolerite dykes and sills, leading to a topography of wide plains with low hills.

  Land-use is predominantly for rough grazing for livestock, particularly sheep, which thrive in the area. There is intensive cultivation of land in the valleys of the Teebus Spruit and the main stem of the Great Fish River (Q12C, Q13A). Some 47 km^2 of land is scheduled for irrigation using water transferred from Gariep Dam on the Orange River, but it has been assumed that 28 km^2 are irrigated every year. The remaining 19 km^2 together with an additional 16 km^2 of land irrigated from local sources of water has been assumed to be irrigated for about 30% of the time, bringing the average area irrigated to 40 km^2. Crops grown are lucerne (68%), wheat, oats and vegetables, mainly under flood irrigation.

- **The Tarka River Catchment**

  The Tarka River is one of the main tributaries of the Fish River and its catchment upstream of Lake Arthur covers an area of 4 498 km^2 (tertiary catchments Q41, Q42, Q43 and quaternary catchments Q44A and Q44B). Rainfall is low, the mean annual precipitation ranging from 540 mm (Q41A) to 320 mm (Q44B).

Land is used predominantly for cattle and sheep ranching, but lucerne and small quantities of maize, wheat, oats and vegetables are grown under flood irrigation along the lower reaches of the catchment (Q14D, Q44A and B). The maximum area of land irrigated is about 21 km^2, with an average area of about 16 km^2.

- **The Upper Middle Fish Catchment**
  For purposes of this discussion, the upper Middle Fish River catchment is defined as the catchment of Elandsdrift Weir, excluding the catchments of Lake Arthur and Grassridge Dam. The area of 7 307 km^2 includes catchments Q13B, Q13C, Q14A to Q14E, Q21A and Q21B, Q30A to Q30E, Q50A and Q44C.

  Along the main stem of the Fish River some 141 km^2 of land is scheduled for irrigation from canals carrying water imported from the Orange River and it has been assumed that about 87 km^2 of this is irrigated each year. Crops grown (DWAF, 1995) are lucerne (60%), wheat (15%), pasture (15%) and maize (10%). A further 8,85 km^2 is scheduled under Commando Drift Dam. About 10 km^2 is irrigated along tributaries from local sources. This area, together with 54 km^2 of land scheduled for Orange River water has been assumed to be irrigated for 30% of the time, on average. This gives an average irrigated area of 115 km^2.

- **The Upper Little Fish Catchment**
  The Little Fish River, which has a catchment of 1 871 km^2, rises in the arid area (Q80A, Q80B) to the south-west of Cradock. Land-use in the upper reaches of its catchment (Q80A, B, C and D) is mainly for rough grazing for sheep, mohair goats and cattle ranching. In the lower portion of catchment Q80D, and further downstream to De Mistkraal Weir (Q80E), there is intensive irrigation using water imported from the Orange River. A total of 46 km^2 of land is scheduled for irrigation in this area. It has been assumed that 28 km^2 is irrigated every year with the reminaing 18 km^2 irrigated for 30% of the time on average, bringing the average irrigated area to 33 km^2. As in the case of the Middle Fish Catchment, the main crop is lucerne, which accounts for about 60% of the irrigated area, with wheat, pasture and maize making up the balance. Application is by flood irrigation.

- **The Middle Fish Catchment**
  The Middle Fish Catchment, defined as the area between Elandsdrift Weir and the confluence of the Little Fish and Great Fish Rivers, including the catchment of the Little Fish River below De Mistkraal Weir, covers an area of 3 345 km^2. It includes catchments Q50B and Q50C, Q60A to Q60C, Q70A to Q70C, Q80F and Q80G. An area of 143 km^2 of land is scheduled for irrigation from canals carrying water imported from the Orange River. It has been assumed that only 109 km^2 of this has been developed and only 66 km^2 is irrigated every year and that the remaining 43 km^2 is irrigated for 30% of the time, bringing the average to 79 km^2. Crops grown (DWAF, 1997a) are Lucerne (60%), wheat (15%), pasture (15%) and maize (10%).

- **The Lower Fish Catchment**
  The Lower Fish River Catchment, defined as extending from downstream of the Little Fish River confluence (Q91A) to the sea (Q93D), has an area of 3 111 km^2.

  Between the confluences with the Great Fish River of the Little Fish and the Koonap Rivers (Q91A, B, C) the land is used mainly for cattle ranching. About 13 km^2 of land is irrigated in this area (DWAF, 1999a), using water abstracted from the Fish River. Crops grown are mainly lucerne and pasture.

The land on the western side of the river downstream of the Koonap confluence (Q93A) comprises freehold commercial farms, used mainly for raising cattle and for dairy farming. Approximately 0,06 km^2 of land is irrigated using water imported from the Orange River. The main crop is lucerne.

The land on the eastern side of the river was formerly part of the Ciskei Republic and is used mainly for subsistence agriculture. In addition, about 4 km^2 of land in this area is cultivated by small scale farmers using water pumped from the Fish River for irrigation. Crops grown (DWAF, 1997) are lucerne (60%), maize (20%) and mixed vegetables (20%).

The total area of land scheduled for irrigation using Orange River water in the Lower Fish catchment is 3,75 km^2. In addition, authorisations have been issued for water pumped from the Fish River to be used on 12,95 km^2 of land. The average area irrigated has been assumed to be 13 km^2.

- **The Koonap River Catchment**
  The Koonap River, with a catchment area of 3 334 km^2, rises in the Winterberg Mountains (Q92A, B, C) where the mean annual precipitation is about 600 mm and flows into the lower reaches of the Great Fish River in a drier area (Q92G) where the mean annual precipitation is 466 mm. The land is used mainly for cattle, sheep, and mohair goat farming.

  A maximum of approximately 27 km^2 (DWAF, 1999b) of land is irrigated directly from the rivers or from farm dams. The average area irrigated is estimated to be approximately 20 km^2. The predominant crop is lucerne.

The Kat River Catchment
The Kat River Catchment, with mean annual precipitation ranging from 804 mm in its upper reaches (Q94A) to 480 mm in the vicinity of its confluence with the Great Fish River (Q94F), is the wettest part of the Fish River Basin. The area of the catchment is 1 715 km^2, and land use is predominantly for livestock farming. However, the Kat River Dam (Q94A), in conjunction with run of river flow further downstream, provides water for the irrigation of 18,7 km^2 of land, of which 13,5 km^2 is under citrus orchards (Q94B, C, D and F). Of this, about 7,4 km^2 is worked by small-scale farmers, and the remainder by larger commercial farming enterprises (DWAF, 1999b).

The Bushman's/Kowie/Kariega River Catchment
The catchments of the Bushman's River (P10A to G), the Kowie River (P40A to C), the Kariega River (P30A to C) and the adjacent coastal catchments (P40D, P20A, P20D), cover an area of 5 322 km^2. The mean annual precipitation ranges from a minimum of 430 mm in the north-western interior (P10D) to a maximum of 715 mm (P20A) at the coast.

Land-use is predominantly for rough grazing for cattle, mohair goats and sheep, but pineapples are grown on a large scale without irrigation along the coast (P20A, P30C, P40C), where chicory is also extensively grown as a dryland crop. It is estimated (DWAF, 1999) that a maximum of about 13 km^2 of land is irrigated from farm dams and run of river flow when sufficient water is available. The areas irrigated vary from year to year, depending on availability of water, with the average being about 6,6 km^2.

The Sundays River Basin

The Sundays River Basin covers an area of some 21 250 km^2, most of which is situated in the arid Great Karoo. (Tertiary catchments N11, N12, N13, N14, N21, N22, N23, N24 and N30). The mean annual precipitation in this area is generally between 250 and 350 mm, and land-use is mainly for sheep and mohair farming.

- **The Upper Sundays Catchment**
  The upper Sundays Catchment, defined as the catchment area of Vanrynevelds Pass Dam, covers an area of 3 673 km^2 comprising tertiary catchments N11 and N12. It is estimated by officials of the DWAF Eastern Cape Regional Office that a maximum area of land of 22 km^2 is irrigated when there is sufficient water available, but the average area irrigated is about 9 km^2. Crops grown are mainly lucerne and other fodder crops.

- **The Middle Sundays Catchment**
  An area of 3 380 ha of land along the middle reaches of the Sundays River (N13C, N21A, N24B) is scheduled for irrigation using water from Van Rynevelds Pass Dam (N12C), but there is insufficient water available to maintain a reasonable assurance of supply, and in some years virtually no land is irrigated because of a lack of water (DWAF, 1997a). Crops grown when water is available are lucerne, other fodder crops, maize and vegetables. Van Rynevelds Pass Dam, together with the allocations of water from it, was sold to Graaff-Reinet Municipality in 2000 and the water will in future be used for urban supplies.

  Water is transferred from the Orange River via the Fish River to Darlington Dam (N23B), and there is intensive cultivation of irrigated lands along the transfer route (N23A, N23B). The total area scheduled in 1995 was 3,18 km^2. Crops grown are citrus (60%), lucerne (20%) and vegetables (20%).

  In years when there is sufficient water from local sources, a considerable amount of irrigation occurs and an area of about 145 km^2 of land is irrigated in the Middle Sundays Catchment, but it is estimated by officials of the DWAF Eastern Cape Regional Office that only about 37% of this area, or 54 km^2, including the scheduled area of 3,18 km^2, is irrigated on average.

- **The Lower Sundays Catchment**
  Along the Sundays River downstream of Darlington Dam (N40A to N40F), water from the Orange River is distributed by canal to 126 km^2 of irrigated land. Crops grown are citrus (60%), lucerne (20%) and vegetables (20%). This area is irrigated every year.

The Algoa Coast

The catchment of the Zwartkops River (M10A to D) and the adjacent coastal catchments (M30A, B and M20A, B) cover an area of 2 630 km^2 and contain the Port Elizabeth/Despatch/Uitenhage urban complex. The lower reaches of the Zwartkops Catchment (M10C, D) are heavily impacted by urban development, but mixed farming is practised on the fringes of the urban areas. It is estimated (DWAF, 2001) that about 1,8 km^2 of land is irrigated, mainly under pasture, in Catchment M10D, using treated sewage effluent direct from the treatment works, or water from the Zwartkops River.

Upstream of Uitenhage (M10C), about 4,3 km^2 is irrigated using groundwater and compensation water released from Groendal Dam (M10A). An additional 2,3 km^2 is irrigated from farm dams and run of river flow along the Elands River tributary of the Zwartkops River (M10B). Crops grown are mainly various types of vegetables and lucerne.

The 265 km^2 area upstream of Groendal Dam is a proclaimed wilderness area.

In the remaining catchments (M20A, B and M30A, B), about 6 km^2 of land, mainly under vegetables, is irrigated using groundwater.

The area of land irrigated in the Algoa Coastal Catchments remains fairly constant from year to year.

The Groot/Gamtoos River Basin
The basin of the Gamtoos River and its two major tributaries, the Groot River and the Kouga River, can conveniently be sub-divided into the catchments of the three rivers for purposes of describing irrigation practices.

- **The Groot River Catchment**
  The catchment of the Groot River (tertiary catchments L11, L12, L21, L22, L23, L30, L40, L50, L60, L70) lies entirely in the Karoo, where it covers an area of 29 560 km^2. The area is dry, with mean annual precipitation being less than 300 mm over most of the catchment, but ranging from a minimum of 152 mm (L12C) in the interior to a maximum of 500 mm at the lower end. The land is used mainly for rough grazing for sheep, but, when there is enough water, approximately 26 km^2 of land is irrigated along the rivers upstream of Beervlei Dam, where the crops grown are mainly lucerne and other fodder types. It is estimated that the average area irrigated is 11 km^2. Along the main stem of the Groot River downstream of Beervlei Dam (L30C, L30D, L50B, L70B), 8 km^2 of land is irrigated, and a further 5 km^2 is irrigated along the tributaries. The total area irrigated in the Groot River Catchment when there is sufficient water is approximately 39 km^2, and officials of the DWAF Eastern Cape Regional Office estimate that about 24 km^2 is irrigated on average. All the land downstream of Beervlei Dam is irrigated in most years and some 2 km^2 is used for double cropping.

- **The Kouga River Catchment**
  The Kouga River, with a catchment area of 4 053 km^2, rises in the Langkloof (L82A, B, C and D), where the mean annual precipitation is 582 mm, but rainfall in the mountains that flank the valley is considerably higher. The fertile soil of the valley floor is intensively cultivated, 41,44 km^2 of deciduous fruit orchards and a small area of pasture being grown under irrigation, using water stored in a large number of farm dams (DWAF, 1994a).

  The main tributary of the Kouga River is the Baviaanskloof River which rises in a narrow valley (L81A, B, C, D) running parallel to the Langkloof. The mean annual precipitation in this valley is 448 mm. The upper portion of the valley (L81A, B, C) is a nature reserve, but some land (1,0 km^2) is irrigated in these catchments. Presumably because of a lack of suitable soils, only 0,4 km^2 of land is irrigated in the lower portion of the valley (L81D), bringing the total irrigated area to 1,4 km^2, which is mainly under pasture. In the catchment of the Kouga River itself, downstream of the Langkloof (L82E to L82J) about 17 km^2 of land is irrigated. The total irrigated area in catchments L81A, B, C, D and L82G, H, J, is estimated to be 18,4 km^2.

- **The Gamtoos River Catchment**
  The Groot and Kouga Rivers join to form the Gamtoos River where the Groot River emerges from a narrow valley through the Baviaanskloof Mountains (L90A). An area of 56 km^2 of land in the river valley downstream (L90A, L90B, L90C) is irrigated from canals which carry water from Kouga Dam (L82G) and Loerie Dam (L90E). Crops grown are vegetables (60%), citrus (22%), lucerne and tobacco. Double cropping is practised on about 18 km^2 of land.

The Upper Krom River Catchment
The Krom River upstream of Impofu Dam drains a narrow valley (K90A, B, C, D) between the Tsitsikamma Mountains and the Suuranys Mountains.

The Krom River is regulated by the Churchill Dam (K90B) and the Impofu Dam (K90E). The valley (K90A, B) upstream of Churchill Dam is an extension of the Langkloof and is intensively cultivated. Areas of 1,0 km^2 of deciduous fruit orchards, 2,17 km^2 of pasture, and 0,2 km^2 of vegetables are irrigated from farm dams and from water abstracted directly from the river (DWAF, 1994a).

Downstream of Churchill Dam, in the catchment (K90C, K90D) of Impofu Dam, 3,53 km^2 of pasture are irrigated, partially from farm dams and partially from run of river flow (DWAF, 1994a).

Thus, the total area of land irrigated in the Upper Krom Catchment is 6,9 km^2, all of which is irrigated in most years.

The Tsitsikamma Coastal Catchments
For the purposes of this report, the Tsitsikamma Coastal Catchments are defined as those that incorporate the southern side of the Tsitsikamma Mountains and drain into the Indian Ocean (K80A, B, C, D, E and F) and the lower part of the Krom River Catchment (K90E, F, G). They cover an area of 1 918 km^2 and the mean annual precipitation is 937 mm.

Catchments K80A to E are heavily afforested. There are also large areas of indigenous forest and much of the land in catchments K80A, B, C and D falls either within the Tsitsikamma Forest Reserve, or the Coastal National Park. The remaining land is used mainly for mixed farming. It is estimated (Midgeley, *et al*, 1994) that about 6,6 km^2 of land is irrigated from diffuse sources in the area. The CSIR land-use maps (CSIR, 1999) show a smaller area of irrigated land and, for the purposes of this assessment, an area of 5,1 km^2 has been assumed. Catchment K80F consists of flatter land to the east of the Tsitsikamma Mountains. There is no significant afforestation in this catchment and land is used mainly for mixed farming. In 1991 an area of 2,0 km^2 of land was irrigated from Klippedrif Dam in the catchment. The irrigated area was expected to increase eventually to 5,95 km^2 (Van Wyk and Louw, 1991), but, according to officials of the DWAF Eastern Cape Regional Office, this has not occurred and the irrigated area remains at 2,0 km^2.

In Catchments K90E, F, G, land is used mainly for mixed farming and about 4,4 km^2 of land (Van Wyk and Louw, 1991) is irrigated from diffuse sources of water.

Thus, the total area of land irrigated in 1995 is estimated to have been 11,5 km^2, but the reliability of this estimate is not known.

3.5.3 Dryland Farming

The area of Dryland cultivation in the WMA is estimated to be 2 273 km^2. This estimate was derived from satellite images (CSIR, 1999) and is at a low level of confidence. The distribution of this total area amongst the key areas is shown in Table 3.5.1.1. No detailed information on the types of dryland crops was obtained in this study, but it is known that large areas of pineapples and chicory are grown in the Albany Coastal Catchments.

3.5.4 Livestock and Game Farming

The distribution of the main types of livestock found in the WMA is shown in Table 3.5.4.1, which also shows the Equivalent Large Stock Units (ELSU).

ELSU are used to measure the water requirements of livestock. Each ELSU is assumed to represent a water requirement of 45 ℓ/day. For example, one ELSU is equivalent to 0,85 head of cattle, or 1 horse, or 6,5 sheep, or 4 pigs. A detailed table for use in converting mature livestock and game populations to ELSU is included in Appendix D. The numbers of livestock shown in Table 3.5.4.1 are approximate only because the information was obtained from the 1994 livestock census (Department of Agriculture, 1994), which gives information in terms of magisterial districts and not hydrological catchments. The data was converted to hydrological catchments by assuming the distribution of livestock to be proportional to land area.

Sheep and goats account for approximately 61%, and cattle 36% of the total number of livestock of approximately 866 000. No information on numbers of game or ostriches could be obtained.

It is known that there are significant numbers of game in the WMA, but no data on these could be found.

3.5.5 Afforestation

The areas of indigenous forests and commercial timber plantations are shown in Table 3.5.5.1 and on Figure 3.5.1.1.

The total area of commercial timber plantations in 1995 was 417 km^2 of which 184 km^2, or 44% was in the Tsitsikamma Coastal Catchments (in K80A to K80F). Table 3.5.1.1 also shows a total of 65 km^2 of indigenous forest which is situated mostly in the Tsitsikamma Coastal catchments (in K80A to K80F) and in the Kat River Catchment (Q94A to Q94F).

3.5.6 Alien Vegetation

The impacts of the widespread infestations by alien plants in South Africa are increasingly recognised. The total incremental water use of invading alien plants was estimated at 3 300 million m^3/a by Le Maitre *et al.* (1999) but this estimate is not widely recognised by the water resources planning community. This estimate is almost twice as high as the estimate for stream flow reduction resulting from commercial afforestation. Le Maitre *et al* (1999) estimate that the impact of alien vegetation will increase significantly in the next 5 to 10 years, resulting in the loss of much, or possibly even all, of the available water in certain catchment areas. Again, this is a debatable point requiring more research to verify these statements.

TABLE 3.5.4.1: LIVESTOCK

CATCHMENT						NUMBERS OF LIVESTOCK					NO. OF ELSU
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		CATTLE	HORSES AND DONKEYS	SHEEP	GOATS	PIGS	
No.	Description	No.	Description	No.	Description						
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	8 437	176	5 987	315	79	11 096
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	19 345	402	13 697	718	174	25 433
		TOTAL IN KROM/TSITSIKAMMA				**27 782**	**578**	**19 684**	**1 033**	**253**	**36 529**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	3 327 252 194	1 575 119 92	48 541 3 679 2 830	17 392 1 318 1 014	375 28 22	15 977 1 193 938
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	4 351	818	18 806	21 405	367	12 565
		L8	Kouga	L81, L82	Western Cape Eastern Cape	2 037 7 744	60 226	2 062 7 836	780 3 060	37 143	2 881 11 135
		L9	Gamtoos	L90A to C	All Eastern Cape	4 220	139	2 053	693	78	5 555
		Total in Groot/Gamtoos Basin in Northern Cape				252	119	3 679	1 318	28	1 193
		Total in Groot/Gamtoos Basin in Western Cape				5 364	1 635	50 603	18 172	412	18 858
		Total in Groot/Gamtoos Basin in Eastern Cape				16 509	1 275	31 525	26 172	610	30 193
		TOTAL IN GROOT/GAMTOOS BASIN				**22 125**	**3 029**	**85 807**	**45 662**	**1 050**	**50 244**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**27 918**	**2 289**	**7 057**	**9 929**	**2 862**	**38 551**
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld's Pass Dam)	N11, N12	Western Cape Eastern Cape	193 5 401	33 933	632 17 652	270 7 536	9 253	404 11 350
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	10 392	1 370	35 682	26 658	354	23 744
		N4	Lower Sundays	N40	All Eastern Cape	40 515	2 254	7 545	18 358	1 541	54 511
		TOTAL IN SUNDAYS BASIN				**56 501**	**4 590**	**61 511**	**52 822**	**2 157**	**90 009**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	72 441	591	14 713	8 750	720	89 756
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	7 905	507	22 725	5 662	67	14 281
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	14 962	846	26 450	10 439	214	24 354
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	16 450	1 664	41 199	21 019	503	31 062
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	3 419	211	5 908	5 026	146	6 042
		Q5-Q8 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	11 141	419	11 238	10 261	191	17 068
		Q9 (Part)	Koonap	Q92	All Eastern Cape	24 674	639	19 156	12 159	339	34 785
		Q9 (Part)	Kat	Q94	All Eastern Cape	5 247	408	11 696	2 546	51	8 817
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	18 203	405	14 073	6 071	255	25 084
		TOTAL IN GREAT FISH BASIN				**102 001**	**5 099**	**152 445**	**73 183**	**1 766**	**161 493**
TOTAL IN WMA IN NORTHERN CAPE						252	119	3 679	1 318	28	1 193
TOTAL IN WMA IN WESTERN CAPE						5 557	1 668	51 235	18 442	421	19 262
TOTAL IN WMA IN EASTERN CAPE						302 959	14 389	286 303	171 619	8 359	446 126
TOTAL IN WMA						**308 768**	**16 176**	**341 217**	**191 379**	**8 808**	**466 581**

Much of the infested areas are in the riparian zones where the degree of infestation is largely independent of the rainfall in the surrounding areas. The acacias, pines, eucalyptus, and prosopis species and melia azedarachs are among the top ten invading aliens, which account for about 80% of the water use.

Commercial afforestation has been one of the major sources of alien vegetation in South Africa, largely as a result of poor past forestry management practices. The results of a recent national scale study (Nel *et al*, 1999) showed that about 44% of the area invaded by plantation trees (pine, eucalyptus and black wattle) overlaps with areas affected by commercial afforestation practices. The new commercial afforestation plantations generally tend to be well-managed, maximising benefits of forestry and minimising environmental impacts.

TABLE 3.5.5.1: AREAS OF AFFORESTATION AND INDIGENOUS FOREST

CATCHMENT						AREA OF AFFORESTATION (km^2)	AREA OF INDIGENOUS FOREST (km^2)
PRIMARY		SECONDARY		TERTIARY/QUATERNARY			
No.	Description	No.	Description	No.	Description		
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	0,55	1,44
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	183,53	27,36
		TOTAL IN KROM/TSITSIKAMMA				**184,08**	**28,80**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	0,00 0,00 0,00	0,00 0,00 0,00
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	0,00	0,00
		L8	Kouga	L81, L82	Western Cape Eastern Cape	0,00 1,82	0,00 0,00
		L9	Gamtoos	L90A to C	All Eastern Cape	88,46	0,00
		Total in Groot/Gamtoos Basin in Northern Cape				**0,00**	**0,00**
		Total in Groot/Gamtoos Basin in Western Cape				**0,00**	**0,00**
		Total in Groot/Gamtoos Basin in Eastern Cape				**90,28**	**0,00**
		TOTAL IN GROOT/GAMTOOS BASIN				**90,28**	**0,00**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**60,55**	**0,00**
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 0,00	0,00
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	0,00	0,00
		N4	Lower Sundays	N40	All Eastern Cape	0,00	0,00
		TOTAL IN SUNDAYS BASIN				**0,00**	**0,00**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**6,28**	**0,00**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,00	0,00
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,00	0,00
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	0,00	0,00
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	0,00	0,00
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	0,00	0,00
		Q9 (Part)	Koonap	Q92	All Eastern Cape	3,07	4,27
		Q9 (Part)	Kat	Q94	All Eastern Cape	73,32	32,32
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	0,00	
		TOTAL IN GREAT FISH BASIN				**76,39**	**36,59**
TOTAL IN WMA IN NORTHERN CAPE						**0,00**	**0,00**
TOTAL IN WMA IN WESTERN CAPE						**0,00**	**0,00**
TOTAL IN WMA IN EASTERN CAPE						**417,58**	**65,39**
TOTAL IN WMA						**417,58**	**65,39**

Alien vegetation infestations across South Africa were mapped under supervision of a CSIR (Environmentek) team using a "best expert knowledge" approach, supplemented by existing detailed localised maps and Geographic Information System (GIS) data sets obtained from certain specific authorities. The expert knowledge was gathered through workshops in different regions and mapped directly onto overlays on 1:250 000 scale topographic maps. Data capture procedures were designed to standardise the approach and terminology and to ensure consistency and comparability in the inputs made by the wide range of people involved.

Areas invaded by alien vegetation were mapped as independent polygons with each polygon accompanied by attribute data regarding species and density. All polygons and attribute data were captured in a GIS (Arc/Info).

The following shortcomings and limitations of the CSIR database on alien vegetation infestation have been highlighted by Görgens (1998):

- The quality of data gathered is known to be variable as it depended on the level of expert knowledge available, the nature of the terrain and the extent and complexity of the actual invasion.

- Mapping of alien vegetation ending very abruptly (and artificially) along some or other administrative boundary.

- Mapping of riparian infestations along rivers at the coarse scale of the available GIS coverages (generally, 1:500 000 with 1:250 000 for some areas) could have led to significant under-estimates of river lengths and, therefore, of infested riparian areas. For example, a pilot comparison by the CSIR of 1:50 000 scale (a suitable scale) and 1:500 000 scale maps yielded a river length ratio of 3,0 and greater.

- Riparian infestation identification in a particular catchment with the simple statement: "all rivers are invaded". In these cases, all the river lengths appearing in the particular coverages were assigned a uniform infested "buffer" strip of specific width, say 20m.

- Small rivers not reflected on the smaller scale mapping were not accounted for and therefore infestation along these particular rivers was not mapped or quantified.

Estimated areas of alien vegetation are shown in Table 3.5.6.1 and diagrammatically for each key area on Figure 3.5.6.1. The values are for condensed areas, which are the equivalent areas that the alien vegetation would occupy if it were condensed to provide completely closed canopy cover. It can be seen that the most severe infestation occurs along the coastal strip (K8, K9, L8 and P4).

TABLE 3.5.6.1: INFESTATION BY ALIEN VEGETATION

CATCHMENT						CONDENSED AREA OF ALIEN VEGETATION (km^2)
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		
No.	Description	No.	Description	No.	Description	
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	32,52
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	116,72
		TOTAL IN KROM/TSITSIKAMMA				**149,24**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	1,50 0,70 0,12
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	34,39
		L8	Kouga	L81, L82	Western Cape Eastern Cape	37,40 258,93
		L9	Gamtoos	L90A to C	All Eastern Cape	9,84
		Total in Groot/Gamtoos Basin in Northern Cape				**0,70**
		Total in Groot/Gamtoos Basin in Western Cape				**38,90**
		Total in Groot/Gamtoos Basin in Eastern Cape				**303,28**
		TOTAL IN GROOT/GAMTOOS BASIN				**342,88**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**113,57**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0,0 3,54
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-243, N30	All Eastern Cape	20,31
		N4	Lower Sundays	N40	All Eastern Cape	11,05
		TOTAL IN SUNDAYS BASIN				**35,33**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**228,93**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,18
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,14
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	18,64
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	1,57
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	3,49
		Q9 (Part)	Koonap	Q92	All Eastern Cape	1,24
		Q9 (Part)	Kat	Q94	All Eastern Cape	21,78
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	22,45
		TOTAL IN GREAT FISH BASIN				**69,49**
TOTAL IN WMA IN NORTHERN CAPE						**0,70**
TOTAL IN WMA IN WESTERN CAPE						**38,90**
TOTAL IN WMA IN EASTERN CAPE						**899,84**
TOTAL IN WMA						**939,44**

3.5.7 Urban Areas

The data on urban areas was obtained from the CSIR land-use maps (CSIR, 1999). The total urban area in the WMA is 364 km^2, which is 0,4% of the area of the WMA. The Nelson Mandela Metropolitan Area covers approximately 240 km^2, and accounts for 66% of the total urban area. The other urban areas are all small. Rural villages in the Kat, Koonap and Lower Fish River catchments occupy about 40 km^2, bringing the combined totals of urban areas and rural villages to 404 km^2.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

Most of the major industries are situated within the Nelson Mandela Metropolitan Area. There are no major power stations within the WMA.

3.7 MINES

Mines in the WMA are small, consisting of a limestone quarry near Hankey (L90E), a gypsum mine near Steytlerville (L70B), and kaolin mines near Grahamstown (P10A, P40A). There is also a quarrying operation in the bed of Zwartkops River upstream of Uitenhage (M10C), where river boulders are excavated and crushed for use as concrete aggregate. The impact of this operation on the ecology of the river, both locally and downstream has caused concern.

3.8 WATER RELATED INFRASTRUCTURE

The urban and rural domestic water supplies in the Fish to Tsitsikamma WMA were generally adequate in 1995, except along the south-eastern edge where supplies to some of the villages in tribal areas were inadequate.

Infrastructure for irrigation, both private and State owned, is well developed.

The water related infrastructure is described in detail in Chapter 4.

CHAPTER 4: WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

The greatest water requirement in the WMA is for the irrigation of approximately 94 800 ha of land. Of this, approximately 31 000 ha is diffuse irrigation from farm dams, run of river flow, or boreholes, and the remainder is controlled irrigation from surface water.

The majority of the controlled irrigation schemes and many of the towns rely on water imported from the Orange River using the infrastructure of the Orange River Project. This is described in Section 4.2.

The total population of the Fish to Tsitsikamma WMA is approximately 1,6 million people. Of these, some 210 000, or 13%, live in rural areas. Of the remainder, about one million live in the Port Elizabeth/Uitenhage/Despatch urban complex (the Nelson Mandela Metropolitan Area), and the rest live in smaller towns. Most of these are situated close to the coast, the interior Karoo area being sparsely populated. Land-use is mainly for commercial farming, except in the south-eastern corner of the WMA, where there are some more densely populated subsistence farming areas. The average standard of domestic rural water supplies in 1995 is reasonably good in the commercial farming areas, but inadequate in parts of the subsistence farming areas.

There are more than fifty towns and small settlements with separate water supplies in the WMA. Detailed information on all the supplies has not been found, but from the available information it has been estimated that in 1995, the capacity of all the schemes combined was about 123 million m;/a. The number of people supplied by the schemes is estimated to have been 1 373 000. Thus the average availability of water was 245 ℓ/c/d, which is well in excess of the Reconstruction and Development Programme requirement of 25 ℓ/c/d. However, inadequate distribution systems within some towns resulted in inadequate water supplies to some areas.

For purposes of describing those schemes for which information is available, they are grouped as follows :

- Towns supplied by the Algoa Water Resources System, described in Section 4.3.
- Towns other than Port Elizabeth supplied from the Orange River, described in Section 4.4.
- Other towns, in Section 4.5.

Approximately 75% of the domestic and industrial water requirements in the WMA occur in the Port Elizabeth/Uitenhage urban area. Thus, the main infrastructure for the supply of potable water is in the vicinity of Port Elizabeth, as shown on Figure 4.1.1.

Some details of the main dams in the WMA are given in Table 4.1.1.

TABLE 4.1.1: MAIN DAMS IN THE FISH TO TSITSIKAMMA WMA

NAME	LIVE CAPACITY (million m^3)	YIELD *				OWNER	CATCHMENT NO.	NOTES	SOURCE OF DATA
		DOMESTIC SUPPLIES (million m^3/a)	IRRIGATION (million m^3/a)	OTHER (million m^3/a)	TOTAL (million m^3/a)				
Grassridge	49,60	0	Balancing dam	0	0	DWAF	Q13A	Operating capacity is 45% of FSC, i.e. 22,3 million m^3 because of dam safety (spillway) requirements.	Hydrology and System Analysis - Eastern Cape Rivers - ORRS Sept 1997 DWAF Report No. P Q000/00/0597.
Commando Drift	55,7	0	7	0	7	DWAF	Q41D	1:20 yield 8,8 million m^3/a (From WR90 curves, equivalent 1:50 year yield is 7,3 million m^3/a)	1:20 year yield calculation by DWAF Eastern Cape Region.
Lake Arthur	10,95	0	Negligible	0	0	Great Fish Irrigation Board	Q44B	Average depth when full is 2,0 m, and 1,4 m when half full.	
Kat River	24,8	1,68	11	0	12,68	DWAF	Q94A	Assurance of yield not known.	Ciskei National Water Development Plan. HKS 1991.
Elandsdrift Weir	9,7	0	Diversion weir	0	0	DWAF	Q50B		
De Mistkraal Weir	3,1	0	Diversion weir	0	0	DWAF	Q80E		
Hermanuskraal Weir	1,2	0	Diversion weir	0	0	DWAF	Q91C		
Glen Melville	6,13	Balancing dam	0	0	0	DWAF	Q93B		
Glen Boyd	0,15	Balancing dam	0	0	0	DWAF	Q93B		
Nuwejaars	4,5	2,1	0	0	2,1	Alicedale TLC	P10B	1:10 year yield 3,28 million m^3/a (From WR90 curves, equivalent 1:50 year yield is 2,1 million m^3/a)	Van Wyk Louw, 1991 : Report to Regional Services Council.
Howiesons Poort Settlers	0,8 5,57	2,2	0,9	0	3,1	Grahamstown TLC	P30A P30B	Yield includes yields of Jameson Dam 0,46 million m^3/a capacity and Milner Dam 0,19 million m^3/a capacity. Assurance not known.	Van Wyk Louw, 1991 : Report to Regional Services Council.
Sarel Hayward ***	2,5	1,6	0	0	1,6	Port Alfred TLC	P40B	Water pumped from Kowrie River. Yield includes yield of Mansfield Dam (0,2 million m^3 capacity) and allows for flushing to improve water quality	Ninham Shand, 1987 : Report to Port Alfred Municipality.
Van Ryneveld Pass	47	3,3	1,2	0	4,5	Van Ryneveld Pass Irrigation Board	N12C	Capacity measured in 1998. 1:50 year yield but uncertainty regarding effects of farm dams upstream. Irrigation allocation bought by Graaff-Reinet.	Ninham Shand Files, 1999.
De Hoop	16	0	Negligible	0	0	Private	N14D	Thought to be silted up - no data found.	
Darlington	187	0	-	0	-	DWAF	N23B	Operating capacity is 21% of FSC, i.e. 39 million m^3 because of dam safety (spillway) requirements. Historical firm yield at full capacity is 28 million m^3/a.	Estimated by DWAF Eastern Cape Region
Koorhaansdrift Weir		0	Diversion weir	0	0	DWAF	N40A		
Groendal	12,3	4,1	2,4	0	6,50	Uitenhage TLC	M10A	1:50 year yield from stochastic analysis	Algoa Stochastic Analysis Report No. PM 000/00/0295.
Sand River Bulk River Van Stadens	2,67 0,65 0,37	3,3	0	0	3,3	Port Elizabeth TLC	M10B M10B L90C	1:50 year yield from stochastic analysis	Algoa Stochastic Analysis Report No. PM 000/00/0295.
Loerie Kouga	3,17 128	23,5	52	0	75,5	DWAF DWAF	L90C L82H	1:50 year yield from stochastic analysis	Algoa Stochastic Analysis Report No. PM 000.00/0295.
Klipfontein	1,8	0,83	0	0	0,83	Klipplaat TLC	L60A	Historical firm yield. Assurance not known.	Ninham Shand Files.
Beervlei	90	0	12	0	12	DWAF	L30C	1:50 year yield	DWAF Eastern Cape Region
Churchill Impofu	32,0 87,0	42,4	0	2,0	44,4	Port Elizabeth DWAF	K90B K90D	1:50 year yield from stochastic analysis.	Algoa Stochastic Analysis Report No. PM 000/00/0295.
Klippedrift	3	0	2,5	0	2,5	Klippedrift Irrigation Board	K80F	1:10 year yield 3,5 million m^3/a (From WR90 curves, equivalent 1;50 year yield is 2,5 million m^3/a).	Van Wyk and Louw, 1991 : Report to Regional Services Council
Joubertina	0,21	Not known	0	0	0	Joubertina TLC	L82D		
Haarlem	4,7	0,2	3,6	0	3,8	Haarlem Irrigation Board	L82A	Design yield of 4,5 million m^3/a at 1:10 year assurance (From WR90 curves, equivalent 1:50 year yield is 3,8 million m^3/a)	Ninham Shand Files, 1989.

* Approximately 1:50 year unless otherwise indicated
*** Off-channel dam

4.2 THE ORANGE RIVER PROJECT

4.2.1 Water Supply Infrastructure

The Orange River Basin is South Africa's largest river basin, having a catchment area of 1 million km^2. This basin bounds the Fish to Tsitsikamma WMA in the north.

The Orange River Project was developed to utilise surplus water from the river. The primary aims of the project were:

- to provide new irrigation development along the Orange River;
- to stabilise the supply of water to existing irrigation schemes and urban areas;
- to supply water to the fertile valleys of the Great Fish River and the Sundays River in the Fish to Tsitsikamma WMA, and
- to generate hydro-electric power.

The portion of the scheme lying within the Fish to Tsitsikamma WMA extends in a southerly direction from the outlet to the Orange-Fish Tunnel (Q12B), to Port Elizabeth at the coast. The scheme affects mainly the Great Fish and the Sundays River Basins.

The main infrastructure components of the scheme are shown on Diagram 4.2.1.1.

The development of water infrastructure in the Fish and Sundays River basins has occurred in two phases:

- Original irrigation schemes and ancillary works in the two mainstem and certain tributary river valleys.
- Augmentation schemes developed as part of the original Orange River Project and its subsequent extensions which rely largely on the availability of Orange River water.

The augmentation schemes along the Great Fish and Lower Sundays Rivers were integrated with pre-existing water infrastructure.

The key feature of the scheme (see Diagram 4.2.1.1) is the 82,9 km long, 5,4 m diameter Orange-Fish Tunnel completed in 1975, which diverts water from the Orange River to the Teebus Spruit and thence to the Great Fish and Sundays Rivers. The water flows from the tunnel outlet to the Grassridge Dam on the Great Brak River, a tributary of the Great Fish River. The capacity of the tunnel is 54 m^3/s, or 1 700 million m^3/a at 100% utilisation. As 95% of the water supplied through the tunnel is used for irrigation purposes, the volume of water supplied fluctuates on an annual basis according to weather conditions and crop mix, areas irrigated, and decisions made by individual farmers. The present day mean annual requirement is 560 million m^3/a.

Water is released from Grassridge Dam down the Great Fish River such that water may be abstracted at several points to supply the various irrigation boards before reaching the Elandsdrift Weir.

ORANGE / FISH TRANSFER SCHEME INFRASTRUCTURE

DIAGRAM 4.2.1.1.

Water is diverted from the Great Fish River at the Elandsdrift Weir into a 108 km long aqueduct. The Cookhouse Tunnel, the main feature of the aqueduct, discharges the water into the Little Fish River. The De Mistkraal Weir situated on the Little Fish River transfers water to the Skoenmakers Canal and into Darlington Dam.

Water from Darlington Dam is released down the river to the Korhaansdrift Weir, which diverts water into the Sundays irrigation canal. Some of the water is used for irrigation and some flows to the Scheepersvlakte Dam from where it is transported to the Nooitgedacht purification works on the right bank of the Sundays River by gravity pipeline. From there it is conveyed to Motherwell Reservoir by a pumping main and gravity pipeline to serve users in the urban areas of Port Elizabeth.

Water is also released from Elandsdrift Weir into the Great Fish River to supply users supplied from the Lower Fish River Scheme (which consists of the Hermanuskraal diversion weir in the Great Fish River and a tunnel to divert water to the Glen Melville Dam on the Ecca River), and to serve users in the Grahamstown area. The distribution system consists of the Glen Boyd balancing dam and canals and pipelines to the irrigable land on both sides of the river. A municipal pumping scheme conveys water from a treatment works at the Glen Melville Dam to Grahamstown.

Irrigation water distribution from the main canals to field edge in most of the large schemes and in all the small schemes is via earth canals. Canal losses are therefore significant.

The Orange/Fish/Sundays Transfer Scheme comprises three main sections (see Diagram 4.2.1.2), namely:

(i) The Orange-Fish Transfer Scheme and the Fish-Sundays Canal Scheme (Fish-Sundays River Government Water Scheme).
(ii) The Lower Sundays River Government Water Scheme, including extension to Port Elizabeth.
(iii) The Lower Fish River Government Water Scheme.

Separate irrigation schemes exist below Graaff-Reinet on the Sundays River as well as on the Tarka and Kat Rivers. These are discussed in Section 4.5.

The Orange-Fish Transfer Scheme and the Fish-Sundays Canal Scheme
The primary function of the Orange-Fish Transfer Scheme and Fish-Sundays Canal scheme is to provide water for irrigation in the Great Fish and Lower Sundays River Valleys and to the Port Elizabeth metropolitan area.

The natural water quality in Darlington Dam is poor because the base flow in the Sundays River is heavily mineralised. A secondary function of this scheme is the improvement of the quality of water in Darlington Dam through dilution with Orange River water.

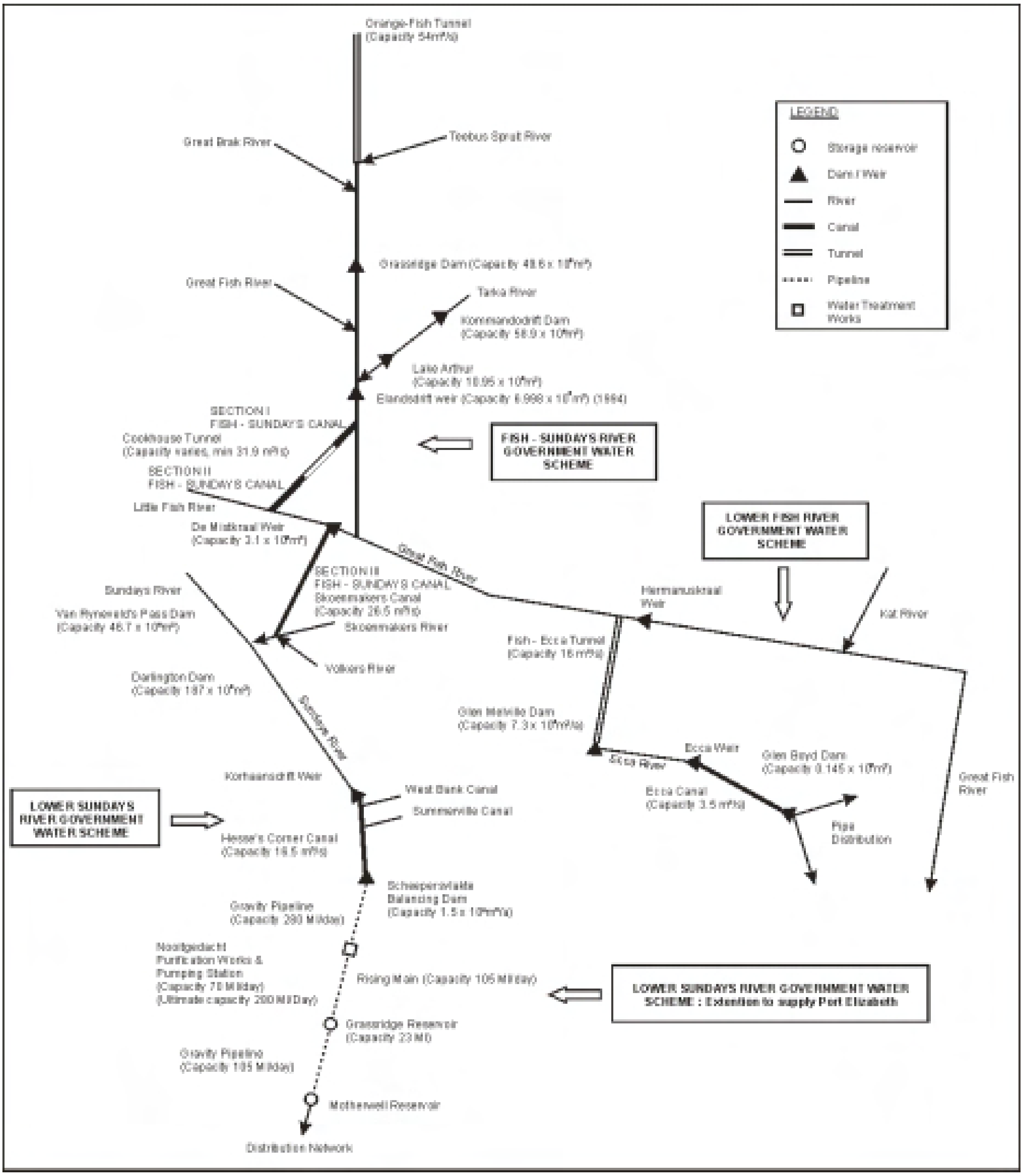

Diagram 4.2.1.2: Schematic diagram of the Orange River Project in the Fish and Sundays River Basins

The key features of the water scheme (commission date in brackets) are:

-	Orange-Fish Tunnel	(1975)
-	Grassridge Dam	(1924)
-	Elandsdrift Weir	(1977)
-	Cookhouse Canal and Tunnel	(1978)
-	De Mistkraal Weir	(1987)
-	Skoenmakers (Fish-Sundays) Canal	(1978)
-	Darlington Dam (Lake Mentz)	(1922)

The Lower Sundays River Government Water Scheme

The primary purpose of the Lower Sundays River Government Water Scheme was to augment supplies from Darlington Dam to the Lower Sundays River valley, thereby making it possible for the 9 500 hectares of citrus farming land under irrigation in the Sundays River valley to be increased by a further 11 000 hectares, considered to be the full irrigation potential of the Sundays River valley. At the same time, water quality could be improved by dilution with fresh Orange River releases. The scheme has only been partially completed.

The key features of the scheme are listed below (commission date in brackets):

-	Darlington Dam (Lake Mentz)	(1922)
-	Koorhaansdrift Weir	(1902)
-	Hesse's Corner Canal	(~ 1990)
-	Scheepersvlakte Balancing Dam	(1990)
-	Heatlieskrantz Tunnels	(~ 1990)

The Lower Sundays Government Water Scheme: Extension to Supply Port Elizabeth

In the past, the Port Elizabeth metropolitan area was supplied with water from the following sources:

-	Kouga Dam	(State owned)
-	Impofu Dam	(State owned)
-	Groendal Dam and springs	(Uitenhage Municipality)
-	Churchill Dam	(Port Elizabeth Municipality)
-	Bulk, Sand and Van Stadens Dams	(Port Elizabeth Municipality)

Prior to 1983, it was considered that the yield from these sources would be adequate up to 1997. However, the 1983 - 1989 drought highlighted the need for a greater long-term assured supply of water to the region. Therefore, the primary function of the scheme is to increase the assurance of supply to the Port Elizabeth metropolitan area.

It is envisaged that the extension of the Lower Sundays River Government Water Scheme might ultimately supply 207 million m^3/a of water to Port Elizabeth from the Orange River. At present, water treatment capacity of approximately 20 million m^3/a has been constructed, the intention being to increase both the treatment and conveyance capacity as dictated by future water requirements.

The Lower Fish River Government Water Scheme

The primary purpose of the Lower Fish River Government Water Scheme was the supply of water for 2 940 ha of irrigation on the banks of the Great Fish River in the Committees Drift area, as well as the supply of supplementary water to Grahamstown.

The main crops in the area are lucerne, cotton, maize and vegetables. The main works of the scheme were completed in 1992.

The original scope of the scheme was subsequently reduced. The main pipeline along the western bank of the river to serve lands both in South Africa and in the former Ciskei was only partially completed. This reduced the number of supply points to serve the Ciskei lands to only a single crossing of the Fish River at Committees Drift. As compensation for the reduced number of supply points, this pipeline was extended 4 km into the Ciskei. The Ciskei Government had intended to extend the pipeline further, but this was overtaken by the demise of the Ciskei as an independent state. The extension of this pipeline is at present under consideration. In 1995, 360 ha of land were being irrigated from the scheme on the western bank of the river, and most irrigation on the eastern bank had come to a standstill, for various reasons, which include the cost of electricity.

The key features of the scheme are:

- Hermanuskraal Diversion Weir
- Fish-Ecca Tunnel
- Glen Melville Dam
- Ecca Weir
- Ecca Canal
- Glen Boyd Balancing Dam
- a pipeline from Glen Boyd Balancing Dam across the Fish River to serve the eastern bank.

4.2.2 Urban Requirements from the Orange River Project

Existing Requirements

Urban centres which make use of or have been allocated water from the Orange River Project (ORP) include Cradock, Cookhouse, Grahamstown, Port Elizabeth, Kirkwood, Enon and Addo. Somerset East has also been supplied since 1997, and Bedford has also been linked to the ORP more recently, to augment its other sources of water.

The approximate abstractions in 1995 of ORP water for these centres are given in Table 4.2.2.1.

TABLE 4.2.2.1: URBAN WATER REQUIREMENTS FROM THE ORANGE RIVER SCHEME IN THE FISH-SUNDAYS RIVER BASINS IN 1995 (1)

CENTRE	ANNUAL REQUIREMENT (million m^3)
Addo	0,1
Cradock	3,5
Cookhouse	0,4
Enon	0,1
Grahamstown	0,8
Kirkwood	0,6
Port Elizabeth	11,5
Total	17,0

(1) Somerset East is not included in the table as it only began to abstract water early in 1997. Its abstraction from this source in 1997 was approximately 0,8 million m^3.

Water for use in Kirkwood and Addo is supplied as a bulk water supply, metered at Korhaansdrift Weir. Water for urban use is abstracted via separate canals owned by the individual local authorities.

The total urban and industrial water consumption for the Port Elizabeth/Uitenhage area in 1995 was 69 million m^3.

Of this, approximately 11,5 million m^3 was supplied from the Orange River Scheme.

Grahamstown is currently supplied with water from four local dams with a combined firm yield of approximately 2,2 million m^3/a. A preliminary allocation of 6 million m^3/a to Grahamstown and environs from Glen Melville Dam is currently in effect, but use in 1995 was only about 0,8 million m^3.

4.3 THE ALGOA WATER SUPPLY SYSTEM

The water supply system serving the Port Elizabeth/Uitenhage area is known as the Algoa System. It has developed from several separate schemes that have become interlinked. The main components of the system are shown on Diagram 4.3.1. The water treatment works associated with the system and their sources of raw water are shown in Table 4.3.1. The system abstracts water from the Krom, Kouga, Zwartkops and Sundays Rivers. The water obtained from the Sundays River is made available by transfer from the Orange River. The various components of the system are as follows:

(i) The Gamtoos River Government Water Scheme, which comprises the Kouga Dam (128,68 million m^3 capacity) and the Loerie Dam (3,17 million m^3 capacity). The 1:50 year yield of the scheme is 75,5 million m^3/a of which 23,0 million m^3/a is allocated to Port Elizabeth Municipality (DWAF, 1994b), approximately 0,5 million m^3/a to Hankey and Patensie for urban use (Van Wyk and Louw, 1991), and the balance to irrigation.

    Water is conveyed from Kouga Dam to Loerie Dam by means of a canal (see Diagram 4.3.1). Irrigation requirements are abstracted from the canal along its route to Loerie Dam. With the exception of that supplied to Hankey and Patensie, all water for urban use is discharged from Loerie Dam to the Loerie Water Treatment Works (105 Mℓ/d capacity). The treated water is conveyed by pipeline from there to the Port Elizabeth area. Hankey and Patensie draw raw water from the scheme and treat it in their own works with capacities of 1 Mℓ/d and 0,05 Mℓ/d, respectively. The town of Loerie is supplied with treated water by Port Elizabeth Municipality.

(ii) The Churchill Water Supply Scheme utilises the water of the Krom River (see Diagram 4.3.1) for supplies to the Port Elizabeth area. Supplies to Humansdorp and smaller towns in the vicinity are also supplemented from this scheme. This generally occurs during the summer to meet the increase in demand caused by holidaymakers.

THE ALGOA WATER RESOURCES SYSTEM	DIAGRAM 4.3.1.

TABLE 4.3.1: ALGOA SYSTEM : BULK WATER SUPPLY INFRASTRUCTURE

TREATMENT WORKS			RAW WATER SOURCE					
NAME	CAPACITY (Mℓ/d)	OWNER/ OPERATOR	NAME	FIRM YIELD * (million m^3/a)	FIRM YIELD * (Mℓ/d)	ADDITIONAL YIELD ALLOCATED TO OTHER USERS (million m^3/a)	OWNER **	OPERATOR **
Linton	16	PE	Bulk River Dam Sand River Dam Van Stadens Dams	3,3	9,0	None	PE	PE
Kabah	20	U	Groendal Dam, springs	3,3	9,0	2,4 to irrigation	U	U
Loerie	105	PE	Kouga Dam Loerie Dam	23	63	52 to irrigation, Hankey and Patensie	DWAF	GIB
Churchill	95	PE	Churchill Dam	42,4	116	2 for environmental purposes	PE	PE
Elandsjacht	105	PE	Impofu Dam	(on the same river)			DWAF	PE
Nooitgedacht	70	PE	Orange River Scheme	25,6 (allocation)	70	See Section 4.2	DWAF	SRIB
Humansdorp	2,2	Humansdorp	Boreholes, springs	0,8	2,2	None	H	H
St Francis Bay	4,3	SFB	Boreholes	1,6	4,3	None	SFB	SFB
Jeffrey's Bay	4,5	JB	Boreholes	1,6	4,3	None	JB	JB
Hankey	1,0	Hankey	Kouga Dam	} 0,5	} 1,4	None	DWAF	GIB
Patensie	0,05	Patensie	Kouga Dam			None	DWAF	GIB
TOTALS	**423,05**			**102,1**	**279,2**			

PE = Port Elizabeth TLC
U = Uitenhage TLC
DWAF = Department of Water Affairs and Forestry
GIB = Gamtoos Irrigation Board
SRIB = Sundays River Irrigation Board
SFB = St Francis Bay TLC
JB = Jeffreys Bay TLC

* The yields of the dams are at 1:50 year assurance
** In 1995

The scheme comprises Churchill Dam (32,5 million m^3 capacity), Impofu Dam (87,03 million m^3 capacity), Churchill (95 Mℓ/d) and Elandsjacht (105 Mℓ/d) Water Treatment Works and pipelines and pumps with a capacity of 146 Mℓ/d, that convey the water to the Port Elizabeth area.

The following towns are also partially supplied from this scheme :

- Humansdorp
- Jeffrey's Bay
- St Francis Bay
- Thornhill (0,011 million m^3/a)
- Paradise Beach (0,012 million m^3/a)

These towns rely as far as possible on their own groundwater schemes which have a combined yield of 4,3 million m^3/a.

(iii) Groendal Dam (11,66 million m^3 capacity) on the Zwartkops River (see Diagram 4.3.1) supplies water by pipeline to the Kabah Water Treatment Works (20 Mℓ/d capacity) whence treated water is supplied to Uitenhage. The dam, treatment works and pipeline were all owned and operated by Uitenhage TLC in 1995. The 1:50 year yield of the dam is 6,5 million m^3/a, of which 4,1 million m^3/a is allocated to urban water supplies and the balance of 2,4 million m^3/a to irrigation of riparian land downstream of the dam. The treatment works is also supplied from springs which have a firm yield of 1,6 million m^3/a.

(iv) Sand River Dam (2,88 million m^3 capacity) and Bulk River Dam (0,65 million m^3 capacity) and the Upper and Lower Van Stadens Dams (combined capacity of 0,37 million m^3) supply the Linton Water Treatment Works (16 Mℓ/d capacity), all of which were owned and operated by Port Elizabeth TLC in 1995. The combined 1:50 year yield of the dams is 3,3 million m^3/a.

(v) The Orange/Sundays River Supply System conveys water from Gariep Dam on the Orange River to the Nooitgedacht Water Treatment Works (see Diagram 4.3.1) whence it is distributed to the northern areas of Port Elizabeth. The treatment works (70 Mℓ/d capacity), pumping station, rising main, Grassridge Balancing Dam and the gravity main to Port Elizabeth were owned and operated by Port Elizabeth TLC in 1995. The rest of the system, which is an extension of the Lower Sundays River Government Water Scheme, described in Section 3.2 above, is owned and operated by the Department of Water Affairs and Forestry. The current 25,6 million m^3/a capacity of this scheme is determined by treatment capacity and could, if necessary, be substantially increased in the future by extending the treatment works and increasing the capacity of some sections of the raw water conveyance system. The original planning for the scheme allowed for an ultimate allocation of water to Port Elizabeth of 560 Mℓ/d or 207 million m^3/a. As this was seen as a long term requirement, it was planned to develop the infrastructure to supply this requirement in stages. Thus, the canal from the Korhaansdrift Weir to Scheepersvlakte Balancing Dam (see Diagram 4.2.1.1), which carries water for both irrigators and the Port Elizabeth supply, has 280 Mℓ/d of its total capacity of 1 425 Mℓ/d available for allocation to the latter. Port Elizabeth has secured the rights to 140 Mℓ/d of this capacity so far and has first option on the rights to the balance of 140 Mℓ/d. When its water requirements from this source exceed 280 Mℓ/d, it is likely that an additional canal will have to be constructed. The pipeline from Scheepersvlakte Balancing Dam to the Nooitgedacht Water Treatment Works has a capacity of 280 Mℓ/d. The treatment works has a capacity of 70 Mℓ/d, but has been designed to be extended in stages to 280 Mℓ/d. The use of water from this source in 1995 was about 11,5 million m^3/a or 31 Mℓ/d.

Port Elizabeth Municipality supplied water to towns within an area extending from Cannonvale and Colchester at the mouth of the Sundays River in the east to Uitenhage in the north, and Humansdorp in the west. As described above, other components of the Algoa System also supply water to some of the towns within this area. The Algoa System in 1995 supplied potable water to some 1 050 000 people and a large number of industries with a total water requirement of 72 million m^3/a. The 1:50 year yield of the system is approximately 76 million m^3/a from local sources (see Table 4.3.1) and 25,6 million m^3/a from the Orange River. In addition, approximately 5 million m^3/a of sewage effluent is recycled for industrial use. Therefore, the total assured supply is approximately 106,6 million m^3/a at present.

4.4 TOWNS SUPPLIED FROM THE ORANGE RIVER

Several smaller towns, in addition to Port Elizabeth, obtain raw water from the Orange River transfers to the Fish and Sundays Rivers. These are:

(i) Grahamstown, which is supplied with water diverted from the Little Fish River at Hermanuskraal Weir and conveyed by means of a tunnel to Glen Melville Dam on the Ecca River. Glen Melville Dam is a balancing dam for raw water supplied to Grahamstown and to the Lower Fish River Irrigation Scheme. It has negligible yield from the Ecca River. The water is treated at a plant near the dam and pumped to Grahamstown. Use in 1995 was about 0,8 million m^3. Raw water availability will be adequate for the foreseeable future.

Water is also obtained from four local dams, namely Settlers, Howiesonspoort, Jameson and Milner Dams. The combined 1:50 year yield of these dams is 2,2 million m^3/a. The water is pumped to an 11 Mℓ/d treatment works on a hill above Grahamstown and distributed from there.

(ii) The towns of Enon, Kirkwood and Addo obtain water from the Sundays River supplied by the Sundays River Irrigation Board. Kirkwood has an allocation of 0,94 million m^3/a of raw water which is processed in its 2,3 Mℓ/d treatment works before distribution. Similarly, Enon and Addo are supplied with raw water by the Irrigation Board and purify it in their own treatment works with capacities of 0,6 Mℓ/d and 1,8 Mℓ/d respectively. The supplies to all three towns are secure for the foreseeable future and only treatment and distribution infrastructure will need to be increased as water requirements grow.

(iii) Until recently, Somerset East relied on three small dams, boreholes and springs with an estimated combined 1:50 year yield of 0,83 million m^3/a for its water supply. Early in 1997 a new scheme was commissioned in which water supplied by DWAF from the Fish/Sundays Canal near Uitkeer is supplied to consumers via a 2,14 Mℓ/d treatment works owned and operated by the municipality. This scheme, together with the old scheme in which water from local sources is chlorinated but not filtered, brings the capacity of the water supply scheme to about 1,5 million m^3/a. This should be adequate to about the year 2005.

(iv) Cookhouse also receives water from the Fish/Sundays Canal supplied by DWAF. Raw water is conveyed by pipeline from the canal to Cookhouse where it is treated before distribution. The existing scheme in 1995 was inadequate in capacity and in a poor state of repair, but the construction of a new scheme incorporating a 1,65 Mℓ/d treatment works and a new pipeline leading from the irrigation canal, from which water is abstracted, to a new raw water balancing dam, began in 1999 and is being implemented in phases.

4.5 OTHER TOWNS

The other towns in the WMA rely upon their own supplies, many of which are inadequate or will become inadequate in the near future. The information that has been obtained on these supplies as they were in 1995 is summarised as follows:

(i) Towns currently relying for their water on boreholes or a combination of boreholes and small dams that have inadequate yields are Oesterbaai, Pearston, Steytlerville, Paterson, Alexandria. Of these, it appears that Pearston and Steytlerville could best be provided for by developing additional boreholes, Oesterbaai could be supplied from the Algoa System, and the remainder will need to be supplied from new surface water schemes.

(ii) The towns of Nieu Bethesda, Aberdeen, Willowmore, Jansenville, Kareedouw, Riebeeck Oos, Boknes and Cannon Rocks all rely on borehole supplies that will be adequate for some years to come. It is likely to be feasible to develop additional boreholes when required.

(iii) Graaff-Reinet obtains water from Van Rynevelds Pass Dam, which is adjacent to the town, and from the Mimosadale Wellfield which is situated about 15 km south-west of the town.

The Van Rynevelds Pass Dam, which was owned and operated by the Van Rynevelds Pass Irrigation Board in 1995, has a live storage capacity of 47 million m^3 (measured in 1998) and a 1:50 year yield estimated in this study to be 4,5 million m^3/a. Graaff-Reinet had an allocation of 3,3 million m^3/a from the yield, the remainder being used for irrigation purposes. In the past, difficulties have been experienced in the operation of the dam when irrigation water has been over-supplied, causing the dam to dry up during droughts. The municipality of Graaff-Reinet bought the dam and the irrigation water allocations from the irrigation board in the year 2000. The water that was previously used for irrigation is now available for the town supply.

It should be noted that the dam is subject to severe siltation, with the result that its live storage capacity decreased from 80 million m^3 when it was constructed in 1924 to 47 million m^3 in 1978 when the basin was again surveyed. A survey carried out by DWAF early in 1998 showed that the capacity has remained at 47 million m;.

Raw water is conveyed from the dam to the water treatment works through two pipelines with a combined capacity of 3,3 million m^3/a. The capacity of the treatment works is 7 Mℓ/d, which limits the quantity of treated water obtainable from the dam to about 2,1 million m^3/a at present.

The Mimosadale Wellfield consists of three boreholes with a combined 1:50 year yield of 0,6 million m^3/a. The water is not filtered but is chlorinated before it is supplied to consumers. The 1:50 year yield of this wellfield, when fully developed, is estimated to be 3,1 million m^3/a. The quantity of water available is sufficient to meet the expected requirements of Graaff-Reinet to beyond 2020.

(iv) The town of Klipplaat obtains raw water from the Klipfontein Dam which is owned by the municipality. The dam has a 1:50 year yield of 0,83 million m^3/a, all of which is allocated to the town supply. The capacity of the water treatment works is 0,4 Mℓ/d or 0,12 million m^3/a, which should be adequate to the year 2010. The raw water source will be adequate to well beyond that.

(v) The town of Alicedale obtains water from the Nuwejaars Dam which has a 1:50 year yield of 3,3 million m^3/a (Van Wyk & Louw, 1991). The water treatment works has a capacity of 1,2 Mℓ/d and should meet water requirements to beyond the year 2020. The dam was owned by Spoornet but was purchased by the Alicedale Municipality in about 1995.

(vi) Port Alfred obtains water from Mansfield Dam (0,2 million m^3 live storage) and the Sarel Hayward Dam (2,5 million m^3 live storage). The latter is an off-channel dam into which water is pumped from a small weir on the Kowie River. Water stored in the dam becomes saline during dry periods because of the marine origins of the shales underlying the dam basin. Regular flushing of the stored water and replacement with fresh water from the Kowie River during periods of high flow is required to counteract this. The combined yield of the two dams is estimated to be 1,60 million m^3/a (Ninham Shand, 1987). Water is pumped from these dams to a water treatment works with a capacity of 6 Mℓ/d. The scheme is owned and operated by the Port Alfred Municipality.

Water is also abstracted from coastal sand dunes near the town. The yield of this scheme is 0,13 million m^3/a.

Water from Mansfield Dam is supplied by Port Alfred to Nolukhango in the neighbouring town of Bathurst. Nolukhango previously relied on borehole water which was inadequate in quantity and found to have higher than desirable nitrate concentrations. It is not known if the borehole supply has been abandoned or if it is still used but mixed with the Mansfield Dam water. The other areas of Bathurst rely on private supplies from rainwater tanks or boreholes.

Raw water supplies to Port Alfred may need to be augmented in the near future.

(vii) Bushman's River Mouth and Kenton-on-Sea are supplied by the Albany Coast Water Board from boreholes and wellpoints in the dunes at Bushman's River mouth and at Diaz Cross. The yield of this scheme is estimated to be 1,1 million m;/a. Because the raw water sources could not meet peak holiday season demand, the supply has been augmented by a reverse osmosis seawater desalination plant. The plant was commissioned in December 1997. It has a capacity of 0,4 Mℓ/d, or 0,12 million m;/a, and draws water from boreholes in the saline groundwater zone near the Bushman's River mouth. The supply should be adequate to about 2005.

(viii) The town of Joubertina obtains water from Joubertina Dam which has a capacity of 0,21 million m;. The yield of the dam could not be ascertained. Water is treated at a purification works with a capacity of 0,65 Mℓ/d. The scheme was owned and operated by Joubertina TLC in 1995 and supplies the villages of Krakeel and Louterwater in addition to Joubertina. The capacity of the treatment works was just adequate for requirements in 1995.

(ix) Tarkastad relies on boreholes for its water supply. The population of the town in 1995 was approximately 5 400 people and present water use was 0,10 million m^3/a, or 50 ℓ/c/d. Groundwater potential in the area is good and it appears that additional boreholes can be developed as required.

(x) The town of Cradock relies on water from the Orange River for the supply to its inhabitants who numbered 28 600 in 1995. The present allocation of water is 6,6 million m^3/a, which is expected to be adequate to the year 2012. The treatment works has a capacity of 19 Mℓ/d or 4,6 million m^3/a. Water requirements in 1995 are estimated to have been 3,8 million m^3/a and availability was 664 ℓ/c/d.

(xi) The town of Hofmeyr, with a population in 1995 of 2 850 people, relies on boreholes for its water supply. Water requirements in 1995 are estimated to have been 0,19 million m^3, but the existing boreholes are reported to have been unable to supply this. The supply has been improved since 1995, but details were not obtained for this study.

(xii) The 17 400 consumers in the town of Middelburg in 1995 were supplied from boreholes. Water requirements are estimated to have been 2,4 million m^3/a. The yield of the existing boreholes is not known, but it is expected to be adequate to the year 2010.

(xiii) The Kat River Dam Water Supply Scheme supplies raw water to the towns of Seymour and Fort Beaufort, as well as for the irrigation of 1 120 ha of land. Water for Seymour is abstracted from the dam and treated at the town's own plant which has a capacity of 0,74 Mℓ/d, or 0,22 million m^3/a. The plant was, therefore, able to supply an average of 102 ℓ/c/d to the 2 700 consumers in Seymour in 1995. Water for Fort Beaufort is released from the dam into the river channel and abstracted at a weir near the town, where it is treated and distributed to the consumers in the town. The capacity of the treatment works is 4,5 Mℓ/d, or 1,36 million m^3/a. Fort Beaufort has an allocation of 2,6 million m^3/a from the Kat River. Average availability of water to the 23 400 consumers in the town in 1995 was 160 ℓ/c/d, and was limited by treatment capacity. The raw water supply was expected (DWAF, 1996) to be adequate to the year 2002. Thereafter, the supply will require augmenting. As the yield of the Kat River Dam is fully allocated, there may be some conflict between the requirements of the towns of Seymour and Fort Beaufort and the requirements of irrigators.

(xiv) The town of Bedford obtains water from a small dam which has a 1:50 year yield of 0,27 million m^3/a. The town also has boreholes with a yield of 0,126 million m^3/a which are held in reserve as an emergency supply during droughts. The treatment works capacity is 2,0 Mℓ/d, or 0,60 million m^3/a. The estimated water requirement of the 10 200 people living in the town in 1995 was 0,47 million m^3/a. A pump and pipeline scheme has recently been constructed to supply Orange River Project water to the town.

The abstraction point is at Eastpoort Station, near Cookhouse. The scheme can deliver 55 m^3/hr to the treatment works at Bedford.

(xv) The town of Adelaide obtains its raw water from a scheme in which water is diverted from the Koonap River into an off-channel storage dam with a capacity of 0,7 million m^3. The 1:50 year yield of the dam is estimated to be 0,40 million m^3/a. The capacity of the treatment works is not known, but is assumed to be equal to the yield of the raw water source. The availability of water to the 16 500 residents of the town in 1995 was, therefore, 0,40 million m^3/a or 68 ℓ/c/d. Water requirements in 1995 were estimated to be 0,67 million m^3/a. The town has suffered serious water shortages in dry years. The Koonap River is a suitable source for further augmentation, but additional storage is needed.

(xvi) The town of Peddie, with a population of 15 100 people in 1995, obtained water from the small Khewekazi Dam. The dam, treatment works and pipeline had a capacity of 0,11 million m^3/a, while water requirements were estimated to be 0,35 million m^3/a. Since 1995 the raw water supply has been augmented from the Keiskamma River and a new treatment works with a capacity of 6,5 Mℓ/d constructed. Treated water is also supplied to 4 villages in the vicinity of Peddie, and the supply will eventually be extended to a total of 16 villages.

4.6 CONTROLLED IRRIGATION

Information on the schemes making up the 60 440 ha of controlled irrigation in the WMA is summarised in Table 4.5.1. Descriptions of the schemes follow, and include sections on schemes falling under the Orange River Project which expand on the information given in Section 4.2. The theoretical water requirements shown in Table 4.5.1 were determined in the Orange River Development Project Replanning Study (DWAF, 1995) as the quantities of water required to maximise crop yields. They are generally higher than the actual quantities of water used.

(i) The upper portion of the Orange-Fish River Transfer Scheme lies between the Teebus Spruit outlet of the canal from the Orange-Fish Tunnel and the Elandsdrift Weir (see Diagram 4.2.1.1). Irrigation along part of the Tarka River, also falls under this scheme. Water is abstracted from the river and distributed to the lands through 383 km of canals, most of which are unlined. The scheduled area in 1995 was 19 287 ha. Estimates of the actual area irrigated in 1995 vary between the 24 342 ha determined in the Orange River Development Project Replanning Study (DWAF, 1995) and the 13 928 ha assumed for this situation assessment on the basis of information provided by officials of the DWAF Eastern Cape Region. Most of the irrigation is by flood. The crops grown are mainly lucerne (68%) plus maize and wheat and small areas of oats and vegetables.

TABLE 4.5.1: CONTROLLED IRRIGATION SCHEMES IN THE FISH TO TSITSIKAMMA WMA IN 1995

SCHEME NAME	SCHEDULED AREA (ha)	AREA IRRIGATED IN 1995		PRODUCE	SUPPLY SOURCE	AVAILABLE WATER (1) (million m³/a)	AVERAGE ANNUAL USE (million m³/a)	QUATERNARY CATCHMENT NO.
		VALUE FROM OTHER DATA SOURCES (ha)	ASSUMED (8) (ha)					
Orange-Fish River Transfer Scheme Upstream of Elandsdrift Weir	19 287	24 342 (7)	13 728	Lucerne, maize, wheat , oats, vegetables	Orange-Fish Transfer Scheme	282 (2)	233	Q12A, B, C Q13A, B, C, Q14E Q30B, C, D, E, Q21B Q44C, Q50A
Fish-Sundays Canal Scheme and Great Fish River	14 334	13 000 (7)	11 199	Lucerne, wheat, pasture, maize	Orange-Fish Transfer Scheme	236 (2)	148	Q50B, C, Q60C Q70A, B, C. Q80D, E, F, G, Q91A, B, C, N22E, N32A, B, C, N40A
Tarka River Government Water Scheme	921	921 (7)	921	Lucerne	Commando Drift Dam	7,3	14,3 (2)	Q44A, B, C
Lower Fish River Government Water Scheme	375	300 (7)	266	Lucerne	Orange-Fish Transfer Scheme	14 (2)	11	Q93B
Tyefu Irrigation Scheme	12 500	Less than 260 (10)	260	Lucerne, maize, vegetables	Orange-Fish Transfer Scheme	6,56	Not known	Q93A, B, C
Lower Sundays River Government Water Scheme	12 500	12 500 (7)	12 500	Citrus (60%) Lucerne (20%) Vegetables	Orange-Fish Transfer Scheme	130(3)	130	N40B, C, D, E, F
Van Rynevelds Pass Irrigation Scheme	3 380	Not known	1 014	Lucerne, maize, vegetables	Van Rynevelds Pass Dam	2,5(4)	Not known	N13C N21A, D N24B
Groot River Government Water Scheme	2 516	2 530 (10)	2 516	Not known	Beervlei Dam	20 (4)	17,3	L30C, D L50B L70B
Gamtoos River Government Water Scheme	7 353	9 880 (9)	5 600	Vegetables (60%) Citrus (22%) Lucerne Tobacco	Kouga Dam Loerie Dam	57 (5)	57 (6)	L90A, B, C
Kat River Irrigation Scheme	1 600	1 030 (6)	1 150	Citrus	Kat River Dam	11,0	11,0	Q94D, Q94F

NOTES :
(1) At approximately 1:50 year reliability unless otherwise indicated.
(2) Includes allowance of 25% of field edge requirements for distribution losses but excludes river losses.
(3) Includes allowance of 15% of field edge requirements for distribution losses but excludes river losses.
(4) Approximate estimate of 1:10 year availability made in this study.
(5) 1:20 year availability.
(6) Ciskei National Water Development Plan (HKS, 1991).
(7) Area determined in the Orange River Development Project Replanning Study (ORRS) (DWAF, 1995).
(8) Average area assumed in this study to agree with the National Water Resources Strategy.
(9) Algoa System Analysis (DWAF, 1994a).
(10) Eastern Cape Water Resources situation Assessment (DWAF, 1999b).

(ii) The Tarka River Government Water Scheme obtains water from Commando Drift Dam, as well as from the recently completed (1992) ORP pump and canal scheme, which serves the area below Lake Arthur. Of the 2 663,4 ha of land originally scheduled under the scheme, 1 742,7 ha is now supplied from the Orange-Fish Transfer Scheme (included in the total area given in (i) above), leaving 920,7 ha to be supplied from Commando Drift Dam in 1995. It is understood that, because of loss of capacity as a result of siltation, together with the building of dams, abstraction works and anti-erosion structures in its catchment, the yield of Lake Arthur is negligible. Recently completed calculations by DWAF indicate that the 1:20 year yield of Commando Drift Dam is 8,8 million m^3/a. This equates to a 1:10 year yield of approximately 10,8 million m^3/a and a 1:50 year yield of 7,3 million m^3/a.

(iii) Along the Fish River below the Elandsdrift Weir and along the Fish-Sundays River Canal the total area of land scheduled in 1995 was 14 334 ha, of which the area irrigated in 1995 was between the 13 000 ha assumed in the Orange River Project Replanning Study (DWAF, 1995b) and the 11 190 ha assumed for this situation assessment. Crops grown are lucerne (60%), wheat (15%), pasture (15%) and maize (10%). The area comprises the part of the Orange River Development Project area that extends along the Great Fish River from Elandsdrift Weir to the confluence with the Little Fish River, from Elandsdrift Weir to De Mistkraal Weir on the Little Fish River and on along the Little Fish to its confluence with the Great Fish, and from De Mistkraal Weir across to the Skoenmakers River and along it to Darlington Dam. The main features of the infrastructure are described in Section 4.2. Water is distributed by means of unlined secondary canals from which seepage and evaporation losses have been estimated to be 25% of the field edge irrigation requirement. The total allocation of water to the scheme is 236 million m^3/a, including the allowance for distribution losses. The theoretical water requirement for the assumed irrigated area of 11 190 ha is 234 million m^3/a, including 25% distribution losses, but excluding river losses. The water is applied by flood irrigation.

(iv) The Lower Fish River Government Water Scheme is also part of the Orange River Development Project. Water for Grahamstown and the Lower Fish River is diverted from the Great Fish River at Hermanuskraal Weir through a tunnel to Glen Melville Dam. Water for the irrigation scheme is conveyed by river and canal from there to the Glen Boyd Balancing Dam, whence it is distributed to irrigators by pipeline. The Lower Fish River Government Water Scheme is situated on the right bank of the Fish River and 375 ha of land was scheduled under it in 1995. The actual area irrigated in 1995 was between 300 ha (DWAF, 1996) and the 266 ha assumed for this situation assessment. Irrigation is mainly by sprinkler and lucerne is the main crop produced. The water allocation is 14 million m^3/a, inclusive of distribution losses, and present average use is about 11 million m^3/a. The main supply pipeline for the scheme was originally intended to be constructed along the west bank of the Great Fish River, with three river crossings to serve 1 449 ha of lands between Committees Drift and Tyefu in the former Ciskei. When this main pipeline was curtailed because of a shortage of funds, only a single connection was provided to serve the Ciskei. However, the pipeline was extended 4 km into the Ciskei as compensation for the reduction in the number of river crossings. This pipeline was to have been extended by the Government of Ciskei, but that was not done before the demise of the Ciskei. The possible extension of the pipeline is at present under investigation. Included in the 1 449 ha of land to be irrigated from the pipelines was the area that was previously farmed under the Tyefu Irrigation Scheme described in (v) below.

(v) The Tyefu Irrigation Scheme comprises a number of small schemes on the left bank of the Great Fish River, over a distance of about 25 km downstream of Committees Drift, based on local dams and water pumped from the Fish River to irrigate 694 ha of land that was cultivated by small scale farmers. This was once described as one of the most successful small scale farmer schemes in the Eastern Cape Province (Water Research Commission, July 1996). After the liquidation of Ulimocor, which originally ran the schemes on behalf of the Ciskei Government, most of the schemes fell into disuse because of non-payment of electricity charges. Crops grown were lucerne (60%), maize (20%) and mixed vegetables (20%). The allocation of water when the schemes were in full operation was 6,88 million m^3/a, but the theoretical requirement was 7,35 million m^3/a (DWAF, 1995). Irrigation was by sprinkler.

In 1999 a feasibility study was done to test the economics of a scheme which would take off water from the pipeline across the Great Fish River described in (iv) above, and distribute it via a network of pipelines and several balancing dams to some 1 430 ha of land. The study showed the scheme to be economically viable and a first phase of the scheme, comprising the development of 346 ha of land, started in mid 2002. If funds are forthcoming, a second phase to irrigate 1 084 ha of land will be constructed in due course. Citrus, sugar beet, and vegetables were identified as ideal crops to ensure a sustainable scheme.

(vi) The Lower Sundays River Government Water Scheme is another part of the Orange River Project. Transfers from the Orange River, together with natural runoff from the upper Sundays River, are regulated by Darlington Dam. It has a full supply capacity of 187 million m^3 but is operated at 21% of this because of concerns about risk of failure of the spillway gates if it is operated at greater capacity. The 1:50 year yield of the dam operated in this way, and without transfers from the Orange/Fish system, would be less than 5 million m^3/a. The allocation of water to the Lower Sundays Scheme, including canal losses of 17 million m;/a, is 131 million m^3/a. It is apparent from this that the Sundays River itself contributes very little to the assured supply to the scheme. (DWAF has calculated that the 1:50 year yield of the dam, if operated at full capacity, would be 28,3 million m^3/a). Enlargement of the scheme was commenced in 1986 to increase the scheduled area from 9 470 ha to 20 510 ha. This work was, however, curtailed, and the present scheduled area is 14 000 ha, and was about 12 500 ha in 1995. Crops grown are citrus (60%), lucerne (20%) and vegetables. The allocation of 130 million m^3/a is less than the theoretical requirement of 152 million m^3/a.

(vii) The Van Rynevelds Pass Irrigation Scheme is situated along the upper Sundays River near Graaff-Reinet. The dam together with the water allocated to irrigation was sold to Graaff-Reinet Municipality in 2000 for use for the town water supply, and the land was descheduled. The 3 380 ha of land that was scheduled under the scheme relied on Van Rynevelds Pass Dam for water. The live storage capacity of the dam decreased from 80 million m^3 when it was constructed in 1924 to 47,2 million m^3 when it was last measured in 1998. The 1:50 year yield of the dam was estimated in this study to be 4,5 million m^3/a. An amount of 3,3 million m^3/a of this was allocated to Graaff-Reinet for urban use, leaving 1,2 million m^3/a for irrigation. This is estimated to be equivalent to about 2,5 million m^3/a at a reliability of 1:5 years. As the theoretical irrigation requirement of the land scheduled under the scheme was 27 million m^3/a, it is clear that water was supplied at low reliability. The crops grown when water was available were lucerne, other fodder crops, maize and vegetables. It was reported that there was virtually no irrigation in this area in 1995 because of lack of water (DWAF, 1995b).

(viii) The Groot River Government Water Scheme relies on Beervlei Dam for water. An area of 2 516 ha was scheduled under the scheme in 1995 and 2 530 ha were irrigated. The theoretical water requirement is 30 million m^3/a, but annual average use is reported to be 18,5 million m^3/a (Midgley *et al*, 1995). The yield of Beervlei Dam was roughly estimated in this study to be 20 million m^3/a at 1:10 year assurance and 12 million m^3/a at 1:50 year assurance.

(ix) The Gamtoos River Irrigation Scheme is supplied with water from a canal that runs between Kouga and Loerie Dams (see Section 4.3). The scheduled area in 1995 was 7 353 ha, but 9 880 ha were irrigated (DWAF, 1994a). Crops grown are vegetables (60%), citrus (22%), lucerne and tobacco. The present allocation of water from Kouga and Loerie Dams is 58,6 million m^3/a to the Gamtoos Irrigation Board and 23 million m^3/a to Port Elizabeth. In addition, canal losses are about 13,5 million m^3/a. Therefore the total requirement from the system in terms of allocations is 95,1 million m^3/a. In discussions held with the Gamtoos Irrigation Board and Port Elizabeth Municipality during the Algoa Water Resources System Analysis (DWAF, 1996), it was established that the required reliability of supply before selective water restrictions are applied is a risk of failure of 1:20 years. A total requirement of 95 million m^3/a cannot be met at this level of assurance. It appears, however, that the farmers at present use only about 75% of their allocation of 58,6 million m^3/a. If their requirements remain at this level, the total requirement reduces by about 15 million m^3/a to 80 million m^3/a, a quantity of water that can be supplied at a risk of failure of about 1:30 years.

4.7 IRRIGATION IN THE LANGKLOOF

The Langkloof in the upper reaches of the catchment of the Kouga River (sub-catchments L82A, B, C and D on Figure 4.1.1) is an area of intensive irrigation from farm dams. It was estimated (DWAF, 1994a) that, in 1992, irrigated land in the area consisted of 5 635 ha of deciduous fruit orchards and 145 ha of pasture.

Irrigation is from a large number of farm dams, the combined capacity of which in 1992 was estimated (DWAF, 1994a) to be some 26 million m;.

Irrigation water use, based on field edge requirements of 5 390 m;/ha for orchards (factored by 0,92 to allow for reduced water requirements of young, non-bearing trees) and 1 450 m;/ha for pasture, were estimated to be 29 million m;/a. The average reduction in runoff into Kouga Dam caused by the irrigation in the Langkloof was calculated to be 32,5 million m;/a, indicating evaporation and distribution losses of 3,5 million m;/a (DWAF, 1994b).

Future growth in irrigation in this area is likely to be determined by availability of water and market forces. The impoundment and abstraction limits were restricted in terms of Section 9B (1c) of the old Water Act (Act 54 of 1956) to 10 000 m^3 and 10 ℓ/s, respectively, upstream of Kouga Dam, which had an effect on development. These limits may only be exceeded with a permit issued by the Minister of Water Affairs and Forestry. Owing to the high degree of development in the area, together with its effect on the yield of Kouga Dam (and other dams which may be constructed downstream for supply to Port Elizabeth) permits for large waterworks in the Langkloof will probably only be given in exceptional circumstances. With the promulgation of the NWA and its licensing system, these limits are now zero, and any new waterwork, or augmentation of an existing waterwork, will require a licence.

4.8 HYDRO-POWER AND PUMPED STORAGE

There is a small hydro-power station at the outlet to the Orange-Fish Tunnel at Teebus. It was originally intended to provide power for the works at the tunnel, but, apart from periodic exercising has been unused since it was installed, power from the national grid being used instead. The plant consists of a 600 kVA Francis turbine driven alternator operated by water discharged from the tunnel. The generator and some electronic control equipment were damaged in an accident in 1990 and have not been repaired.

A small hydro-power station at Kouga Dam has been decommissioned because of deterioration of the mechanical plant and severe leakage from the balancing dam that was a component of the scheme.

There are no other hydro-power stations in the WMA.

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

Water requirements in the Fish to Tsitsikamma WMA totalled an estimated 1 401 million m³/a in 1995, distributed amongst user groups as shown in Table 5.1.1. The major requirements were for agriculture, which, at 911 million m³/a, accounted for 65% of total water requirements, and the riverine ecosystem, which required an estimated 243 million m³/a (17,4%) to sustain it. Alien vegetation used a substantial 88 million m^3/a, and afforestation used 54 million m^3/a. Urban and domestic water requirements were significant at 105 million m³/a (7,5%), and the remaining groups of bulk water use, water transfer, neighbouring states and hydro-power required no water in this WMA.

The values shown in Table 5.1.1 include conveyance and distribution losses, where applicable, and have not had return flows that are re-used further downstream deducted from them. Therefore, they represent estimates of gross water use.

It should be noted that, because of the limited availability of reliable data, the level of confidence in the estimates is not high. Values are given to one decimal place in Table 5.1.1 for ease of correlation with other more detailed tables appearing later in this chapter, but that does not mean that the values are accurate to one decimal place.

The agricultural water requirements shown in Table 5.1.1 represent irrigation and livestock watering requirements. Livestock accounts for 14 million m³/a.

The distribution of total water requirements at 1:50 year assurance is shown on Figure 5.1.1, and water requirements per user group are shown in Figure 5.1.2.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP IN 1995

USER GROUP	ESTIMATED WATER REQUIREMENT		REQUIREMENTS AT 1:50 YEAR ASSURANCE (5)	
	(million m^3/a)	%	(million m^3/a)	%
Ecological Reserve (4)	242,9	17,4	30,3	4,5
Domestic (1)	104,9	7,5	104,9	11,0
Bulk water use	0,0	0,0	0,0	0,0
Neighbouring States	0,0	0,0	0,0	0,0
Agriculture (2)	911,5	65,0	773,5	81,5
Afforestation	53,7	3,8	7,1	0,7
Alien vegetation	88,4	6,3	21,6	2,3
Water transfers (3)	0,0	0,0	0,0	0,0
Hydro-power	0,0	0,0	0,0	0,0
TOTALS	1401,4	100,0	937,4	100,0

(1) Includes urban and rural domestic requirements (excluding stock watering) and commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, dry land sugar cane, livestock and game.
(3) Only transfers out of the WMA are included.
(4) At outlet of WMA.
(5) The requirement shown at 1:50 year assurance represents the impact on the system yield, as developed in 1995, of the estimated water requirement.

The requirements at 1:50 year assurance for the domestic and agricultural user groups are equivalent requirements. They are presented in this way to bring quantities of water that are required at different assurances of supply by consumers to a common base for purposes of comparing water requirements with the available yield. For example, a portion of the yield of a dam might be allocated to industrial use at 1:200 year assurance, a portion to irrigation of orchards at 1:20 year assurance, and a portion to annual crops at 1:5 year assurance. The yield/assurance curve for a dam defines the quantity of water that can be supplied at any particular assurance: the lower the assurance, the greater the quantity of water that can be provided. Thus, for the hypothetical dam of the above example, the quantity of water supplied at 1:200 year assurance could be converted to a theoretical equivalent greater quantity of water at 1:50 year assurance by using the yield/assurance curve. Similarly, the quantities of water supplied at 1:20 year assurance and 1:5 year assurance could be converted to equivalent theoretical smaller quantities at 1:50 year assurance. Adding together the three equivalent quantities at 1:50 year assurance would give the total equivalent requirement at 1:50 year assurance. This value could be compared with the yield of the dam at 1:50 year assurance to determine the balance between yield and allocations of water.

Domestic water requirements and the drinking water requirements of livestock have been assumed to be supplied at 1:50 year assurance under normal conditions. The assurances at which water for irrigation is required have been assumed to vary with the commercial value of the crops irrigated. This accounts for the smaller requirement at 1:50 year assurance for agriculture in Table 5.1.1.

The estimated water requirement for the ecological Reserve shown in Table 5.1.1 is the average volume of water that needs to be allowed to flow into the sea from the WMA. The requirement at 1:50 year assurance is the impact of the requirement for the ecological Reserve on the 1:50 year yield of the water resources as developed in 1995. It should be noted that, if more major dams were constructed, the impact of the ecological Reserve on the 1:50 year yield would increase.

Similarly, the estimated requirements for afforestation and alien vegetation are the reductions that they cause in mean annual runoff, while the requirements at 1:50 year assurance are their impacts on the developed 1:50 year yield in 1995.

5.2 ECOLOGICAL COMPONENT OF THE RESERVE

5.2.1 Introduction

The classification of the main stem rivers in the vicinity of the outlets of the quaternary catchments is described in Section 2.6.3. On the basis of this classification, a so-called desktop method has been developed (Hughes and Münster, 1999) to provide a low-confidence estimate of the quantity of water required for the ecological component of the Reserve, which is suitable for use in this water resources situation assessment.

The method involves the extrapolation of high confidence results of previous instream flow requirement (IFR) workshops, the use of a reference time series of monthly runoff at the outlet of the quaternary catchment and a number of hydrological indices or parameters that have been defined for 21 desktop Reserve parameter regions in South Africa. These desktop Reserve parameter regions are described and shown in Figure 5.2.1.1. The instream flow requirements that were determined previously were mostly based on the use of the Building Block Method (King and Louw, 1998).

The monthly time series of natural flow that has been used is described in Section 6.3. The following are the two main hydrological parameters :

- a measure of the longer term variability, which is a combination of the coefficients of variation of winter and summer volumes (CV); and
- an estimate of the proportion of the total flow that occurs as base flow (BFI), which can be considered to be a measure of short-term variability.

The ratio of the above two indices (CV/BFI) has been used as an overall hydrological index of flow variability or reliability. Rivers with low variability and a high base flow response have very low hydrological indices of flow variability and vice versa.

A relationship has been found between the hydrological index of flow variability, the ecological status and the annual requirements for low and high flows for the so-called maintenance and drought periods of the modified flow regime for the river. The essence of the relationship is that for a particular ecological status or class, the water required for the ecological component of the Reserve will increase as the hydrological index of flow variability decreases, and vice versa. Furthermore, the water requirement will decrease as the ecological status is decreased.

The method that has been used is based on a series of assumptions, many of which have not yet been verified due to either a lack of information or of time since the method was developed. The following is a summary of the main limitations in order to provide an indication of the level of accuracy that can be expected:

- The extrapolations from past IFR workshops are based on a very limited data set, which does not cover the whole of the country. While some development work has been completed to try and extend the extrapolations and has improved the high flow estimations for dry and variable rivers, this has been limited.
- The extrapolations are based on a hydrological index and no allowance (in the desktop method adopted for this water resources situation assessment) has been made for regional, or site-specific ecological factors. It is unlikely that an index based purely on hydrological characteristics can be considered satisfactory but it represents a pragmatic solution in the absence of sufficient ecological data.
- The method assumes that the monthly time series of natural flows are representative of real natural flow regimes and many of the algorithms rely upon the flow characteristics being accurately represented. Should the data indicate more extended base flows than actually occur, the hydrological index of flow variability would be under-estimated and the water requirements for the ecological component of the Reserve would be over-estimated.

5.2.2 Quantifying the Water Requirements

A simulation model has been developed to simulate the relationships that were found to exist between the hydrological index of flow variability, the ecological status and the annual requirements for low and high flows and for so-called maintenance and drought flow periods (Hughes and Münster, 1999).

The simulation model provides annual maintenance and drought low flows and maintenance high flows (expressed as a proportion of the mean annual runoff). The model also provides for the seasonal distribution and assurances associated with the monthly flows on the basis of a set of default parameters that has been developed for each of the 21 desktop Reserve parameter regions of South Africa referred to in Section 5.2.1. The quaternary catchments in the Fish to Tsitsikamma WMA fall within the so-called Southern Cape (wet), Southern Karoo, Eastern Cape (arid), Eastern Karoo and Eastern Cape regions.

The monthly time series of natural flows at the outlets of the quaternary catchments have been used to generate an equivalent time series of water requirements for the ecological component of the Reserve. This has been accomplished by relating the assurances of the natural flows in a particular month to the assurances of the flow required for the ecological component of the Reserve during the same month.

In the water balance model it is necessary to express the water requirements for the ecological component of the Reserve in terms of annual requirements that are directly comparable to those of any other sector. It therefore becomes necessary to reduce these water requirements to a common assurance and more specifically the effect that these requirements will have on the capacity of the river system to supply water at a specific assurance, i.e. the effect on the yield of the river system.

The effects on the yield of the river system of the water required for the ecological component of the Reserve have been based on an analysis of the monthly time series of these water requirements for the same 70-year period as for the natural time series of flows that is described in Section 6.3. This has been estimated by establishing the average annual quantity of water required for the ecological component of the Reserve during the most severe or so-called critical drought that has determined the yield of the river system at a recurrence interval of 50 years. The duration of the critical drought can be approximated by the (inverse of) marginal rate of increase of the yield of the river system per unit increase in storage capacity, i.e. the slope of the storage-yield curve at the storage capacity under consideration. The periods of high and low flows in the monthly time series of water requirements for the ecological component of the Reserve also mimic the periods of high and low flows in the monthly time series of natural flows used to establish the yield of the river system. Therefore, the portion of the yield of the system that is required for the ecological component of the Reserve can be estimated by finding the least average flow for all periods in the monthly time series of water requirements for the ecological component of the Reserve that are as long as the critical drought period.

The monthly time series of water requirements for the ecological component of the Reserve has been determined at the outlet of each quaternary catchment for each of the ecological status Classes A to D. These time series have been analysed for various lengths of the critical drought to establish the system yield required for the ecological component of the Reserve. This has been done for a range of system capacities, from which the appropriate value corresponding to the storage capacity being considered has then been selected for use in the water balance.

The method that has been used to quantify the water requirements is based on a series of assumptions, many of which have not yet been verified due to either a lack of information or of time since the method was developed. The following is a summary of the main limitations in order to provide an indication of the level of accuracy that can be expected:

- The seasonal distributions of the annual estimates of water requirements are based on analyses of the base flow characteristics of some 70 rivers using daily data, the results of which were then regionalised. Some individual quaternary catchments that have been allocated to a specific region may however, have somewhat different characteristics.

- Similarly, the regional parameters for the assurance rule curves have been based on the duration curve characteristics of the natural flow regimes represented by the monthly time series of flow described in Section 6.3 and some experience of setting assurance rules used at past IFR workshops. Regionalising was done by investigating a representative sample of quaternary catchments and it is therefore possible that some have been assigned to the wrong regions.

- The estimates of water required for the ecological component of the Reserve are the best estimates that can be given at this stage, but must be regarded as low confidence estimates. As more detailed estimates are made for a wider range of rivers, the estimates will be improved through modifications made to the delineation of the regions and the regional parameters that have been assigned. It is also anticipated that a better way of accounting for regional or site specific ecological considerations will be added in due course.

5.2.3 Comments on the Results

The determination of the PESC, as described in Section 2.6 is a critical component of quantifying the water requirements of the ecological component of the Reserve.

The members of the specialist team that carried out the assessment by means of which this was done expressed their opinions on the strengths and weaknesses of the processes. These opinions are summarised below:

- The process could be improved with the use of up to date GIS land usage maps with the EISC on them.

- Inclusion of an amphibian and vegetation expert would aid the process and validity of the Eastern Cape data.

- Findings should be treated with extreme caution and only used as a desktop estimate as some of the confidence levels are very low.

- There is a need for a follow-up survey to validate the data.

- Quaternary catchments are a problem as they are non-ecological (should be an eco-region approach).

- There is a need to note that present status of rivers can vary within groupings due to localised degradation of sections of rivers.

- In order to aid the process, more readily available information in the form of maps (e.g. land-use coverages, vegetation zones, etc) should have been made available.

- Even where very little or no direct knowledge of a river was available, it proved possible for some quaternary catchments to provide quite a good assessment by using regional expertise to extrapolate and using 1:250 000 maps to examine contours (for gradient, gorges, etc), roads (for indicators of access or isolation), towns and villages (as indications of population density) and land uses (e.g. plantations).

- Confidence scores should be extrapolated to ensure that where riverine systems are not well known this can be indicated.
- The models are based only on flow and water quality, with the result that improvements to the riverine system by means of changing land use practices was not taken into account.

5.2.4 Presentation of Results

The water requirements of the ecological component of the Reserve derived from the assessment are shown in Table 5.2.4.1 in terms of percentage of MAR, long term average annual flow volume and impact on 1:50 year yield, for key points. The key points are all located at the outlets of the key areas described in Section 2.1.

The long-term average total ecological flow requirement for the whole WMA is 243 million m^3/a, or 11% of the total natural MAR. However, it can be seen from Table 5.2.4.1 that the percentage of the MAR required for ecological flows varies considerably from key point to key point within the WMA. The highest requirement in terms of percentage of MAR is in the Tsitsikamma coastal area where up to 26% is required, because of the high conservation value of many of the rivers, for the reasons given in Section 2.6.3. In many areas, where the rivers have been largely modified by human activities, only about 6% of the MAR is required, on average. It should be noted that the requirements are for the preservation of the rivers in their existing state and do not provide for improvement.

TABLE 5.2.4.1: WATER REQUIREMENTS FOR THE ECOLOGICAL COMPONENT OF THE RESERVE

KEY POINT	PRESENT (1) ECOLOGICAL STATUS CLASS (PESC)	RIVERINE ECOLOGICAL WATER REQUIREMENTS FOR PESC		
		% VIRGIN MAR	LONG-TERM AVERAGE REQUIREMENT (million m^3/a)	IMPACT ON 1:50 YEAR YIELD (million m^3/a)
Upper Krom (K90D)	D	10,6	9,2	4,5 (2)
Tsitsikamma Coast (K80A to F, K90E, F, G)	C, D, B	19,3 to 26,2	107,0 (2)	13,4 (2)
Upper Groot (L23D)	C	9,1	13,0	0,0
Lower Groot (L70G)	C	8,7	18,2	0,0
Kouga (L82J)	D	10,3	20,0	2,3 (2)
Gamtoos (L90C)	D	7,9	39,0 (2)	0,0
Algoa Coast (M20A, B, M10D, M30B)	C, D, F	5,6 to 10,4	15,0 (2)	1,5 (2)
Upper Sundays (N12C)	D	6,7	3,0	1,1 (2)
Middle Sundays (N23B)	F	6,3	13,1	0,0
Lower Sundays (N40F)	D	7,0	19,8 (2)	3,7 (2)
(2)Albany Coastal Catchments (P10G, P20A, P20B, P40C, P40D)	D, C	6,7 to 10,6	15,3 (2)	0,0
Upper Fish (Q13A)	D	7,5	4,5	1,2 (2)
Tarka (Q44B)	D	6,9	4,6	1,3 (2)
Upper Middle Fish (Q50A)	D	7,2	15,5	0,0
Upper Little Fish (Q80E)	C	10,9	4,2	0,0
Middle Fish (Q91A)	D	7,3	23,2	0,0
Koonap (Q92G)	C	12,6	9,6	0,0
Kat (Q94F)	D	10,1	7,1	1,3 (2)
Lower Fish (Q93D)	D	7,6	46,8 (2)	0,0
TOTAL FOR WMA (K80A to F, K90E, F, G, L90C, M10D, M20A, B, N30B, N40F, P10G, P20A, B, P30C, P40C, P40D, Q93D)	-	**11,3**	**242,9**	**30,3**

(1) The class allocation in the table denotes that of the river at the key point (i.e. outlet of the catchment). In "combined outlet" catchments, more than one class is applicable as a common outlet does not physically occur.

(2) Contributions to total for WMA.

5.2.5 Discussion and Conclusions

The determination of the impact of the ecological flow requirements on the 1:50 year yield of the Fish to Tsitsikamma WMA is complex because there are several dams of significant size and there is also use of run-of-river yield in some areas. The estimated impact on the total 1:50 year yield of the WMA is 42,5 million m^3/a, made up as shown in Table 5.2.4.1. These estimates are at a low level of confidence and it is possible that the true impact is higher than estimated. The impacts are a combination of impacts on the yields of dams and impacts on utilised run-of-river yield, calculated as described in Section 7.1.3.

Descriptions of the derivations of the estimates follow:

- In the Upper Krom the impact on the 1:50 year yield of Impofu Dam (K90D) was estimated to be — 4,5 million m^3/a

- In the Tsitsikamma Coastal catchments the impact on the utilised 1:50 year run-of-river yields of the rivers was estimated to be — 13,4 million m^3/a

- In the Kouga catchment the impact on the 1:50 year yield of Kouga Dam (L82H) was estimated to be — 2,3 million m^3/a
  (The releases from Kouga Dam would flow into the Gamtoos River which would be dry under 1:50 year drought conditions and have no ecological flow requirement. Therefore, it is assumed that no ecological releases would be made during a severe drought and that the estimated impact on the 1:50 year yield is caused by ecological releases made during wetter seasons which deplete the quantity of water stored in the dam for use during severe droughts).

- In the Algoa Coastal Catchments the impacts on the 1:50 year yields of Groendal, Bulk River and Sand River Dams was estimated to be — 1,5 million m^3/a

- In the Sundays River Basin the impacts on the 1:50 year yields of Van Ryneveld's Pass (1,1 million m^3/a) and Darlington (3,7 million m^3/a) Dams were estimated to total — 4,8 million m^3/a
  (Impacts on run-of-river yields downstream of these dams were estimated to be zero).

- In the Fish River Basin the impacts on the 1:50 year yields of Grassridge Dam (1,2 million m^3/a), Commando Drift Dam (1,3 million m^3/a) and Kat River Dam (1,3 million m^3/a) were estimated to total — 3,8 million m^3/a
  (Impacts on run-of-river yields downstream of the dams were all estimated to be less than the impacts on the yields of the dams. Therefore, the ecological flow requirements of these reaches were assumed to be provided by the releases from the dams).

- This gives a total for the WMA of — 30,3 million m^3/a

It should be noted that the impact of the ecological flow requirements on the 1:50 year yield of the system would increase if more dams were to be developed or the utilised run-of-river yield increased. It is emphasised that the estimates of the ecological Reserve originating from the procedure used in this study should be used only for broad, very general planning purposes. The confidence levels in the management classes determined for individual quaternary catchments are highly variable as they depend on the levels of knowledge of the individuals of the specialist team. This should be borne in mind when using the data. In all cases where information requirements go beyond the general planning level, the procedures developed for the determination of the ecological Reserve at the Rapid, Intermediate, or Comprehensive levels should be applied.

5.3 URBAN AND RURAL

5.3.1 Introduction

The distribution of urban water requirements and rural domestic water requirements is shown on Figure 5.3.1.1 and in Table 5.3.1.1. The requirements shown include distribution and conveyance losses.

The total combined requirement at 1995 levels of development was estimated to be 105 million m^3/a, of which approximately 100 million m^3/a was required by towns and 5 million m^3/a by consumers in the rural areas. Most of the water requirements in these categories occur in the densely populated south-western part of the WMA. It was assumed that the full requirement was at 1:50 year assurance.

Table 5.3.1.1 also shows the Human Reserve requirement, calculated on the basis of 25 ℓ/person/day for the total population, and totalling 14,8 million m^3/a for the WMA. This requirement is included in those requirements shown in the other columns of Table 5.3.1.1.

5.3.2 Urban

Introduction

A study by Schlemmer *et al* (2001) in support of the development of the National Water Resource Strategy developed a methodology to provide a framework for estimation of both direct and indirect water requirements for the entire South Africa, as well as for the development of long-term projections. A framework methodology was developed on the basis of available information. Information collected in the field as part of the Water Resources Situation Assessments was used to refine the analysis, identify default values and where available update the default database figures.

Methodology

Urban water requirements were classified into direct use by the population plus indirect use by commerce, industries, institutions and municipalities related to the direct use. These are dealt with below.

TABLE 5.3.1.1: URBAN AND RURAL DOMESTIC WATER REQUIREMENTS IN 1995

CATCHMENT						URBAN REQUIREMENTS (million m^3/a)	RURAL DOMESTIC WATER REQUIREMENTS (million m^3/a)	COMBINED URBAN AND RURAL DOMESTIC REQUIREMENTS (million m^3/a)	REQUIREMENTS AT 1:50 YEAR ASSURNACE (million m^3/a)	HUMAN RESERVE (million m^3/a)
PRIMARY		SECONDARY		TERTIARY/QUATERNARY						
No.	Description	No.	Description	No.	Description					
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	0,20	0,05	0,25	0,25	0,03
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	2,72	0,23	2,95	2,95	0,43
		TOTAL IN KROM/TSITSIKAMMA				**2,92**	**0,28**	**3,20**	**3,20**	**0,46**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	0,32 0,00 0,04	0,08 0,01 0,08	0,40 0,01 0,12	0,40 0,01 0,12	0,05 0,01 0,04
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	0,66	0,18	0,84	0,84	0,16
		L8	Kouga	L81, L82	Western Cape Eastern Cape	0,15 0,67	0,07 0,22	0,22 0,89	0,22 0,89	0,04 0,14
		L9	Gamtoos	L90A to C	All Eastern Cape	1,03	0,12	1,15	1,15	0,21
		Total in Groot/Gamtoos Basin in Northern Cape				0,00	0,01	0,01	0,01	0,01
		Total in Groot/Gamtoos Basin in Western Cape				0,47	0,15	0,62	0,62	0,09
		Total in Groot/Gamtoos Basin in Eastern Cape				2,40	0,60	3,00	3,00	0,55
		TOTAL IN GROOT/GAMTOOS BASIN				**2,87**	**0,76**	**3,63**	**3,63**	**0,65**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**69,00**	**0,35**	**69,35**	**69,35**	**9,47**
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 0,11	0,00 0,10	0,00 0,21	0,00 0,21	0,00 0,03
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	3,36	0,31	3,67	3,67	0,50
		N4	Lower Sundays	N40	All Eastern Cape	1,31	0,36	1,67	1,67	0,35
		TOTAL IN SUNDAYS BASIN				**4,78**	**0,77**	**5,55**	**5,55**	**0,88**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**8,32**	**0,70**	**9,02**	**9,02**	**1,24**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,61	0,14	0,75	0,75	0,13
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,14	0,21	0,35	0,35	0,09
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C, Q30, Q50A, Q44C	All Eastern Cape	6,19	0,42	6,61	6,61	0,51
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	1,13	0,08	1,21	1,21	0,17
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	0,30	0,22	0,52	0,52	0,11
		Q9 (Part)	Koonap	Q92	All Eastern Cape	1,12	0,28	1,40	1,40	0,27
		Q9 (Part)	Kat	Q94	All Eastern Cape	2,20	0,40	2,60	2,60	0,52
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	0,34	0,36	0,70	0,70	0,34
		TOTAL IN GREAT FISH BASIN				**12,03**	**2,11**	**14,14**	**14,14**	**2,14**
TOTAL IN WMA IN NORTHERN CAPE						0,00	0,01	0,01	0,01	0,01
TOTAL IN WMA IN WESTERN CAPE						0,47	0,15	0,62	0,62	0,09
TOTAL IN WMA IN EASTERN CAPE						99,45	4,81	104,26	104,26	14,71
TOTAL IN WMA						**99,92**	**4,97**	**104,89**	**104,89**	**14,81**

Direct Water Use

The following criteria were considered significant in identifying categories of direct water use:

- Economic strata.
- Types of housing.
- Levels of service provided.
- Extent of local authority records.

It was recognised that a critical factor to be considered was the dependence on data that was required from Local and Water Service Authorities. Generally many authorities have records of water supplied to different users; individual households, and at times to flats and multi-household complexes. Further detail is not common

Categories of direct water use were then identified in order to develop profiles of use per urban centre (see Table below). The populations of the urban centres that had been determined were allocated to these categories by Schlemmer *et al* (2001), on the basis of socio-economic category characteristics of each centre.

The study then proceeded to derive per capita water use for each of these categories using information from the South African Local Government Handbook, and the data collected as part of the Water Resources Situation Assessments from local authorities at the time. Where detailed data was not available, an estimation procedure was followed. The categories defined were associated with default unit water uses to generate overall water use estimates where hard data was not available. These categories and default unit water uses are listed in Table 5.3.2.1.

TABLE 5.3.2.1: DIRECT WATER USE: CATEGORIES AND ESTIMATED UNIT WATER USE

CATEGORY		WATER USE ℓ/c/d
1.	Full service : Houses on large erven > 500m^2	320
2.	Full service: Flats, Town Houses, Cluster Houses	320
3.	Full service : Houses on small erven <500m^2	160
4.	Small houses, RDP houses and shanties with water connection but minimal or no sewerage service	90
5.	Informal houses and shanties with service by communal tap only	10
6.	No service from any water distribution system	6
7.	Other/Miscellaneous	90

Indirect Water Use

Indirect water use was considered in terms of four categories, viz. commercial, industrial, institutional and municipal. Again, available information was complemented by data collected as part of the Water Resources Situation Assessments from local authorities at the time. Limited hard data was obtained at the level of detail sought.

In order to develop a comprehensive set of estimates, a standard table relating the components of indirect water use to the total direct water use of an urban centre was developed. The urban centres were first classified according to shared characteristics related to water use. The classification used is shown in Table 5.3.2.2.

TABLE 5.3.2.2: CLASSIFICATION OF URBAN CENTRES RELATED TO INDIRECT WATER USE

CLASSIFICATION	TYPE OF CENTRE	PERCEPTION
1.	Long established Metropolitan centres (M)	Large conurbation of a number of largely independent local authorities generally functioning as an entity.
2.	City (C)	Substantial authority functioning as a single entity isolated or part of a regional conurbation.
3.	Town: Industrial (Ti)	A town serving as a centre for predominantly industrial activity.
4.	Town: Isolated (Tis)	A town functioning generally as a regional centre of essentially minor regional activities.
5.	Town: Special (Ts)	A town having significant regular variations of population consequent on special functions. (Universities, holiday resorts, etc.).
6.	Town: Country (Tc)	A small town serving essentially as a local centre supporting only limited local activities.
New Centres		
7.	Contiguous (Nc)	A separate statutory authority, or number of authorities adjacent to, or close to, a metropolis or city and functioning as a component part of the whole conurbation.
8.	Isolated (Nis)	A substantial authority or group of contiguous authorities not adjacent to an established metropolis or city.
9.	Minor (Nm)	Smaller centres with identifiable new or older established centres not constituting centres of significant commercial or industrial activity.
10.	Rural (Nr)	All other areas not having significant centres.

Default profiles of indirect water use in relation to total water use were developed on the basis of available information for these classes, and are given in the Table 5.3.2.3.

TABLE 5.3.2.3: INDIRECT WATER USE AS A COMPONENT OF TOTAL DIRECT WATER USE

<table>
<tr><th>URBAN CENTRE CLASSIFICATION</th><th>COMMERCIAL</th><th>INDUSTRIAL</th><th>INSTITUTIONAL</th><th>MUNICIPAL</th></tr>
<tr><td>Metropolitan</td><td rowspan="4">0.2</td><td rowspan="4">0.3</td><td rowspan="4">0.15</td><td rowspan="4">0.08</td></tr>
<tr><td>Cities</td></tr>
<tr><td>Towns Industrial</td></tr>
<tr><td>Towns Isolated</td></tr>
<tr><td>Towns Special</td><td>0.30</td><td>0.15</td><td>0.08</td><td>0.03</td></tr>
<tr><td>Towns Country</td><td>0.10</td><td>0.15</td><td>0.03</td><td>0.10</td></tr>
<tr><td>New Centres</td><td>0.15</td><td>0.08</td><td>0.08</td><td>0.08</td></tr>
</table>

Where detailed data was not available, Table 5.3.2.3 was used as a basis for estimating the indirect water use.

The distribution of urban water requirements determined on this basis is shown in Table 5.3.2.4, where bulk conveyance losses and distribution losses have been added to the estimated direct and indirect water requirements to derive total water requirements.

Information on water use by different categories of housing and on the ratios of indirect to direct water use is not available for the towns in the Fish to Tsitsikamma WMA. Therefore, the appropriate ratios of those shown in the above tables were used to estimate the split between direct and indirect water use.

The full requirements of the seven categories of direct water use shown in Table 5.3.2.1 and the four categories of indirect water use shown in Table 5.3.2.3 are supplied at different assurances, some at more than 1:50 year assurance and some at less than 1:50 year assurance. However, as neither the quantities of water required in the various user categories, nor the assurances at which they are supplied are accurately known for all urban areas, it was assumed that the average assurance of supply is 1:50 year.

Water Losses

Water losses occur in the conveyance of water from the raw water source to the water treatment works and from the treatment works to bulk treated water storage reservoirs. These are referred to in this report as bulk conveyance losses. They occur as a result of spillage, leakage and evaporation from canals, leakage from pipelines and storage reservoirs, and backwashing of filters at water treatment works.

Further losses occur between the bulk treated water storage reservoirs and consumers, mainly as a result of leaking or broken pipes and fittings. These are known as distribution losses.

Little information on losses in the various town supplies could be obtained. Therefore it was necessary to make assumptions based on the type of raw water supply, the distance over which water is conveyed, and the nature of the distribution system. The assumed values are shown in Table 5.3.2.4.

Return Flows

Return flows of treated sewage effluent are estimated to have totalled approximately 48 million m^3/a in 1995. Of this, 35,5 million m^3/a occurred in the Port Elizabeth/ Uitenhage area. This was less than the total volume of effluent produced as about 5 million m^3/a of the effluent was reclaimed and used by industry and 0,4 million m^3/a was conveyed from the sewage treatment works to storage for irrigation of lands. Of the 35,5 million m^3/a of return flows, 4,8 million m^3/a was discharged to the Zwartkops River and the rest was discharged to the sea. An estimated 0,5 million m^3/a (DWAF, 2001) is abstracted from the Zwartkops River by irrigators, and the rest flows out to sea. The effluent discharged to the Zwartkops River contributes to the quantity of the ecological flow requirements of the river and the Zwartkops Estuary, as it compensates to some extent for water that is abstracted upstream. Unfortunately, it has an adverse effect in terms of water quality because of its high nutrient content.

TABLE 5.3.2.4 : URBAN WATER REQUIREMENTS IN 1995

CATCHMENT						REQUIREMENTS						RETURN FLOW			
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		DIRECT (million m^3/a)	INDIRECT (million m^3/a)	LOSSES		TOTAL (million m^3/a)	TOTAL AT 1:50 YEAR ASSURANCE (million m^3/a)	EFFLUENT (million m^3/a)	IMPERVIOUS URBAN AREA (million m^3/a)	TOTAL RETURN FLOW (million m^3/a)	RETURN FLOW AT 1:50 YEAR ASSURANCE (million m^3/a)
No.	Description	No.	Description	No.	Description			(million m^3/a)	%						
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	0,14	0,05	0,01	5	0,20	0,20	0,10	0,05	0,15	0,10
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	1,26	0,77	0,69	25	2,72	2,72	1,20	0,78	1,98	1,20
		TOTAL IN KROM/TSITSIKAMMA				**1,40**	**0,82**	**0,70**	**25**	**2,92**	**2,92**	**1,30**	**0,83**	**2,13**	**1,30**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12, L21, L22, L23	Western Cape Northern Cape Eastern Cape	0,16 0,00 0,02	0,09 0,00 0,01	0,07 0,00 0,01	22 - 25	0,32 0,00 0,04	0,32 0,00 0,04	0,09 0,00 0,01	0,07 0,00 0,02	0,16 0,00 0,03	0,09 0,00 0,01
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	0,36	0,13	0,17	25	0,66	0,66	0,23	0,17	0,40	0,23
		L8	Kouga	L81, L82	Western Cape Eastern Cape	0,08 0,37	0,03 0,13	0,04 0,17	27 25	0,15 0,67	0,15 0,67	0,05 0,32	0,00 0,12	0,05 0,44	0,05 0,32
		L9	Gamtoos	L90A to C	All Eastern Cape	0,56	0,21	0,26	25	1,03	1,03	0,36	0,20	0,56	0,36
		Total in Groot/Gamtoos Basin in Northern Cape				**0,00**	**0,00**	0,00	-	0,00	0,00	0,00	0,00	0,00	0,00
		Total in Groot/Gamtoos Basin in Western Cape				**0,24**	**0,12**	0,11	23	0,47	0,47	0,14	0,07	0,21	0,14
		Total in Groot/Gamtoos Basin in Eastern Cape				**1,31**	**0,48**	0,61	25	2,40	2,40	0,92	0,51	1,43	0,92
		TOTAL IN GROOT/GAMTOOS BASIN				**1,55**	**0,60**	**0,72**	**25**	**2,87**	**2,87**	**1,06**	**0,58**	**1,64**	**1,06**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**31,40**	**20,10**	**17,50**	**25**	**69,00**	**69,00**	**35,50**	**11,21**	**46,71**	**35,50**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 0,06	0,00 0,02	0,00 0,03	- 27	0,00 0,11	0,00 0,11	0,00 0,03	0,00 0,02	0,00 0,05	0,00 0,03
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	1,55	0,96	0,85	25	3,36	3,36	1,50	0,48	1,98	1,50
		N4	Lower Sundays	N40	All Eastern Cape	0,72	0,26	0,33	25	1,31	1,31	0,47	0,20	0,67	0,47
		TOTAL IN SUNDAYS BASIN				**2,33**	**1,24**	**1,21**	**25**	**4,78**	**4,78**	**2,00**	**0,70**	**2,70**	**2,00**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**4,13**	**2,09**	**2,10**	**25**	**8,32**	**8,32**	**3,43**	**1,47**	**4,90**	**3,43**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,34	0,12	0,15	25	0,61	0,61	0,18	0,07	0,25	0,18
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,08	0,03	0,03	21	0,14	0,14	0,04	0,03	0,07	0,04
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	2,71	1,90	1,58	25	6,19	6,19	2,84	0,40	3,24	2,84
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	0,62	0,22	0,29	25	1,13	1,13	0,44	0,22	0,66	0,44
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	0,17	0,06	0,07	23	0,30	0,30	0,09	0,06	0,15	0,09
		Q9 (Part)	Koonap	Q92	All Eastern Cape	0,62	0,22	0,28	25	1,12	1,12	0,38	0,18	0,56	0,38
		Q9 (Part)	Kat	Q94	All Eastern Cape	0,99	0,65	0,56	25	2,20	2,20	0,85	0,13	0,98	0,85
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	0,19	0,06	0,09	26	0,34	0,34	0,09	0,12	0,21	0,09
		TOTAL IN GREAT FISH BASIN				**5,72**	**3,26**	**3,05**	**25**	**12,03**	**12,03**	**4,91**	**1,21**	**6,11**	**4,91**
TOTAL IN WMA IN NORTHERN CAPE						0,00	0,00	0,00	-	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL IN WMA IN WESTERN CAPE						0,24	0,12	0,11	23	0,47	0,47	0,14	0,07	0,21	0,14
TOTAL IN WMA IN EASTERN CAPE						46,29	27,99	25,22	25	99,45	99,45	48,06	15,93	63,99	48,06
TOTAL IN WMA						**46,53**	**28,11**	**25,33**	**25**	**99,92**	**99,92**	**48,20**	**16,00**	**64,20**	**48,20**

NOTE : The values of increased runoff from urban areas are for average rainfall conditions. The quantities at 1:50 year assurance are assumed to be negligible.

Where there are large urban areas, increased runoff from paved areas can significantly increase the runoff to rivers. This runoff can be considered to be a component of urban return flows. In the Fish to Tsitsikamma WMA most of the main urban areas are at the coast and most of the additional runoff generated in this way is discharged to watercourses close to the sea and that are not economically utilisable as sources of water supply. The increased runoff from impervious areas shown in Table 5.3.2.4 is for average rainfall conditions. It has assumed that the corresponding increase in runoff at 1:50 year assurance is negligible.

5.3.3 Rural

Rural water users include the inhabitants of farms, small rural settlements not classified as towns, and coastal resorts that are not classified as towns. No detailed information on rural water use was found. The rural population in the Fish to Tsitsikamma WMA constitutes only 13% of the total and, consequently, the rural water use is small when compared to the urban water use.

In order to obtain an estimate of the total water requirements, consumers were considered to fall into three economic categories, with associated unit water requirements. These categories are "Rural", being people living far from towns and not part of the communities of large commercial farms, "Developing Urban" being people of the lower income group living close to towns and typically on smallholdings, and "Commercial Farming" being the owners of large commercial farms and their workers.

The assumed unit water requirements are shown in Table 5.3.3.1. For want of better information, losses were assumed to be 20% of total water requirements, including losses.

TABLE 5.3.3.1: PER CAPITA WATER REQUIREMENTS IN RURAL AREAS IN 1995

USER CATEGORY	UNIT WATER REQUIREMENTS			
	Direct Use (ℓ/c/d)	Distribution losses		Total (ℓ/c/d)
		(ℓ/c/d)	(%)	
Rural	30	7,5	20	37,5
Developing urban	100	25	20	125
Commercial farming	150	38	20	188

Rural water requirements were calculated from the estimated number of people in each user category in each quaternary catchment. In the Fish to Tsitsikamma WMA, about 30% of the rural population was assumed to fall into the "rural" category, 30% into the "developing urban" category and 40% into the "commercial farming" category. This assumption requires verification. Detailed estimates are given in Appendix F and the results are summarised in Table 5.3.3.2.

Drinking water for livestock is also considered to be part of rural water requirements and was calculated as 45ℓ/ELSU/day using the Equivalent Large Stock Units shown in Table 3.5.4.1.

The distribution of water requirements for livestock is shown in Table 5.3.3.2 where it can also be seen that all rural water requirements were estimated to total 19,2 million m³/a in 1995, including distribution losses.

It was assumed that the total rural water requirement is at 1:50 year assurance.

TABLE 5.3.3.2: RURAL DOMESTIC WATER REQUIREMENTS IN 1995

CATCHMENT						RURAL WATER REQUIREMENTS						RETURN FLOWS	
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		DOMESTIC (million m^3/a)	LIVESTOCK AND GAME (million m^3/a)	LOSSES		TOTAL (million m^3/a)	TOTAL AT 1:50 YR ASSURANCE (million m^3/a)	NORMAL (million m^3/a)	TOTAL AT 1:50 YR ASSURANCE (million m^3/a)
No.	Description	No.	Description	No.	Description			(million m^3/a)	%				
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	0,05	0,25	0	0	0,30	0,30	0	0
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	0,23	0,56	0	0	0,79	0,79	0	0
		TOTAL IN KROM/TSITSIKAMMA				**0,28**	**0,81**	**0**	**0**	**1,09**	**1,09**	**0**	**0**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	0,08 0,0 0,08	0,67 0,05 0,61	0 0 0	0 0 0	0,75 0,06 0,69	0,75 0,06 0,69	0 0 0	0 0 0
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	0,18	0,75	0	0	0,93	0,93	0	0
		L8	Kouga	L81, L82	Western Cape Eastern Cape	0,07 0,22	0,09 0,30	0 0	0 0	0,16 0,52	0,16 0,52	0 0	0 0
		L9	Gamtoos	L90A to C	All Eastern Cape	0,12	0,12	0	0	0,24	0,24	0	0
		Total in Groot/Gamtoos Basin in Northern Cape				0,01	0,05	0	0	0,06	0,06	0	0
		Total in Groot/Gamtoos Basin in Western Cape				0,15	0,76	0	0	0,91	0,91	0	0
		Total in Groot/Gamtoos Basin in Eastern Cape				0,60	1,78	0	0	2,38	2,38	0	0
		TOTAL IN GROOT/GAMTOOS BASIN				**0,76**	**2,59**	**0**	**0**	**3,35**	**3,35**	**0**	**0**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**0,35**	**0,82**	**0**	**0**	**1,17**	**1,17**	**0**	**0**
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld's Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 0,10	0,01 0,44	0 0	0 0	0,01 0,54	0,01 0,54	0 0	0 0
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	0,31	1,23	0	0	1,54	1,54	0	0
		N4	Lower Sundays	N40	All Eastern Cape	0,36	1,15	0	0	1,51	1,51	0	0
		TOTAL IN SUNDAYS BASIN				**0,77**	**2,92**	**0**	**0**	**3,69**	**3,69**	**0**	**0**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**0,70**	**1,60**	**0**	**0**	**2,30**	**2,30**	**0**	**0**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,14	0,61	0	0	0,75	0,75	0	0
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,21	0,87	0	0	1,08	1,08	0	0
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C, Q30, Q50A, Q44C	All Eastern Cape	0,42	1,32	0	0	1,74	1,74	0	0
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	0,08	0,24	0	0	0,32	0,32	0	0
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	0,22	0,55	0	0	0,77	0,77	0	0
		Q9 (Part)	Koonap	Q92	All Eastern Cape	0,28	0,94	0	0	1,22	1,22	0	0
		Q9 (Part)	Kat	Q94	All Eastern Cape	0,40	0,33	0	0	0,73	0,73	0	0
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	0,36	0,63	0	0	0,99	0,99	0	0
		TOTAL IN GREAT FISH BASIN				**2,11**	**5,49**	**0**	**0**	**7,60**	**7,60**	**0**	**0**
TOTAL IN WMA IN NORTHERN CAPE						0,01	0,05	0	0	0,06	0,06	0	0
TOTAL IN WMA IN WESTERN CAPE						0,15	0,77	0	0	0,92	0,92	0	0
TOTAL IN WMA IN EASTERN CAPE						4,81	13,42	0	0	18,23	18,23	0	0
TOTAL IN WMA						**4,97**	**14,24**	**0**	**0**	**19,21**	**19,21**	**0**	**0**

Return flows from rural users are assumed to be negligible.

5.4 BULK WATER USE

No bulk water users with their own supply schemes, or supplied individually by DWAF or one of the district councils, were identified in the Fish to Tsitsikamma WMA.

5.5 NEIGHBOURING STATES

No water is supplied to neighbouring states, nor are any water resources shared with them.

5.6 IRRIGATION

5.6.1 General

Comprehensive detailed observed data on water use for irrigation in the WMA is not available. Therefore, irrigation water requirements were estimated from available information on irrigated areas, typical quotas and assurances of supply.

The information on irrigated areas is that shown in Table 3.5.2.1, which was obtained from the sources described in Section 3.5.2. Water requirements were calculated by applying typical values of water use per hectare, provided by officials of the DWAF Eastern Cape Regional Office, to the irrigated areas shown in Table 3.5.2.1.

5.6.2 Water Use Patterns

Estimated average water requirements for irrigation in 1995 and equivalent requirements at 1:50 year assurance are shown for key areas in Table 5.6.2.1. The table also shows estimated conveyance losses, and estimated return flows. Insufficient information is available for a distinction to be made between conveyance losses to farms and "on-farm" conveyance losses.

The typical annual average irrigation requirements per hectare, on which the calculation of the field edge water requirements shown in Table 5.6.2.1 was based, are shown in Table 5.6.2.2.

Leaching of soils is not generally practised. Along those reaches of the Great Fish and Sundays River where water for irrigation is imported from the Orange River and released into the river channels, the effects of the high salinities of the natural low flows in the rivers are countered by making additional freshening releases of low salinity water from the Orange River to maintain the overall salinity of the water abstracted from the rivers for irrigation at acceptably low levels.

TABLE 5.6.2.1: IRRIGATION WATER REQUIREMENTS

CATCHMENT						WATER REQUIREMENTS					RETURN FLOWS				
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		FIELD EDGE [1] WATER REQUIREMENT (million m^3/a)	CONVEYANCE LOSSES [2]		TOTAL WATER REQUIREMENT	TOTAL WATER REQUIREMENT AT 1:50 YR [2] ASSURANCE	LEACHING BEYOND THE ROOT ZONE	RETURN FLOW FROM LANDS	FROM CONVEYANCE LOSSES	TOTAL RETURN FLOW (million m^3/a)	
No.	Description	No.	Description	No.	Description		(million m^3/a)	%	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	NORMAL (million m^3/a)	AT 1:50 YR ASSURANCE (million m^3/a)
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	4,5	0,2	5	4,7	4,0	0	0,45	0,02	0,47	0,40
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	7,4	0,4	5	7,8	6,7	0	0,74	0,04	0,78	0,67
		TOTAL IN KROM/TSITSIKAMMA				**11,9**	**0,6**	**5**	**12,5**	**10,7**	**0**	**1,19**	**0,06**	**1,25**	**1,07**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	7,4 3,3 4,8	0,4 0,2 0,3	5 5 5	7,8 3,5 5,1	6,1 2,7 3,9	0 0 0	0,00 0,00 0,00	0,00 0,00 0,00	0,00 0,00 0,00	0,00 0,00 0,00
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	16,4	0,9	5	17,3	13,8	0	0,82	0,04	0,86	0,70
		L8	Kouga	L81, L82	Western Cape Eastern Cape	3,7 31,1	0,4 3,2	10 10	4,1 34,3	3,6 29,8	0 0	0,18 1,55	0,02 0,16	0,20 1,71	0,18 1,50
		L9	Gamtoos	L90A to C	All Eastern Cape	44,7	8,0	15	52,7	43,6	0	4,90	0,90	5,80	4,82
		Total in Groot/Gamtoos Basin in Northern Cape				**3,3**	**0,2**	**5**	3,5	2,7	0	0,0	0,00	0,00	0,00
		Total in Groot/Gamtoos Basin in Western Cape				**11,1**	**0,8**	**7**	11,9	9,7	0	0,18	0,02	0,20	0,18
		Total in Groot/Gamtoos Basin in Eastern Cape				**97,0**	**12,4**	**11**	109,4	91,1	0	7,27	1,10	8,37	7,02
		TOTAL IN GROOT/GAMTOOS BASIN				**111,4**	**13,4**	**11**	**124,8**	**103,5**	**0**	**7,45**	**1,12**	**8,57**	**7,20**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**12,3**	**1,2**	**9**	**13,5**	**11,5**	**0**	**1,23**	**0,12**	**1,35**	**1,15**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0,0 11,7	0,0 0,6	- 5	0,0 12,3	0,0 9,8	0 0	0,00 0,00	0,00 0,00	0,00 0,00	0,00 0,00
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	70,6	3,7	5	74,3	59,4	0	19,29	3,40	22,69	18,33
		N4	Lower Sundays	N40	All Eastern Cape	113,4	17,0	13	130,4	104,3	0	11,46	2,02	13,48	11,17
		TOTAL IN SUNDAYS BASIN (All Eastern Cape)				**195,7**	**21,3**	**15**	**217,0**	**173,5**	**0**	**30,75**	**5,42**	**36,17**	**29,50**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**7,9**	**1,4**	**15**	**9,3**	**7,6**	**0**	**0,00**	**0,00**	**0,00**	**0,00**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	53,4	13,9	21	67,3	58,5	0	0,00	0,00	0,00	0,00
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	21,0	3,3	21	24,3	21,1	0	0,00	0,00	0,00	0,00
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir)	Q14, Q21, Q22, Q13B, C, Q30, Q50A, Q44C	All Eastern Cape	155,8	40,4	21	196,2	170,6	0	36,50	9,12	45,62	39,64
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	41,4	10,8	21	52,2	45,4	0	9,70	2,40	12,10	10,54
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	98,9	25,6	21	124,5	108,2	0	23,20	5,80	29,00	25,10
		Q9 (Part)	Koonap	Q92	All Eastern Cape	21,4	1,2	5	22,6	19,6	0	1,00	0,06	1,06	0,98
		Q9 (Part)	Kat	Q94	All Eastern Cape	12,1	2,2	15	14,3	12,8	0	0,60	0,11	0,71	0,64
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	16,0	2,8	15	18,8	16,3	0	0,00	0,00	0,00	0,00
		TOTAL IN GREAT FISH BASIN				**420,0**	**100,2**	**19**	**520,2**	**452,5**	**0**	**71,00**	**17,49**	**88,49**	**76,90**
TOTAL IN WMA IN NORTHERN CAPE						**3,3**	**0,2**	**5**	3,5	2,7	0	0,00	0,00	0,00	0,00
TOTAL IN WMA IN WESTERN CAPE						**11,1**	**0,8**	**7**	11,9	9,7	0	0,18	0,02	0,20	0,18
TOTAL IN WMA IN EASTERN CAPE						**744,8**	**137,1**	**16**	881,9	746,9	0	111,44	24,19	135,63	115,64
TOTAL IN WMA						**759,2**	**138,1**	**15**	**897,3**	**759,3**	**0**	**111,62**	**24,21**	**135,83**	**115,82**

1. The field edge water requirement is calculated from the total land area irrigated in average years given in Table 3.5.2.1 and the unit field edge irrigation requirements given in Table 5.6.2.2.
2. Conveyance losses are estimated canal and on-farm losses, but do not include river channel losses.

TABLE 5.6.2.2: TYPICAL ANNUAL FIELD EDGE IRRIGATION REQUIREMENTS

AREA	TERTIARY/ QUATERNARY CATCHMENTS	PREDOMINANT CROP	ASSUMED FIELD EDGE WATER REQUIREMENT FOR A TYPICAL MIX OF CROPS (m^3/ha/a)
Upper Krom	K90A to D	Deciduous fruit Pasture Vegetables	6 500
Tsitsikamma Coast	K80A to F, K90E to G	Vegetables Pasture Lucerne	6 500
Upper Groot	L11, L12, L21, L22, L23	Lucerne	13 000
Lower Groot	L30 to L70	Lucerne Vegetables	13 000
Kouga	L81, L82	Deciduous fruit Pasture	5 100
Gamtoos	L90A to C	Vegetables Citrus Lucerne Tobacco	8 000
Algoa Coast	M10A to D, M20A, B M30A, B	Vegetables Lucerne Pasture	8 500
Upper Sundays	N11, N12	Lucerne	13 000
Middle Sundays	N13, N14, N21-N23, N30	Lucerne Maize Citrus Vegetables	13 000
Lower Sundays	N40A to F	Citrus Lucerne Vegetab;es	9 000
Albany Coastal	P10 to P40	Vegetables Pasture	12 000
Upper Fish	Q11, Q12, Q13A	Lucerne Maize Wheat Pasture	13 500
Tarka	Q41, Q42, Q43, Q44A, Q44B	Lucerne Maize Wheat Vegetables	13 500
Upper Middle Fish	Q13B, Q13C, Q14, Q21, Q30, Q50A, Q44C	Lucerne Wheat Pasture Maize	13 500
Upper Little Fish	Q80A to Q80E	Lucerne Wheat Pasture Maize	12 500
Middle Fish	Q50B, Q50C, Q60, Q70, Q80F, Q80G	Lucerne Wheat Pasture Maize	12 500
Koonap	Q92A to Q92G	Lucerne	10 900
Kat	Q94A to Q94F	Citrus	9 000
Lower Fish	Q91A to Q91C, Q93A to Q93D	Lucerne Maize Vegetables	12 500

5.6.3 Water Losses

Irrigation water losses are considered in two categories, namely:

- Canal and river losses incurred in conveying water from the dam in which it is stored to the farms where it is used for irrigation, and
- On-farm conveyance losses, which occur in conveying the water from the point at which it is abstracted from a canal, river or farm dam to field edge.

As reliable information on farm conveyance losses is not available, estimates of combined canal and on-farm conveyance losses were provided by officials of the DWAF Eastern Cape Regional Office. These are reported as combined conveyance losses in Table 5.6.2.1 where they are shown as percentages of total water use.

The above losses do not include river conveyance losses occuring in the Fish River and the Sundays River through seepage losses, evapotranspiration and evaporation, which have been estimated to average 112 million m^3/a (DWAF, 1997b). These are not included in Table 5.6.2.1 or in Table 5.1.1, but are dealt with in Section 5.14 as transfer losses.

Freshening releases of some 32 million m^3/a made to the Fish River are not included in the river losses as the water has been assumed to be partially used for irrigation by farmers whose land is not scheduled under the Orange/Fish Transfer Scheme, with the remainder contributing to ecological flow requirements.

5.6.4 Return Flows

Irrigation return flows are generated from water lost during conveyance to irrigated lands, by surface runoff and seepage of irrigation water applied to lands, and by excess water applied to leach unwanted salts from the soils of irrigated lands.

Leaching of soils is not widely practised in the Fish to Tsitsikamma WMA, and most of the irrigation return flows arise from conveyance losses and normal irrigation of lands.

No reliable observed data on the quantity of irrigation return flows were found. Therefore estimates, provided by officials of the DWAF Eastern Cape Regional Office, of the percentages of field edge applications that become return flows were used to obtain an indication of the volume of return flows generated. The assumed percentages are shown in Table 5.6.4.1.

Return flows along those parts of the Fish and Sundays Rivers that receive water imported from the Orange River are high because the substantial seepage losses from distribution canals as well as the seepage from irrigated lands contribute to the totals. Elsewhere they are low to negligible because much of the irrigation occurs in areas in which there is little or no flowing surface water during the summer months.

TABLE 5.6.4.1: ESTIMATED IRRIGATION RETURN FLOWS AS PERCENTAGES OF FIELD EDGE IRRIGATION REQUIREMENTS

AREA	CATCHMENTS	RETURN FLOWS (% OF TOTAL IRRIGATION REQUIREMENTS)
Upper Krom	K90A to D	10%
Tsitsikamma Coast	K80A to F, K90E to G	10%
Upper Groot	L11, L12, L21, L22, L23	0%
Lower Groot	L30 to L70	0%
Kouga	L81, L82	5%
Gamtoos	L90A to C	11%
Algoa Coast	M10A to D, M20A, B, M30A, B	10%
Upper Sundays	N11, N12	0%
Middle Sundays	N13, N14, N21-N23, N30	30%
Lower Sundays	N40A to F	10%
Bushmans, Kowie, Kariega	P10, P20, P30, P40	0%
Upper Fish	Q11, Q12, Q13A	0%
Tarka	Q41, Q42, Q43, Q44A, Q44B	0%
Upper Middle Fish	Q13B, Q13C, Q14, Q21, Q30, Q50A, Q44C	23%
Upper Little Fish	Q80A to Q80E	23%
Middle Fish	Q50B, Q50C, Q60, Q70, Q80F, Q80G	23%
Koonap	Q92A to Q92G	5%
Kat	Q94A to Q94F	5%
Lower Fish	Q91A to Q91C, Q93A to Q93D	0%

5.7 DRYLAND SUGARCANE

No sugarcane is grown commercially in the Fish to Tsitsikamma WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

The main river losses occur in the portions of the Fish River and the Sundays River that are used to convey water imported from the Orange River. The losses occur as a result of evaporation from the surface of the rivers and evapotranspiration by riparian vegetation. They have been estimated by numerical modelling to average 112 million m^3/a (DWAF, 1997b).

About 32 million m^3/a of water (2 m^3/s for six months) imported from the Orange River are released from Elandsdrift Weir into the Great Fish River in addition to irrigation requirements to control the salinity of the water abstracted for irrigation. Some of this water is used by irrigators downstream of Hermanuskraal Weir, but the rest flows to the sea. This water has not been regarded as a loss in this study, but as a contribution to the ecological flow requirements of the Great Fish River. However, under 1:50 year drought conditions the lower portion of the Great Fish River has been assumed to have no ecological flow requirement, but freshening releases would still be required. Therefore, the assumption is not entirely accurate.

It is probable that river channel losses also occur in the Groot River from water released from Beervlei Dam, but these have not been quantified and have been ignored in this assessment.

Approximately 140 million m^3/a of water is estimated to evaporate from dams. Major dams are estimated to account for 106 million m^3/a of this quantity, and the remainder of some 34 million m^3/a is from farm dams and small municipal dams.

These are rough estimates only, and are probably indicative of the upper limits of evaporation losses, which vary widely from year to year, depending on climatic conditions and the storage volumes in the dams.

The distribution of evaporation losses from dams is shown in Table 5.8.1.

TABLE 5.8.1: EVAPORATION LOSSES FROM DAMS

CATCHMENT				EVAPORATION LOSSES FROM DAMS (million m^3/a)		
PRIMARY		QUATERNARY				
No.	Description	No.	Description	MAJOR DAMS (million m^3/a)	MINOR DAMS (million m^3/a)	TOTAL (million m^3/a)
K Part	Krom/Tsitsikamma	K90A to D	Catchment of Impofu Dam	3,86	0,19	4,05
		K80A to F K90E to G	Tsitsikamma Coast	0,0	2,32	2,32
		TOTAL IN KROM/TSITSIKAMMA		**3,86**	**2,51**	**6,37**
L	Groot/Gamtoos	L11, L12, L21, L22, L23	Catchment of Beervlei Dam	25,47	14,18	39,65
		L30 to L70	Groot below Beervlei Dam	0,00	2,12	2,12
		L81 to L82	Catchment of Kouga Dam	3,85	1,98	5,83
		L90A to L90C	Gamtoos River Catchment	0,30	0,06	0,36
		TOTAL IN GROOT/GAMTOOS BASIN		**29,62**	**18,34**	**47,96**
M	Algoa Coast	M10, M20, M30	Zwartkops, Port Elizabeth, Coega	0,80	0,17	0,97
N	Sundays	N11, N12,	Catchment of Van Rynevelds Pass Dam	9,45	1,27	10,72
		N13, N14, N21-N24, N30	Incremental Catchment of Darlington Dam	27,89	3,68	31,57
		N40	Lower Sundays	0,0	0,39	0,39
		TOTAL IN SUNDAYS BASIN		**37,34**	**5,34**	**42,68**
P	Albany Coast	P10, P20, P30, P40	Bushmans, Kowie, Kariega River Catchments	3,85	0,91	4,76
Q	Great Fish	Q11, Q12, Q13A	Catchments of Grassridge Dam	11,69	0,63	12,32
		Q41, Q42, Q43, Q44A, B	Catchment of Lake Arthur (Tarka River)	14,61	0,78	15,39
		Q13B, C, Q21, Q22, Q30, 44C, Q50A	Incremental Catchment of Elands Drift Weir	1,80	0,61	2,41
		Q80A to Q80E	Catchment of Little Fish River upstream of De Mistkraal Weir	0,61	0,51	1,12
		Q50B, C, Q60, Q70, Q80F, G	Middle Fish River Catchment between Little Fish River confluence and Elandsdrift and De Mistkraal Weirs	0,00	0,60	0,60
		Q92	Catchment of Koonap River	0,00	1,02	1,02
		Q94	Catchment of Kat River	1,20	1,53	2,73
		Q91A to Q91C, Q93A to Q93D	Incremental Catchment of Great FishRiver below its confluence with the Little Fish River	0,47	1,04	1,51
		TOTAL IN GREAT FISH BASIN		**30,38**	**6,72**	**37,10**
TOTAL IN WMA				**105,85**	**33,99**	**139,84**

5.9 AFFORESTATION

The water use by commercial afforestation is based on the so-called CSIR curves (CSIR, 1995), which have replaced the so-called Van der Zel curves that were used for the preparation of WR90 (Midgley *et al*, 1994). The Van der Zel curves were considered to be too simplistic compared to the CSIR curves, which now take the species, age and site conditions into account in estimating the stream flow reductions. A study was undertaken (Ninham Shand, 1999) to provide adjusted naturalised flow sequences for the Water Situation Assessment Model (WSAM) (DWAF, 2000a) based on the WR90 naturalised flow data. This now enables the CSIR curve-based stream flow reduction estimates to be used in the WSAM and these reduction estimates have been used in the WRSA reports. Details of the method of estimating the reduction in runoff by or water use of commercial afforestation are described in CSIR (1995) curve-based stream flow reduction estimates to be used in the WSAM and these reduction estimates have been used in the WRSA reports. Details of the method of estimating the reduction in runoff by or water use of commercial afforestation are described in CSIR (1995).

The impact of the reduction in runoff due to afforestation on the yield of a catchment depends on the storage in that catchment. It was accepted that the storage/yield characteristics of a catchment with afforestation were similar to those of the natural catchment and that the latter characteristics could be used to estimate the yield of a catchment with afforestation. The estimates of the impact on the yield of a catchment were made separately for each of the incremental catchments between key points. The total storage within the incremental catchment was transposed to its outlet and formed the basis for determining the incremental yield of the catchment under both natural conditions and the effects of only the afforestation. The yields were estimated from the storage yield characteristics used in the WSAM for any particular recurrence interval of concern. The difference between the incremental yields under natural conditions and with only the effects of afforestation was the impact of the reduction in runoff due to afforestation in the incremental catchment on the yield of the catchment.

An area of 418 km^2 of commercial timber plantations is found in the Fish to Tsitsikamma WMA. The plantations are found in the high rainfall catchments. The reduction in runoff due to afforestation is estimated to be 54 million m^3/a. The corresponding reduction in the system 1:50 year yield (estimated by the WSAM development team) is 7,1 million m^3/a.

The impact on yield is so low because very little of the afforestation is in catchments regulated by major dams. The estimate is at a low level of confidence and requires verification.

The 65 km^2 of indigenous forest in the WMA reduces runoff by more than an equal area of grassland would, but, being a natural feature, its effect is not included in the water use shown in Table 5.9.1.

TABLE 5.9.1: WATER USE BY AFFORESTATION IN 1995

CATCHMENT						AVERAGE WATER USE		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		(million m^3/a)	(mm/a) [(1)]	(million m^3/a)	(mm/a) [(1)]
No.	Description	No.	Description	No.	Description				
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	0,08	0,09	0,00	0,00
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	39,86	20,78	4,70	2,45
		TOTAL IN KROM/TSITSIKAMMA				39,94	14,50	4,70	1,70
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	0,00 0,00 0,00	0,00 0,00 0,00	0,00 0,00 0,00	0,00 0,00 0,00
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	0,00	0,00	0,00	0,00
		L8	Kouga	L81, L82	Western Cape Eastern Cape	0,10 0,00	0,00 0,00	0,00 0,00	0,00 0,00
		L9	Gamtoos	L90A to C	All Eastern Cape	6,70	5,60	0,50	0,42
		Total in Groot/Gamtoos Basin in Northern Cape				0,00	0,00	0,00	0,00
		Total in Groot/Gamtoos Basin in Western Cape				0,10	0,00	0,00	0,00
		Total in Groot/Gamtoos Basin in Eastern Cape				6,70	0,38	0,50	0,03
		TOTAL IN GROOT/GAMTOOS BASIN				6,80	0,20	0,50	0,02
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	3,92	0,74	0,20	0,04
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 0,00	0,00 0,00	0,00 0,00	0,00 0,00
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-23, N30	All Eastern Cape	0,00	0,00	0,00	0,00
		N4	Lower Sundays	N40	All Eastern Cape	0,00	0,00	0,00	0,00
		TOTAL IN SUNDAYS BASIN				0,00	0,00	0,00	0,00
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	0,14		0,00	0,00
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,00	0,00	0,00	0,00
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,00	0,00	0,00	0,00
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	0,00	0,00	0,00	0,00
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	0,00	0,00	0,00	0,00
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	0,00	0,00	0,00	0,00
		Q9 (Part)	Koonap	Q92	All Eastern Cape	0,10	0,03	0,00	0,00
		Q9 (Part)	Kat	Q94	All Eastern Cape	2,76	1,60	1,70	0,99
		Q9 (Part)	Lower Fish	Q91B, C Q93A to D	All Eastern Cape	0,00	0,00	0,00	0,00
		TOTAL IN GREAT FISH BASIN				2,86	0,09	1,70	0,06
TOTAL IN WMA IN NORTHERN CAPE						0,00	0,00	0,00	0,00
TOTAL IN WMA IN WESTERN CAPE						0,10	0,00	0,00	0,00
TOTAL IN WMA IN EASTERN CAPE						53,56	0,67	7,10	0,09
TOTAL IN WMA						53,66	0,55	7,10	0,05

(1) Based on total catchment area, not area of afforestation only.

5.10 HYDRO-POWER AND PUMPED STORAGE

There is no water use by hydro-power or pumped storage schemes. (Small hydro-power stations at Kouga Dam and at the outlet of the Orange/Fish Tunnel are not used).

5.11 ALIEN VEGETATION

Quaternary catchment information for condensed areas of infestation by alien vegetation and stream flow reductions was obtained from the CSIR (Environmentek) (Versfeld *et al*, 1997).

It has been assumed that water consumption of alien vegetation outside of the riparian zone cannot exceed the natural runoff and water use inside and outside of the riparian zone has been estimated separately wherever possible. In the absence of any better information, it was assumed that 10% of the condensed area under alien vegetation is riparian. The reduction in runoff due to alien vegetation was taken from WSAM using the above assumptions. The impact of this reduction in runoff on catchment yield was determined in the same manner as for afforestation.

The distribution of alien vegetation in the Fish to Tsitsikamma WMA is described in Section 3.5.6. Corresponding estimates of average reduction in runoff and reduction in the system 1:50 year yield are shown in Table 5.11.1 and on Figure 5.11.1.

TABLE 5.11.1: WATER USE BY ALIEN VEGETATION IN 1995

CATCHMENT						AVERAGE REDUCTION IN RUNOFF		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
PRIMARY		SECONDARY		TERTIARY/QUATERNARY		(million m^3/a)	(mm/a) [1]	(million m^3/a)	(mm/a) [1]
No.	Description	No.	Description	No.	Description				
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	4,66	6,00	3,50	4,51
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	25,57	14,40	3,00	1,70
		TOTAL IN KROM/TSITSIKAMMA				30,23	10,20	6,50	2,19
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	0,05 0,00 0,00	0,00 0,00 0,00	0,00 0,00 0,00	0,00 0,00 0,00
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	1,87	0,21	0,00	0,00
		L8	Kouga	L81, L82	Western Cape Eastern Cape	1,42 19,84	2,10 5,87	0,70 10,20	1,04 3,02
		L9	Gamtoos	L90A to C	All Eastern Cape	1,12	0,93	0,00	0,00
		Total in Groot/Gamtoos Basin in Northern Cape				0,00	0,00	0,00	0,00
		Total in Groot/Gamtoos Basin in Western Cape				1,47	0,08	0,70	0,04
		Total in Groot/Gamtoos Basin in Eastern Cape				22,83	1,34	10,20	0,60
		TOTAL IN GROOT/GAMTOOS BASIN				24,30	0,70	10,90	0,31
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	10,91	4,15	0,40	0,15
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	0,00 0,11	0,00 0,03	0,00 0,00	0,00 0,00
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	0,65	0,05	0,30	0,02
		N4	Lower Sundays	N40	All Eastern Cape	0,46	0,10	0,00	0,00
		TOTAL IN SUNDAYS BASIN				1,22	0,06	0,30	0,01
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	17,32	3,26	2,30	0,43
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	0,01	0,00	0,00	0,00
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	0,00	0,00	0,00	0,00
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C, Q30, Q50A, Q44C	All Eastern Cape	0,51	0,06	0,00	0,00
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	0,09	0,05	0,00	0,00
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	0,15	0,04	0,00	0,00
		Q9 (Part)	Koonap	Q92	All Eastern Cape	0,11	0,03	0,00	0,00
		Q9 (Part)	Kat	Q94	All Eastern Cape	2,49	1,45	1,20	0,58
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	1,08	0,41	0,00	0,00
		TOTAL IN GREAT FISH BASIN				4,44	0,15	1,20	0,04
TOTAL IN WMA IN NORTHERN CAPE						0,00	0,00	0,00	0,00
TOTAL IN WMA IN WESTERN CAPE						1,47	0,08	0,70	0,04
TOTAL IN WMA IN EASTERN CAPE						86,95	1,09	20,90	0,26
TOTAL IN WMA						88,42	0,91	21,60	0,22

(1) Based on total catchment area.

It can be seen from the Table that most of the reduction in runoff caused by alien vegetation occurs in the coastal strip, particularly in the catchment of the Kouga River (L81, L82). Considerable infestation by alien vegetation is also found in the catchments of the Krom River (K90A to G), the Tsitsikamma Coast (K80A to K80F) and the Albany area (P10 to P40). The total reduction in runoff for the Fish to Tsitsikamma WMA, due to alien vegetation is estimated at 88 million m^3/a. The reduction in the 1:50 year yield is estimated as 21,6 million m^3/a.

It should be noted that the reliability of these estimates is uncertain, as neither the true extent of infestation by alien vegetation, nor its effect on runoff is accurately known.

5.12 WATER CONSERVATION AND DEMAND MANAGEMENT

5.12.1 Introduction

The Department of Water Affairs and Forestry is entrenching and insisting on efficient water management and use. This concept has been strongly emphasised, both in legislation and through key demonstration water conservation and water demand management projects. The Department of Water Affairs and Forestry is therefore developing a National Water Conservation and Demand Management Strategy, which is aimed at the water supply industry and South African society at large and aims to cover all water use sectors including agriculture, forestry, industry, recreational, ecological, and water services.

Evidence of inefficient water usage can be found in all water use sectors throughout the country and the value of water seems largely unrecognised by many water users. South Africa is a developing country that is water stressed and requires improved management of its limited water resources.

The implementation of water conservation and demand management principles is essential in meeting the national goals of basic water supply for all South Africans and the sustainable use of water resources.

Water conservation and water demand management are not synonymous. The following meanings are therefore assigned to these terms in this report:

- Water conservation is the minimisation of loss or waste, the preservation, care and protection of water resources and the efficient and effective use of water. Water conservation should be both an objective in water resource and water services management as well as a strategy.

- Water demand management is the adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water requirements and use of water in order to meet any of the objectives of economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability. Water supply institutions should set water demand goals and targets by managing the distribution systems and consumer requirements in order to achieve the above objectives.

Water demand management is deemed to include the entire water supply chain - from the point of abstraction at the source to the point of use. This includes all levels of water distribution management and consumer demand management. The conservation measures related to the water resources and return flow are part of water resource management and return flow management respectively.

Various obstacles and constraints have to be overcome before the full potential of water conservation and demand management can be achieved.

This section describes the National Water Conservation and demand management objectives that will lead to the development of action plans to be implemented by the various water institutions. The needs and opportunities for the implementation of water conservation are described, as are some of the important principles on water conservation and demand management. This section also describes the platform on which the National Water Conservation and demand management strategy will be based. This National Strategy Framework will also be used to develop the functions of the Directorate : Water Conservation within the Department of Water Affairs and Forestry and the functions of other departments and other water institutions. It is also intended that those principles will assist the water industry to comprehensively implement water conservation and demand management.

5.12.2 Background

Water resources and supply

The sustainability of the limited water resources is threatened in terms of quantity and quality. Unless the current water use pattern is changed, future water requirements will greatly exceed existing available fresh water resources. Frequently the water supply and quality are unreliable or improperly managed, leading to the wasteful use of water by consumers in anticipation of possible supply failures.

Environment

Environmental degradation and the prevention thereof is a key focus in the current policy and legislation. Measures such as providing for water of suitable quality in sufficient quantity in the Reserve to protect the integrity, health and productivity of the rich and diverse ecosystems have become necessary.

Neighbouring states

South Africa and the neighbouring states of Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe have certain common water resources and must collaborate to achieve the optimal use of these resources. Except for Lesotho all of these countries are water scarce and it is imperative that none of them should allow the wastage of water resources to the detriment of the other countries.

Basic water supply needs

By the application of water demand management measures to existing water services, water resources and bulk infrastructure can be reallocated for the provision of new services where adequate services do not yet exist. Water demand management is also essential in ensuring the sustainability of the new water service delivery projects and can help to ensure that water remains affordable.

Existing water services

It is estimated that up to 50% of the total quantity of water that is supplied is not accounted for in many of the urban areas. This unaccounted for water consists of a combination of reticulation system leaks, unauthorised water connections, faulty water meters and domestic plumbing leaks. These factors, combined with the low levels of payment and institutional problems of local authorities, affect the sustainability of water services. Current indications are that levels of unaccounted for water are growing despite the formulation of several water conservation strategies in the past.

Irrigation

Irrigation accounts for an estimated 77% of total consumptive water requirements (i.e. excluding the ecological Reserve) in the Fish to Tsitsikamma WMA. Irrigation losses are often quite significant and it is estimated that often no more than 80% of water abstracted from water resources is correctly applied to the root systems of plants. Some irrigation system losses return to the river systems but this return water can be of reduced quality. Irrigation methods, irrigation scheduling, soil preparation, crop selection, crop yield targets and evaporation all affect the efficient use of water.

Forestry

Forestry accounts for an estimated 5% of total consumptive water use in the Fish to Tsitsikamma WMA. Issues such as site selection and preparation, species selection, rotation periods and plantation management all affect the efficient use of water.

Industry, mining and power generation

Industry is expected to be the biggest contributor to future economic growth in South Africa. The industrial sector is projected to have the greatest growth in water requirements. Much of this growth will occur in major urban centres that only have limited water resources nearby. It is imperative to have assured water supplies at a reasonable cost to support the industrial development and for the industrial sector to improve its efficiency of water use and to minimise waste.

5.12.3 Legal and Regulatory Framework

General

The Water Services Act (No. 108 of 1997) and the National Water Act (No. 36 of 1998) variously require and provide for the implementation of water conservation and demand management measures. One of the functions of the National Water Conservation and Demand Strategy is to fulfil the requirements made through the legislation and to utilise the opportunities created through the legislation to develop comprehensive policies and to identify and develop regulations.

Complimentary to the regulations promulgated in terms of the above two Acts are codes of practice that present guidelines for the maintenance of uniform standards within the water supply industry.

Water Services Act

The Water Services Act (No. 108 of 1997) sets out a framework to ensure the provision of basic water supply and sanitation and a regulatory framework for water services institutions. All water services institutions are required to develop conditions for the provision of water services that must include for measures to promote water conservation and demand management.

National Water Act

The purpose of the National Water Act (No. 36 of 1998) is to, inter alia, ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways that, amongst others, promote efficient, sustainable and beneficial use of water in the public interest.

Codes of Practice

The SABS Code of Practice 0306: 1998 title The Management of Potable Water in Distribution Systems has been drafted to establish the management, administrative and operational functions required by a water services institution to account for potable water within distribution systems and apply corrective actions to reduce and control unaccounted for water.

5.12.4 The Role of Water Conservation and Demand Management

Security of supply

The role of water conservation and demand management in ensuring security of supply can be divided into short-term rationing measures during droughts, which amount to a reduction in assurance of supply in respect of some of the water, and sustainable long-term functions.

With the current growth of water requirements it is estimated that unless water conservation and sustainable development policies are implemented, South African will utilise all its natural fresh water resources within 30 years. Possible alternative water resources such as importation of water from neighbouring states, desalination and harvesting icebergs are considered to be too expensive.

Protection of the aquatic environment

Aquatic ecosystems are under threat from current land use practices and over-utilisation of water resources. Reducing water requirements reduces water abstractions that affect the aquatic environment and results in increased streamflows and/or decreased demand on groundwater sources and also reduces or defers the need for dams, that have their own impacts on the environment.

Protection of existing water resources

The protection of water resources through water conservation measures can be achieved as follows:

- The removal of alien invading plants, which reduce surface runoff and the yield of existing resources.
- Rehabilitation of wetlands.
- Protection of groundwater resources by limiting abstraction to the sustainable yield.
- Minimising pollution of water resources.

Economic efficiency

One of the main objectives of water demand management is economic efficiency through the entire water cycle.

In the potable water services sector, economic efficiency may often be a more important objective than water resource considerations. A certain measure that may be economically efficient from the perspective of society may not be economically efficient from the perspective of a specific water institution or user, which can be a major constraint on water demand management. However, the perspective of society needs to have priority over the economic efficiency perspective of the various water institutions or users.

Reducing the growth in water requirements can postpone large infrastructure development costs.

Social development, equity and accountability
Water demand management can enhance the objectives of social development and equity in a number of ways, some of which are given below:

- To promote maintenance, management and prevention of abuse of water infrastructure.
- To reduce domestic water consumption and waste and the cost of potable water services.
- To provide new services to people by using existing resources and bulk infrastructure.
- To offer more employment opportunities to the community.
- To make water institutions accountable to the public and understand the consumers and their needs.

5.12.5 Planning Considerations

Water conservation and demand management initiatives are not only strategies associated with environmental or communications initiatives but must be integrated into the water resource planning process as potential alternatives to increasingly expensive supply side management options.

All water demand management activities that decrease the water requirement tend to affect supply management because existing system capacity is released for other users.

The opportunities for water demand management exist where there are high levels of loss and inefficient use, particularly where water is used for the service that is derived from it and not for the water itself.

5.12.6 Water Conservation and Demand Management Measures

There are a number of categories of water conservation and demand management measures and initiatives that can be implemented. The following categories are general for all water sectors and are according to the different components of the water supply chain:

- Water conservation measures in resource management.
- Water demand management in distribution of supply management.
- Water demand management measures of customer or end user.
- Water conservation measures for return flow management.

5.12.7 Objectives of the National Water Conservation and Demand Management Strategy

The objectives of the National Water Conservation and Demand management Strategy are as follows:

- Create a culture of water conservation and demand management within all water management and water service institutions in South Africa.
- Support water management and water services institutions to implement water demand management and water conservation.
- Create a culture of water conservation and demand management for all consumers and users in South Africa.

- Promote international co-operation and participate with other Southern African countries, particularly co-watercourse states, to develop joint water conservation and demand management strategies.
- Enable water management and water resources institutions to adopt integrated resource planning.
- Promote social development and equity in South Africa.
- Contribute to the protection of the environment, ecology and water resources.
- Contribute to the parameters of water economics to development planning processes.

5.12.8 Water Conservation in South Africa

History
Since 1982 the droughts have accentuated the awareness of the need to conserve water. In 1985 the Water Research Commission initiated a process to establish the National Water Supply Regulation (NWSR), which was proposed to be promulgated under the then Water Act. Participating local authorities were however, encouraged to promulgate the NWSR as their own Water Regulations (by-laws). Port Elizabeth Municipality was the first to adopt the NWSR in 1987. However, in 1992 the Department of Water Affairs and Forestry indicated it would not be involved with the administration of the (then) proposed NWSR and although the United Municipal Executive resolved in 1993 that the NWSR should be adopted by local authorities, little progress was made.

The proceedings of the National Water Supply and Sanitation Policy Conference of 1994 included an estimate of the extent of the problem of water losses due to leakage at 330 million m^3 /a and proposed a policy of water demand management. The subsequent Water Supply and Sanitation Policy White Paper published in 1994 referred to water conservation and demand management and encouraged a culture of water conservation and the introduction of stringent water demand management strategies to reduce water usage and the stress on resources.

The Working for Water programme
The Working for Water programme is part of the National Water Conservation Campaign and is based on the key assumption that invading alien plants pose a considerable threat to South Africa's extremely rich biological diversity, and to the ecological functioning of its natural systems. Also provided by the campaign is a catalogue of devices that can contribute to the efficient consumption of water.

Water restrictions
Restricting water use during extreme droughts through the imposition of conservation measures on consumers is an intermittent form of water demand management. The effects of past water restrictions give an indication of the extent and direction that future water conservation strategies could have.

Overall savings in water use (median estimates) achieved through water restrictions were found to vary according to region and severity of restriction. In the Rand Water area of supply mild restrictions saved about 15% whereas stringent restrictions saved about 27%. For the rest of Gauteng, Free State and Northern Cape these savings were about 19% (mild) and 34% (stringent). In the Umgeni Water area of supply mild restrictions saved only 1% to 5%, whereas stringent measures saved as much as 50%. For the rest of KwaZulu/Natal these savings were 29% (mild) and 46% (stringent).

It was difficult to determine the financial effects of water restrictions. In the Vaal River Supply Area the reduction in water requirements due to water restrictions for the Rand Water, Goldfields and Vaal River supply areas for the period 1982 to 1984 was almost 240 million m^3 of water or 22,5% of the requirement for the year 1982. The greatest total direct tangible financial impact was on public institutions such as the Department of Water Affairs and Forestry, Water Boards, Local Authorities and Eskom. Private households also bore a large financial impact of water restrictions. Mining had the least financial burden to bear because of water restrictions, yet achieved a net saving in water use of almost 32% in the same period. The greatest reduction in water use was for the agricultural sector, which had the second lowest direct financial impact.

From analyses of return flows in Gauteng it is concluded that the ratio of return flow to water use is not materially altered by the imposition of water restrictions. In other words, if the supply is reduced by (say) 20%, it can be assumed that the return flow will also be reduced by 20%.

Experience from past water restrictions that have proved to be the most effective during times of drought, which are relevant to future water conservation efforts are:

- The overall reduction in water use depends on a number of factors. However, when water use is reduced beyond 30% it can be detrimental to the user from a financial and motivational perspective.

- Voluntary reduction in water use fails to achieve the savings possible with mandatory steps.

- The most effective methods of reducing water use are higher tariffs, restriction of garden watering times, the banning of domestic hose pipe usage and allotting quotas to industry, bulk consumers and irrigators.

- The most effective motivations are pamphlets/newsletters, higher tariffs and punitive measures.

- The major interventions required to reduce both physical and non-physical losses from pipe networks are leak detection/monitoring, replacing old plumbing and the repair/ monitoring of meters.

- The most effective methods of saving water used by commerce and industry are technical adjustments, recycle/re-use and promotion campaigns.

- The ratio of return flow to water use is not materially changed by changes in water use.

The measures implemented during the drought in the mid- 1980s reduced water use and the growth rate in water usage after the drought had ended. However, there is little or no incentive for existing or new consumers to continue to retain or to adopt the water saving measures when there is no drought.

5.12.9 Water Conservation in the Fish to Tsitsikamma Water Management Area

Based on experience elsewhere in South Africa an overall sustainable reduction in urban water use of up to 25% can be expected without having a detrimental effect on users. Urban return flows could be reduced by up to 10% of total water use.

Irrigation water losses could perhaps be reduced by about 10% by lining irrigation canals and improving application efficiencies in areas where flood irrigation is practised, but it might not be financially viable to do this under present market conditions for agricultural products.

5.13 WATER ALLOCATIONS

5.13.1 Introduction

As explained in Section 3.4, numerous allocations of water have been made in the past under the provisions of the Water Act of 1956 and earlier legislation. Under the National Water Act (Act No. 36 of 1998) these allocations will be replaced by general authorisations or by licensing of specific water uses. The previous allocations were, however, still valid in 1995, and are discussed in this section of the report for comparison with estimated water availability in 1995.

Allocations of water were made and permits for use of water issued under the following articles of the Water Act of 1956:

(a) Article 63: Irrigation scheduling and quotas from Government Water Schemes.
(b) Article 56(3): Allocations to other users from Government Water Schemes.
(c) Article 62: Scheduling and quotas from Government Water Control Areas.
(d) Articles 32A and 32B: Scheduling and quotas from Government Subterranean Water Control Areas.
(e) Industrial, mining and effluent permits (including Articles 12, 12B and 21).
(f) Other allocations (including Section 9B permits, Water Court orders and older legislation).

Under (c) and (d) above, reference is made to Government Water Control Areas and Government Subterranean Water Control Areas. The first mentioned were a feature of the Water Act of 1956 which was applied to areas in which it was necessary in the public interest for the allocation of rights to the use of public water to be based on considerations other than only the extent of irrigable riparian land. The Water Act of 1956 provided for such cases to be dealt with by empowering the State President to declare the relevant area a Government Water Control Area in which the Minister of Water Affairs was entitled to allocate water. In all other areas water could be allocated only by a Water Court, primarily in proportion to the extent of irrigable riparian land.

Government Subterranean Water Control Areas provided for a similar situation in areas where over-exploitation of groundwater aquifers occurred.

With the implementation of the National Water Act of 1998, Government Water Control Areas no longer exist.

In the Fish to Tsitsikamma WMA, some areas adjacent to the main stems of the Fish and Sundays Rivers as well as the Kouga and Gamtoos River valleys were Government Water Control Areas. Part of the Zwartkops River catchment (M10C, M10D) and part of the Coega River catchment (M30A, M30B) was a Government Subterranean Water Control Area.

The Water Act of 1956 provided for the promotion of the interests of local communities through the establishment of irrigation districts. This could be done upon the request of a local community, or on the recommendation of the Minister of Water Affairs on his own initiative. After an irrigation district had been proclaimed by the State President, irrigation board members were elected by those landowners who had an interest in the irrigation of land within the district. An irrigation board administered its district by means of a schedule of rateable areas which recorded the quantity of public water to which each owner of land in the district was entitled. Where the district incorporated land that lay within a Government Water Control Area and in respect of which the Minister of Water Affairs had determined water rights the irrigation board had to include the Minister's determinations in its schedule of rateable areas.

With the introduction of the National Water Act (Act No.36 of 1998), irrigation boards were required to apply for registration as water user associations and, as explained in Section 3.4, the previous concept of riparian rights and private ownership of water was done away with. The nation's water resources became common property, belonging to the nation as a whole, and all water use for irrigation on a commercial scale is now subject to control by the Minister of Water Affairs.

In 1995 there were 32 irrigation districts in the Fish to Tsitsikamma WMA. They are listed in Table 5.13.1.1. A number of the irrigation districts were within Government Water Control Areas, and most received some, or all, of their water from Government Water Schemes. Those that did not are marked by asterisks in Table 5.13.1.1.

Allocations of water for irrigation under Government Water Schemes and in Government Water Control Areas were made on the basis of scheduled areas of irrigable land for each property to which water was allocated and a quota of a prescribed quantity of water per annum per hectare of land. The annual quantity of water allocated to each property was calculated as the scheduled area multiplied by the quota. A similar system was generally used by irrigation boards to allocate water within the irrigation districts under their control.

Where sources of water are not regulated by large dams annual fluctuations in the amounts of water available for irrigation tend to be large and there is frequently insufficient water to provide the full allocations. This is the case in many of the irrigation districts that rely on run-of-river diversions from local sources during the low flow months. In these circumstances, the quantity of water that was available each year was generally allocated by irrigation boards in proportion to the scheduled areas of land. This was done on the basis of "turns" where the available flow was supplied to individual landowners in rotation for prescribed periods of time.

TABLE 5.13.1.1: IRRIGATION DISTRICTS IN THE FISH TO TSITSIKAMMA WMA

NAME (1)	CATCHMENT (2)	SCHEDULED AREA (3) (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)	SOURCE OF WATER
(a) Irrigation Districts supplied by the Orange-Fish Transfer Scheme					
Teebus	Q12C	1188,6	13 500	16,0	Canals
Upper Granssridge	Q13A	3547,2	13 500	47,9	Canals
Brak River	Q13B	944,1	13 500	12,7	Brak River
Knutsford	Q13C	3284,8	13 500	44,3	Great Fish River
Baroda	Q13C	1697,9	13 500	22,9	Great Fish River
Marlow	Q30D	1921,7	13 500	25,9	Great Fish River
Scanlen	Q30E	1871,7	13 500	25,3	Great Fish River
Tarka	Q44C	1712,7	13 500	23,1	Great Fish River
Mortimer	Q50A	1467,5	13 500	19,8	Great Fish River
Renfield	Q70A	1549,1	12 500	19,4	Great Fish River
Hougham Abrahamson	Q70A	2995,7	12 500	37,4	Great Fish River
Middleton	Q70B	2149,0	12 500	26,9	Great Fish River
Klipfontein	Q50B, Q50C	2396,3	12 500	29,9	Great Fish River
Boschberg	Q20B	664,5	12 500	8,3	Fish/Sundays Canal
Somerset East	Q80E	1341,1	12 500	16,8	Fish/Sundays Canal
Sheldon	Q80G	1599,5	12 500	20,0	Little Fish River
Sundays River	N40C to N40F	13863,5	9 000	124,8	Canal from Korhaansdrift Weir
Sub-total	-	44194,9	-	521,4	
(b) Irrigation districts in the Langkloof					
Apies River *	L82A to L82D	360,0	-	-	Run-of-river and farm dams
Haarlem *		889,0	-	-	
Heights *		96,0	-	-	
Louterwater *		471,9	-	-	
Misgund Oos *		240,0	-	-	
Wabooms River *		229,2	-	-	
Sub-total	-	2286,1	-	-	-
(c) Other irrigation districts					
Blyde River *	N30A	86,3			Blyde River Dam
Commdando Drift	Q44A, Q44B	884,9	13 500	11,9	Commendo Drift Dam
Gannavlakte	Q44C				Lake Arthur
Gamtoos	L90A, B, C	7161,3	8 000	57,3	Kouga Dam
Kat River	Q94B, C, D	1600,0	10 900	17,5	Kat River Dam
Klippedrift *	Q80F	586,0			Klippedrift Dam
Koonap *	Q92E	2713,9			Koonap River
Van Rynevelds Pass *	N13C, N21A	3380,2			Van Rynevelds Pass Dam
Zwartkops *	M10C, M10D	868,0			Zwartkops River
Sub-total	-	17280,6			-
TOTALS	-	63761,6	-		-

(1) Irrigation districts that do not receive water partially or entirely from Government Water Schemes are marked with an asterisk.
(2) Confidence in the accuracy of this data is low and verification of the catchments indicated is required.
(3) Data obtained from DWAF Directorate of Water Resources Planning.

5.13.2 Permits and Other Allocations in the Fish to Tsitsikamma WMA

Information on allocations from Government Water Schemes is summarised in Tables 5.13.2.1 and 5.13.2.2.

The data in Table 5.13.2.1 was provided by the DWAF Regional Office in Cradock. The scheduled areas do not agree exactly with the areas scheduled in irrigation districts shown in Table 5.13.1.1, which were provided by the DWAF Directorate of Water Resources Planning. It is beyond the scope of this situation assessment to reconcile the differences, but reasons for the differences may include the following :

- Scheduled areas change from time to time and, even though the data supplied was supposed to be for 1995, it may in fact be for different years.

- Allocations from some Government Water Schemes include water for land that does not form part of irrigation districts in addition to water for land in irrigation districts.

- Irrigation districts may extend into other quaternary catchments in addition to those shown in Table 5.13.1.1.

Even in catchments where water is supplied mainly by Government Water Schemes, the data given in Tables 5.13.2.1 and Table 5.13.2.2 do not necessarily add up to give the areas of irrigation shown in Table 3.5.2.1: Irrigation Land-use, because :

- the areas in Table 3.5.2.1 may include some land irrigated from groundwater and from surface water sources other than the Government Water Schemes, and
- farmers may choose to use their allocations of water from Government Water Schemes to irrigate more or less than the scheduled area of land.

Table 5.13.2.2 shows allocations under Section 56(3) of the Water Act of 1956. The data was supplied by the DWAF Directorate of Water Resources Planning. It does not include the allocation of water to Port Elziabeth of 102 million m^3/a which appears not to have been made under Section 56(3).

TABLE 5.13.2.1: SECTION 63 SCHEDULING AND QUOTAS FROM GOVERNMENT WATER SCHEMES IN THE FISH TO TSITSIKAMMA WMA

SCHEME	QUATERNARY CATCHMENTS	SCHEDULING (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)
Orange/Fish Transfer Scheme				
• Orange-Fish Tunnel	Q12A, Q12C, Q13A	5 168,9	13 500	69,8
• Grassridge Dam to Elandsdrift Weir	Q13B, C, Q30B to E, Q44C, Q50A	14 118,1	13 500	190,6
• Elandsdrift Weir to Great/Little Fish confluence	Q50B, C, Q70A to Q70C	9 534,2	12 500	119,2
• Little Fish between Cookhouse Tunnel and De Mistkraal Weir	Q70B, Q80E	2 548,0	12 500	31,8
• Little Fish between De Mistkraal Weir and Great Fish Confluence	Q80G	2 252,2	12 500	28,2
• Great Fish downstream of Hermanuskraal Weir	Q91A to C, Q93A to D	375,4	12 500	4,7
• Fish-Sundays : Skoenmakers Canal to Darlington Dam	N23A, N23B	317,8	12 500	4,0
• Lower Sundays	N40C, D, E, F	13 863,0	9 000	124,8
• Total Orange/Fish Transfer Scheme	-	48 177,6	-	573,1
Tarka River Government Water Scheme	Q44A, Q44B	884,9	13 500	11,9
Gamtoos River Government Water Scheme	L90A, B, C	7 353,3	8 000	58,8
Groot River Government Water Scheme	L30C, D, L50, L70B to G	2 516,0	11 900 (1)	29,9
TOTALS		58 931,8	-	673,7

1. The actual requirement is 13 000 m^3/ha/a. Less than the scheduled area of land is irrigated to compensate for this.

TABLE 5.13.2.2: SECTION 56(3) ALLOCATIONS FROM GOVERNMENT WATER SCHEMES TO CONSUMERS IN THE FISH TO TSITSIKAMMA WMA

SCHEME	ALLOCATION (million m^3/a)					
	HOUSEHOLD & STOCK WATERING	MUNICIPALITIES	BULK INDUSTRIAL	BULK MINING	IRRIGATION	TOTAL
Great Fish River	0,03	7,73	0,00	0,00	3,18	10,94
Lower Sundays River	0,02	0,97	0,00	0,00	3,68	4,67
Tarka River	0,00	0,00	0,00	0,00	Available water	-
Kat River	0,00	2,69	0,00	0,00	0,00	2,69
Krom River	0,00	38,50	0,00	0,00	0,00	38,50
Gamtoos River	0,04	36,94	0,00	0,00	3,53	40,51
TOTALS	**0,09**	**86,83**	**0,00**	**0,00**	**10,39**	**97,31**

(1) Has been reduced to 23,5 million m^3/a in exchange for water supplied to Port Elizabeth from the Lower Sundays River Government Water Scheme.

5.13.3 Allocations in Relation to Water Requirements and Availability

The allocations from Government Water Schemes listed in Tables 5.13.2.1 and 5.13.2.2 total 771,0 million m^3/a. A quantity of 588,7 million m^3/a, or 76% of the total is allocated from the Orange/Fish Transfer Scheme, which relies on water imported from Gariep Dam to supplement local supplies. The remainder is allocated from water resources within the Fish to Tsitsikamma WMA.

In the case of the Orange/Fish Transfer Scheme, river channel losses of 112 million m^3/a, canal losses of 129 million m^3/a, freshening releases of 32 million m^3/a and the allocation to Port Elizabeth of 102 million m^3/a should be added to give a full allocated quantity of 963 million m^3/a. Re-used return flows of 131 million m^3/a reduce this amount to 832 million m^3/a.

Part of this is provided from natural runoff in the Fish and Sundays Rivers and part from Gariep Dam on the Orange River. The relative quantities vary from year to year, depending on climatic conditions in the WMA. Actual transfers between 1986 and 1993 ranged from a minimum of 399 million m^3/a in 1988, to a maximum of 639 million m^3/a in 1990. The average in the five year period from 1989 to 1993, inclusive, was 536 million m^3/a.

Modelling of the system (DWAF, 1997b) with water requirements at 1994 levels applied to historical flow sequences for the period 1920 to 1993, showed a maximum transfer from the Orange River of 707 million m^3/a (for weather conditions that occurred in 1948) and a minimum of 259 million m^3/a, with a mean for the 74 year period of 560 million m^3/a. The modelling also showed that, if no water were imported from the Orange River, the Fish/Sundays system alone could provide only 4 million m^3/a at 1:50 year assurance to the areas supplied by the Orange/Fish Transfer Scheme.

At present, the full requirement of 832 million m^3/a can be supplied from the Orange River if necessary. However, the information gathered for this situation assessment suggests that water use from the scheme in 1995 was less than the allocated quantity, as shown by the comparison in Table 5.13.3.1. The fact that the use was, at an estimated 600 million m^3/a, lower than the allocated quantity, is attributable to Port Elizabeth using only 11,5 million m^3 of its allocation of 102 million m^3/a and the estimated use for irrigation of only 77% of the allocated quantity.

TABLE 5.13.3.1: ORANGE FISH TRANSFER SCHEME: COMPARISON OF ESTIMATED WATER USE IN 1995 WITH THE ALLOCATED QUANTITY

ALLOCATED QUANTITY		ESTIMATED USE IN 1995	
Section 56 (3)	15,6 million m^3/a	Urban use (Table 4.2.2.1)	17,0 million m^3/a
Section 63 (48 177,6 ha)	573,1 million m^3/a	Irrigation field edge requirement (Table 4.5.1) :	
Allocation to Port Elizabeth	102,0 million m^3/a	13 728 ha @ 13 500 m^3/ha/a (1)	185,3 million m^3/a
		11 199 ha @ 12 500 m^3/ha/a (2)	140,0 million m^3/a
		292 ha @ 12 500 m^3/ha/a (3)	3,6 million m^3/a
		12 500 ha @ 9 000 m^3/ha/a (4)	112,5 million m^3/a
Total allocations	**690,7 million m^3/a**	**Total use**	**458,4 million m^3/a**
Canal losses :		Canal losses :	
25% of 19 287 ha @ 13 500 m^3/ha/a (1) =	65,1 million m^3/a	25% of 13 728 ha @ 13 500 m^3/ha/a (1) =	46,3 million m^3/a
25% of 14 334 ha @ 12 500 m^3/ha/a (2) =	44,8 million m^3/a	25% of 11 199 ha @ 12 500 m^3/ha/a (2) =	35,0 million m^3/a
15% of 13 863 ha @ 9 000 m^3/ha/a (4) =	18,7 million m^3/a	15% of 12 500 ha @ 9 000 m^3/ha/a (4) =	16,9 million m^3/a
Total canal losses	**128,6 million m^3/a**	**Total canal losses**	**98,2 million m^3/a**
Allocation + canal losses	**819,3 million m^3/a**	**Use and canal losses**	**556,6 million m^3/a**
River losses	112,0 million m^3/a	River losses	112,0 million m^3/a
Freshening releases	32,0 million m^3/a	Freshening releases	32,0 million m^3/a
Gross allocated quantity	**963,3 million m^3/a**	**Gross utilised quantity**	**700,6 million m^3/a**
Less return flows (6)	131,0 million m^3/a	Less return flows (5)	100,1 million m^3/a
Net allocated quantity	**832,3 million m^3/a**	**Net utilised quantity**	**600,5 million m^3/a**

1. Upstream of Elandsdrift Weir.
2. Fish-Sundays Canal and Great Fish River.
3. Lower Fish River and Tyefu.
4. Lower Sundays River.
5. From Table 5.6.2.1 : Middle Sundays + Upper Middle Fish + Middle Fish and 2,8 Urban (Upper Middle Fish from Table 5.3.2.4).
6. 100,1 x 128,6/98,2 = 131,0.

Allocations from Government Water Schemes relying entirely on the water resources of the Fish to Tsitsikamma WMA have been made from three schemes:

- The Tarka River Government Water Scheme in which 11,9 million m^3/a of water is allocated from Commando Drift Dam. The theoretical requirement is estimated to be equal to the allocation plus conveyance losses of 25%, bringing the total requirement to 14,9 million m^3/a. The 1:20 year yield of the dam is estimated to be 8,8 million m^3/a, which is considerably less than the requirement. Consequently, irrigation practices are adapted to suit the quantity of water available each year.

- The Gamtoos River Government Water Scheme in which 58,8 million m^3/a of water was allocated in 1995 from Kouga and Loerie Dams for irrigation and Port Elizabeth Municipality was allocated 23 million m^3/a. The irrigators require 44,7 million m^3/a, which is less than their allocation of 58,8 million m^3/a, and Port Elizabeth requires its full allocation of 23 million m^3/a, and Hankey and Patensie their combined allocation of 0,5 million m^3/a. Canal conveyance losses amount to about 13,5 million m^3/a, bringing the total requirement from the dams to 81,7 million m^3/a, which is more than the 1:50 year yield of 75,5 million m^3/a. However, the irrigation farmers can reduce field edge requirements during droughts to about 40 million m^3/a, which, with a corresponding reduction in conveyance losses, reduces requirements to 75,6 million m^3/a.

- The Groot River Government Water Scheme in which 29,9 million m^3/a of water from Beervlei Dam is allocated to irrigation. Actual requirements are estimated to be 16,4 million m^3/a at field edge, plus distribution losses of 0,9 million m^3/a, bringing the total requirement to 17,3 million m^3/a. The yield of Beervlei Dam was roughly estimated in this study to be 20 million m^3/a at 1:10 year assurance.

It can be seen from Table 5.13.1.1 that water allocations have been made by irrigation boards in a number of areas that are not supplied by Government Water Schemes. In these areas supplies are generally from small dams or run-of-river diversions. The areas of land irrigated are balanced against the availability of water and the actual quantity of water available each year is distributed in proportion to the allocations.

5.14 EXISTING WATER TRANSFERS

The only import of water into the Fish to Tsitsikamma WMA is that imported from Gariep Dam on the Orange River in the Upper Orange WMA. The quantity of water imported varies considerably from year to year, but averages about 560 million m^3/a.

No water is exported from the Fish to Tsitsikamma WMA, but the following internal transfers occur:

- The transfer of an average of 148 million m^3/a from Elandsdrift Weir (Q50A) on the Great Fish River to the Little Fish River (Q80E).

- The transfer of an average quantity of about 108 million m^3/a from De Mistkraal Weir (Q80E) on the Little Fish River to the Skoenmakers tributary (N23A) of the Sundays River.

- The transfer of 0,8 million m^3/a (in 1995, but likely to increase in future) from Hermanuskraal Weir (Q91C) on the Great Fish River to Grahamstown (P40A).

- The transfer of approximately 12 million m^3/a (in 1995, but likely to increase in future) from the Scheepersvlakte Balancing Dam (N40D) to Uitenhage, Despatch and the suburbs of Port Elizabeth in the Zwartkops River Catchment (M10D).

- The transfer of 23 million m^3/a (in 1995) from Churchill and Impofu Dams (K90C, K90D) to Port Elizabeth (M20A).

- The transfer of 23 million m^3/a from Kouga Dam (L82H) to Port Elizabeth (M20A).

- The transfer of 0,1 million m^3/a from the Van Stadens Dams (L90C) to Port Elizabeth (M20A).

- The transfer of 4 million m^3/a from the Bulk River and Sand River Dams (M10B) to Port Elizabeth (M20A).

- The transfer of 21,5 million m^3/a from the southern portion of Port Elizabeth (M20A) to the northern suburbs of Port Elizabeth and Despatch (M10D).

The transfers are shown on Figure 5.14.1 and statistics on them are summarised in Tables 5.14.1 and 5.14.2.

TABLE 5.14.1: AVERAGE INTER-WATER MANAGEMENT AREA TRANSFERS UNDER 1995 DEVELOPMENT CONDITIONS

DESCRIPTION OF TRANSFER	SOURCE WMA	RECEIVER WMA	TRANSFER QUANTITY RECEIVER WMA (million m^3/a)	TRANSFER QUANTITY SOURCE WMA (million m^3/a)		
				TRANSFER	LOSSES (1)	TOTAL (2)
TRANSFERS OUT OF WMA :						
None	-	-	-	-	-	-
TRANSFERS INTO WMA :						
Orange/Fish	Upper Orange	Fish to Tsitsikamma	560	448	112	560

1. Losses within the Upper Orange WMA are not known and have been assumed to be zero. River losses of 112 million m^3/a occur in the Fish to Tsitsikamma WMA.
2. The quantity varies from year to year. It averages about 560 million m^3/a.

TABLE 5.14.2: AVERAGE TRANSFERS WITHIN THE FISH TO TSITSIKAMMA WMA AT 1995 DEVELOPMENT LEVELS

DESCRIPTION OF TRANSFER	SOURCE QUATERNARY	DESTINATION QUATERNARY	QUANTITY (million m^3/a)
Little Fish River to Sundays River	Q80E	N23A	108,0
Great Fish River to Little Fish River	Q50B	Q80E	148,0
Great Fish River to Grahamstown	Q91C	P40A	0,8
Sundays River to Port Elizabeth	N40D	M10D	12,0
Churchill/Impofu Dams to Port Elziabeth	K90B, K90D	M20A	23,0
Kouga Dam to Port Elizabeth	L82H	M20A	23,0
Van Stadens Dams to Port Elizabeth	L90C	M20A	0,1
Bulk and Sand River Dams to Port Elizabeth	M10B	M20A	4,0
Southern suburbs of Port Elizabeth to northern suburbs	M20A	M10D	21,5

5.15 SUMMARY OF WATER LOSSES AND RETURN FLOWS

A summary of water requirements, losses and return flows is presented in Table 5.15.1. These numbers are also represented as pie charts in Diagrams 5.15.1 and 5.15.2.

TABLE 5.15.1: SUMMARY OF WATER REQUIREMENTS, LOSSES AND RETURN FLOWS

CATEGORY		ON-SITE WATER REQUIREMENTS (million m^3/a)	LOSSES		RETURN FLOW (million m^3/a)
			(million m^3/a)	(%)	
Irrigation		759	138	15%	136 (1)
Urban		75	25	25%	64
Rural		19			
Bulk	a) strategic	0	0	0	0
	b) mining	0	0	0	0
	c) other	0	0	0	0
Hydro-power		0	0	0	0
Rivers, wetlands		-	112	-	-
Dams		-	140	-	-
TOTAL		853	415	-	200

1. Equivalent irrigation return flow at 1:50 year assurance is 116 million m^3/a.
2. This value includes 16 million m^3/a of increased runoff from impervious urban areas which is at low assurance. The urban return flow at 1:50 year assurance is 48 million m^3/a.

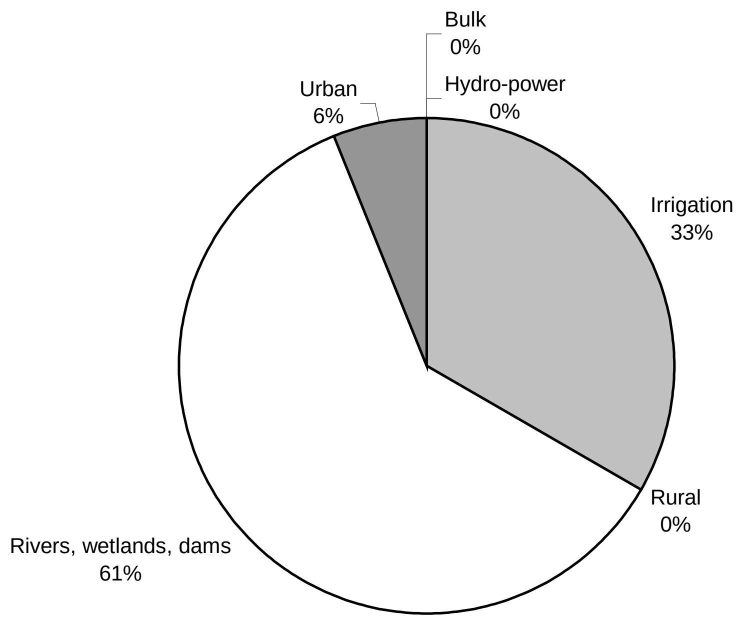

Diagram 5.15.1: Category loss as a proportion of the total losses in the WMA

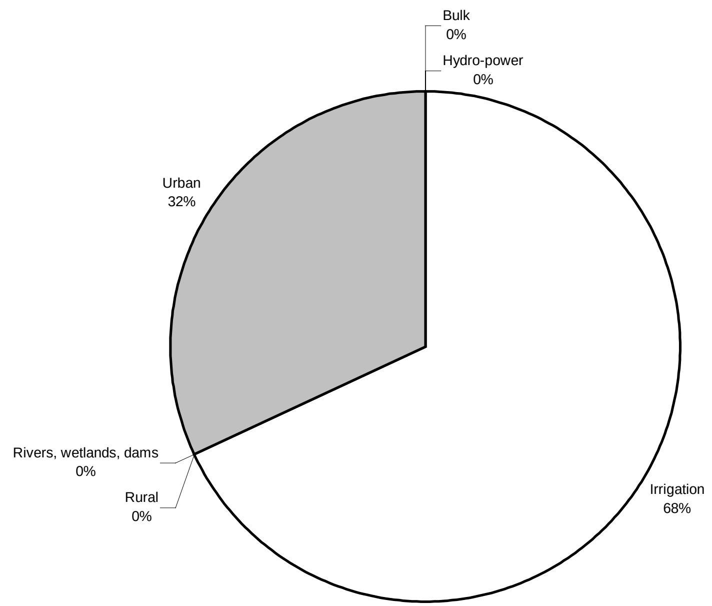

Diagram 5.15.2: Category return flow as a proportion of the total return flow in the WMA

CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

It has been estimated from the data provided in the Water Research Commission publication, "The Surface Water Resources of South Africa, 1990" (Midgley *et al*, 1994) that, under virgin conditions, the total natural MAR of the Fish to Tsitsikamma WMA was 2 154 million m^3. Approximately 25% of this, or 544 million m^3, flowed out to sea through the mouths of the rivers along the Tsitsikamma coastal strip (K80A to K80F, K90E to K90G). The catchments of these rivers constitute only 5% of the surface area of the WMA. The basin of the Great Fish River, which occupies 30% of the area of the WMA provided 24% of the natural runoff, and the Groot/Gamtoos River Basin, 23% from 36% of the area of the WMA. The lowest yield in terms of runoff per unit area of catchment is from the Sundays River which provided 12% of the natural MAR from 22% of the surface area of WMA.

The natural runoff has been reduced by evaporation losses from dams, the pumping of water from rivers and by the effects of timber plantations and alien vegetation, and has been increased by water imported from outside the WMA. The present day MAR of the WMA as a whole is roughly estimated from the water requirements, evaporation losses, return flows, and water imports described in this report to be 1 620 million m^3/a, which is 75% of the natural MAR. Twenty two major dams and about 290 smaller farm dams have been constructed in the WMA, in addition to infrastructure for the abstraction of run-of-river flow. It is estimated that, as a result of this development, a yield of 425 million m^3/a can be obtained from the surface water resources under 1:50 year drought conditions. The distribution of this yield amongst the catchments making up the WMA is shown in Table 6.1.1 as the "1:50 year developed yield in 1995". It should be noted that this does not include the yield obtained from water that is imported to the WMA.

If more large dams were constructed, the yield available from surface water at 1:50 year assurance could be increased to an estimated maximum of 654 million m^3/a. The derivation of the estimate of the maximum potential surface water yield is discussed in Section 6.3. This estimate does not take into account the possible adverse effects on the financial viability of surface water development schemes of the poor ratios of yield to storage volume or of the naturally high salinities of the base flows of rivers in many areas of the WMA. Consequently, more detailed investigations of surface water development potential may show the economically utilisable yield to be significantly less than 654 million m^3/a.

The yields shown in Table 6.1.1 are those available before the ecological Reserve has been provided for. As the National Water Act (No. 36 of 1998) provides for the Reserve to take preference over water uses other than for basic human needs in the allocation of water resources, the yield available for user sectors is less than the totals shown in Table 6.1.1. However, it has been estimated, as described in Chapter 7, that the effect of making releases for the ecological Reserve will be to reduce the 1:50 year yield available for water users by only about 30 million m^3/a at levels of development as they were in 1995. This value will increase if more dams are constructed or abstractions from run-of-river flow are increased in those areas (mainly the Tsitsikamma coastal strip) where the run-of-river flow was not fully used in 1995.

TABLE 6.1.1: WATER RESOURCES

CATCHMENT					SURFACE WATER RESOURCES (million m^3/a)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL NOT CONTRIBUTING TO SURFACE WATER BASE FLOW (million m^3/a)		TOTAL WATER RESOURCE (million m^3/a)	
PRIMARY		SECONDARY		TERTIARY/ QUATERNARY	CUMULATIVE NATURAL MAR	1:50 YEAR UTILISED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR UTILISED YIELD IN 1995	1:50 YEAR TOTAL YIELD POTENTIAL
No.	Description	No.	Description	No.							
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	86,6	50,5	50,5	1,4	41,6	51,9	51,9
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	544,4	15,7	104,7	4,3	4,3	20,0	109,0
		TOTAL IN KROM/TSITSIKAMMA			**544,4**	**66,2**	**155,2**	**5,7**	**45,9**	**71,9**	**160,9**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	142,5	12,0	29,0	2,6	75,3	14,6	75,3
		L3 to L7	Lower Groot	L30 to L70	209,4	2,7	13,0	0,7	70,7	3,4	70,7
		L8	Kouga	L81, L82	193,9	130,0	119,7	0,1	138,8	130,1	138,8
		L9	Gamtoos	L90A to C	490,9	5,5	5,5	1,6	16,2	7,1	16,2
		TOTAL IN GROOT/GAMTOOS BASIN			**490,9**	**150,2**	**167,2**	**5,0**	**301,0**	**155,2**	**301,0**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	**147,0**	**11,8**	**11,8**	**6,0**	**52,8**	**17,8**	**52,8**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	43,7	15,0	15,0	0,5	24,7	15,5	15,5
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	217,6	56,0	56,0	12,8	71,4	68,8	71,4
		N4	Lower Sundays	N40	279,9	14,0	14,0	2,2	37,3	16,2	37,3
		TOTAL IN SUNDAYS BASIN			**279,9**	**85,0**	**85,0**	**15,5**	**133,4**	**100,5**	**124,2**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	**173,6**	**17,1**	**53,0**	**1,6**	**48,2**	**18,7**	**54,6**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	60,5	2,0	11,0	0,3	22,4	2,3	22,4
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	65,9	9,0	12,0	1,8	30,6	10,8	30,6
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q13B, C Q30, Q50A, Q44C	215,6	2,0	16,0	1,7	52,1	3,7	52,1
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	38,8	20,0	20,0	0,7	10,2	20,7	20,7
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	310,0	5,7	15,0	1,3	15,1	7,0	16,3
		Q9 (Part)	Koonap	Q92	76,4	20,0	37,0	0,2	17,2	20,2	37,0
		Q9 (Part)	Kat	Q94	70,0	23,0	36,0	0,1	7,9	23,1	36,0
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	518,5	13,0	35,0	0,2	14,9	13,2	35,0
		TOTAL IN GREAT FISH BASIN			**518,5**	**94,7**	**182,0**	**6,3**	**170,4**	**101,0**	**250,1**
TOTAL IN WMA					**2154,4**	**425,0**	**654,2**	**40,1**	**751,7**	**465,1**	**943,6**

The base flow in rivers originates from seepage from groundwater. Therefore, where boreholes extract water from the same groundwater source, the surface water runoff is reduced by the quantity of water abstracted from the boreholes. However, in areas where the nature of the topography or the climate make it impractical to develop surface water resources on a large scale, groundwater may be the more important component of the utilisable water resources.

In an assessment of the extent to which the groundwater resources are additional to the surface water resources of the Fish to Tsitsikamma WMA it was concluded for the reasons given in Section 6.2 that, as a rough approximation, groundwater resources and surface water resources should be assumed to be linked to the extent that the maximum potential for the additional development of surface water resources shown in Table 6.1.1 would be reduced if the groundwater potential were to be fully developed.

On this basis, the following assumptions were made when deriving the 1:50 year yields for the total water resource shown in Table 6.1.1:

- Both the surface water yield at 1995 development levels and the potential maximum surface water yield made allowance for the effects on surface water runoff of groundwater use as it was in 1995.
- The yield developed in 1995 is the sum of the developed surface water and groundwater yields.
- The total potential yield for each key area is the greater of the sum of the incremental total potential surface water yield and the groundwater yield developed in 1995, or the total groundwater exploitation potential not contributing to surface water base flow.
- Some of the groundwater exploitation potential that does contribute to base flow is part of the ecological Reserve and is not, therefore, available as developable yield. As the quantum is not known, it has been conservatively assumed for the purposes of this assessment that it all contributes to the ecological Reserve.

The total developed water resource in 1995 was estimated to have a yield, at 1:50 year assurance, of 465 million m^3/a (425 million m^3/a from surface water and 40 million m^3/a from groundwater). The total potential yield at 1:50 year assurance is estimated to be 943 million m^3/a (a maximum of 654 million m^3/a from surface water and a minimum of 289 million m^3/a from groundwater or combinations within these limits). The distribution of the yield in 1995 amongst the key areas is shown diagrammatically on Figure 6.1.1 and Figure 6.1.2 shows the total potential yield in each key area.

6.2 GROUNDWATER

Groundwater is an important part of the total water resources of South Africa and is included in the hydrological cycle. The information provided here gives an overview of the groundwater resources, its interaction with the base flow component of the surface water, the present groundwater use (1995), and its potential for further development.

It must be noted that this information is intended for regional strategic planning and is not suitable for local site evaluations. More detailed information on the approach and methodology can be obtained in Appendix G. All information was collated on a quaternary catchment basis.

The Groundwater Harvest Potential (Seward and Seymour, 1996) was used as the basis for the evaluation. The Harvest Potential is defined as the maximum volume of groundwater that is available for abstraction without depleting the aquifer systems, and takes into account recharge, storage and drought periods (see Figure 6.2.1).

The Harvest Potential was reduced by an exploitation factor, determined from borehole yield data, to obtain an exploitation potential, i.e. the portion of the Harvest Potential which can practically be exploited (see Table 6.2.1 and Figure 6.2.2).

The interaction of the groundwater and the surface water was assessed by evaluating the base flow component of the surface water, or more specifically, the contribution of the Harvest Potential to the base flow. This contribution can be seen as water which can either be abstracted as groundwater or surface water. From this, the extent to which groundwater abstraction will reduce the base flow component of the surface water has been qualitatively evaluated (see Appendix G). Where the contribution of groundwater to the base flow component of the surface flow is zero the impact will be negligible, where the contribution is less than 30% of the base flow the impact will be low, where the contribution is between 30% and 80% of the base flow the impact will be moderate, and where the contribution to base flow is more than 80% the impact will be high. This assessment of the interaction of groundwater and the base flow component of the surface water can, however, not be used directly to determine the additional contribution of groundwater abstraction to the total utilisable water resource without also taking account of the effect of surface water storage capacity and the reduction in surface water runoff that is caused by the increase of groundwater recharge (induced recharge) that results from groundwater abstraction. The estimates of utilisable surface water given in Section 6.3 have been derived on the basis of no increased groundwater abstraction. It has been assumed for the purposes of the water resources assessment that any increase in groundwater abstraction would result in a corresponding decrease in surface water development potential. This is a conservative assumption as the impact of groundwater abstraction on surface water yields is rated "negligible" or "low" in most areas except in part of the Tsitsikamma coastal strip (K80A, B, C, D), where it is rated "high", and in the vicinity of Seymour (Q92A, Q94B, C), where it is rated "moderate".

The existing groundwater use was determined by Baron and Seward (2000). Estimates of groundwater use were also made at a workshop held on the Fish to Tsitsikamma WMA by the water resources situation assessment team. This provided local input to the estimates of groundwater use provided by Baron and Seward which were then adjusted accordingly to obtain the estimated groundwater use shown in Table 6.2.1 and Figure 6.2.4.

The groundwater balance compares existing groundwater use to the Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilised (see Figure 6.2.5 and Appendix G). If the total use was greater than the Harvest Potential the groundwater in the catchment was considered to be over-utilised, if the total use was greater than the Exploitation Potential but less than the Harvest Potential the groundwater in the catchment was considered to be heavily utilised, if the total use was more than 66% of the Exploitation Potential the groundwater in the catchment was considered to be moderately utilised, and if the total use was less than 66% of the Exploitation Potential, the groundwater in the catchment was considered to be under-utilised.

TABLE 6.2.1: GROUNDWATER RESOURCES AT 1:50 YEAR ASSURANCE OF SUPPLY

CATCHMENT						UTILISABLE GROUNDWATER EXPLOITATION POTENTIAL (million m^3/a)	GROUNDWATER USE IN 1995 (million m^3/a)	UNUSED GROUNDWATER EXPLOITATION POTENTIAL IN 1995 (million m^3/a)	GROUNDWATER CONTRIBUTION TO SURFACE BASE FLOW (million m^3/a)	PORTION OF GROUNDWATER EXPLOITATION POTENTIAL NOT CONTRIBUTING TO SURFACE BASE FLOW (million m^3/a)
PRIMARY		SECONDARY		TERTIARY/QUATERNARY						
No.	Description	No.	Description	No.	Description					
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	All Eastern Cape	58,3	1,4	56,9	16,7	41,6
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	All Eastern Cape	71,8	4,3	67,5	67,5	4,3
		TOTAL IN KROM/TSITSIKAMMA				**130,1**	**5,7**	**124,4**	**84,2**	**45,9**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	Western Cape Northern Cape Eastern Cape	46,2 12,5 16,7	1,3 0,4 0,9	44,9 12,1 15,8	0,1 0,0 0,0	46,1 12,5 16,7
		L3 to L7	Lower Groot	L30 to L70	All Eastern Cape	72,5	0,7	71,8	1,7	70,7
		L8	Kouga	L81, L82	Western Cape Eastern Cape	22,0 129,5	0,0 0,1	22,0 129,4	2,1 10,6	19,9 118,9
		L9	Gamtoos	L90A to C	All Eastern Cape	24,3	1,6	22,7	8,1	16,2
		Total in Groot/Gamtoos Basin in Northern Cape				**12,5**	**0,4**	12,1	0,0	12,5
		Total in Groot/Gamtoos Basin in Western Cape				**68,2**	**1,3**	66,9	2,3	65,9
		Total in Groot/Gamtoos Basin in Eastern Cape				**243,0**	**3,3**	240,0	20,4	222,6
		TOTAL IN GROOT/GAMTOOS BASIN				**323,7**	**5,0**	**318,7**	**22,7**	**301,0**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	All Eastern Cape	**58,1**	**6,0**	**52,1**	**5,3**	**52,8**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	Western Cape Eastern Cape	1,1 23,9	0,0 0,5	1,1 23,4	0,1 0,2	1,0 23,7
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	All Eastern Cape	72,5	12,8	59,7	1,1	71,4
		N4	Lower Sundays	N40	All Eastern Cape	38,3	2,2	36,1	1,0	37,3
		TOTAL IN SUNDAYS BASIN				**135,8**	**15,5**	**120,3**	**2,4**	**133,4**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	All Eastern Cape	**51,1**	**1,6**	**49,5**	**2,9**	**48,2**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	All Eastern Cape	22,5	0,3	22,2	0,1	22,4
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	All Eastern Cape	31,3	1,8	29,5	0,7	30,6
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C Q30, Q50A, Q44C	All Eastern Cape	53,0	1,7	51,3	0,9	52,1
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	All Eastern Cape	13,6	0,7	12,9	3,4	10,2
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	All Eastern Cape	15,8	1,3	14,5	0,7	15,1
		Q9 (Part)	Koonap	Q92	All Eastern Cape	23,4	0,2	23,2	6,2	17,2
		Q9 (Part)	Kat	Q94	All Eastern Cape	16,6	0,1	16,5	8,7	7,9
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	All Eastern Cape	15,2	0,2	15,0	0,3	14,9
		TOTAL IN GREAT FISH BASIN				**191,4**	**6,3**	**185,1**	**21,0**	**170,4**
TOTAL IN WMA IN NORTHERN CAPE						12,5	0,4	12,1	0,0	12,5
TOTAL IN WMA IN WESTERN CAPE						**69,3**	**1,3**	68,0	2,3	67,0
TOTAL IN WMA IN EASTERN CAPE						**808,4**	**38,4**	770,0	136,2	672,2
TOTAL IN WMA						**890,2**	**40,1**	**850,1**	**138,5**	**751,7**

In the Fish to Tsitsikamma WMA, groundwater was considered to be under-utilised in the Tsitsikamma, Kouga, Groot, Gamtoos, Algoa and Albany areas. It is heavily utilised to over-utilised in many parts of the Upper Fish, Upper Middle Fish and Tarka areas, and moderately utilised to heavily utilised in parts of the Middle Sundays area.

In view of the fact that a Government Subterranean Water Control Area was declared in the Zwartkops catchment (M10C, M10D), it is surprising that groundwater was found to be under-utilised in that area. This requires verification.

The total exploitable groundwater resource that does not contribute to surface base flow is 752 million m^3/a, but only 550 million m^3/a of this is potable without being desalinated.

6.3 SURFACE WATER RESOURCES

6.3.1 Streamflow Data

The basis for the analysis of surface water resources was the synthesised streamflow data at quaternary catchment level developed for the Water Research Commission funded study of the water resources of South Africa (Midgley *et al*, 1994) which is commonly referred to as WR90. Certain adjustments, as described below were made to these flow sequences.

The WR90 natural flows have taken account of afforestation-related streamflow reductions according to the "Van der Zel curves". Recently these curves have been seen as too simplistic, and have been superseded by the "CSIR curves". These curves allow the species, age and site conditions of the afforested area to be taken into account in estimating the streamflow reduction, and are currently the preferred estimation method.

For the purpose of the Water Situation Assessment Model it was decided to adjust the WR90 quaternary naturalised flows to reflect the CSIR afforestation-related streamflow reduction effects. An investigation to determine a method of making the adjustments without serious time or cost implications was conducted (Ninham Shand, 1999). The selected method consisted of the following steps:

(1) The afforestation water use time series based on the Van der Zel 15-year rotation curve was generated
.

(2) This time series (the result of (1)) was then subtracted from the Van der Zel-based naturalised flow time series generated for the whole calibration catchment.

(3) The naturalised flow from the afforested portion of the catchment (Van der Zel-based) was used to obtain an afforestation water use time series based on the CSIR curves. This result was added to the result of (2), yielding a time series of adjusted (CSIR-based) naturalised flows.

These adjusted flows have been used for the catchments that contain afforestation.

A validation of this adjustment method was carried out for five gauged catchments from three geographically different regions, which had full hydrological studies available from recent basin studies. Calibration configurations were obtained from these studies. An identical configuration was set up to include the CSIR afforestation-related flow reduction function, and the Pitman model was recalibrated. This resulted in two calibrated" sets of Pitman model parameters for each catchment, the one using the Van der Zel, and the other using the CSIR afforestation-related streamflow reduction functions.

Monthly naturalised flows were simulated using the two calibrated parameter sets. The CSIR series was used as the "true" series for validation and compared with the Van der Zel time series after it was adjusted as described above.

Differences between the MARs of the adjusted (CSIR-based) naturalised flows and the re-calibrated "true" naturalised flows were within 5%, which was considered to be acceptable.

Based on the three steps described above, the WR90 naturalised flow series were then adjusted for all the afforested quaternary catchments in the country. If the runoff reduction due to afforestation estimated by means of the CSIR curves was lower than the runoff reduction estimated by means of the Van der Zel curves, the virgin runoff of WR90 would have been reduced and vice versa. The difference between the adjusted MARs and the original WR90 values ranges between a reduction of 18% and an increase of 28%. For most of the catchments the difference varies between zero and an increase of 7%. In the Fish to Tsitsikamma WMA the differences ranged between an increase of 7% in Tsitsikamma Coast area and an increase of 8% in the Kat River Catchment.

The proposed methodology ensures that the calculated runoff from an afforested catchment (which would be observed at a streamflow gauge) is the same, irrespective of the afforestation water use model that has been used.

The most important limitations of the method described above are:

- The updated afforestation water use was estimated by means of the CSIR curves (as described in (3)), but the uncorrected naturalised flows based on the original Van der Zel curves were used as an input into this calculation. As a refinement, one could consider the possibility of repeating the process, but this time estimating afforestation water use, not using the original WR90 naturalised flows, but rather the newly adjusted ones. This could then be used to make a second estimate of the CSIR-based natural flows. Further re-iterations of this process might improve the accuracy.
- Catchments upstream of some calibration gauges contained quaternaries with and without afforestation. Changing the MARs of only afforested quaternary catchments therefore made the naturalised MAR of the total catchment less accurate, as the MARs of unafforested catchments were not adjusted.

The perfect solution is to re-calibrate all affected catchments. However, as was explained above, at this stage it was considered inappropriate.

Three detailed studies of the hydrology of portions of the Fish to Tsitsikamma WMA have been carried out in the past. Brief descriptions of them follow.

- The Algoa Water Resources System Analysis (DWAF, 1994b) included hydrological modelling of the Kouga (L81, L82), Krom (K90A to K90D) and Upper Zwartkops (M10A, M10B) River catchments.
- The Algoa Water Resources Stochastic Analysis (DWAF, 1996) involved stochastic analysis of the yields of the dams in the catchments covered by the Algoa System Analysis.

- The Orange River Development Project Replanning Study in which the WR90 natural flow sequences for the Great Fish and the Sundays River catchments were updated using additional rainfall and evaporation records and a range of scenarios using water imported from the Orange River was modelled (DWAF, 1997b).

6.3.2 Yield Analysis

Where appropriate, the results of the above studies were used to derive the 1995 yields shown in Table 6.3.2.1. In those areas not covered by the above studies, and those areas where the study data were not sufficiently detailed from localised studies, the appropriate storage-draft-frequency curves from WR90 were used to estimate the yields of the main dams. The effects of water use in the catchments of the dams by afforestation, farm dams, run-of-river abstractions, alien vegetation, etc. were taken into account in determining the yields of the dams, i.e. the yields are net of upstream water use.

The combined run-of-river and farm dam yields were estimated in consultation with officials of the DWAF Eastern Cape Regional Office as the differences between the yields of the major dams and the officials' perception, based on their knowledge of the area, of the total quantities of water for irrigation available at 1:50 year assurance. These estimates are, therefore, at a low level of confidence, and subsequent reference to the WR90 deficient flow-duration-frequency curves has indicated that they may be unrealistically high, particularly in the Fish and Sundays River catchments. However, as the higher estimates have been used for the National Water Resource Strategy, they have been retained in this report.

In this report, the yield obtainable from dams together with the yield that can be abstracted from rivers by means of diversion weirs, pumps, or other equipment or infrastructure is referred to as developed surface water yield. Streamflow is also affected by afforestation and alien vegetation, and their impact on yield, together with the developed yield, is referred to as the utilised surface water yield.

The utilised surface water yields in 1995 shown in Table 6.3.2.1 for the key areas are based on the following assumptions:

- In the Krom River Catchment upstream of Impofu Dam:
  - the combined yields of Churchill and Impofu Dams of 44,4 million m^3/a,
  - an estimated yield of 2,6 million m^3/a from farm dams and run-of-river abstractions,
  - the estimated impact on yield of water use by alien vegetation of 3,5 million m^3/a,
  - giving a total of 50,5 million m^3/a.

- In the Tsitsikamma Coastal area:
  - the yield of Klippedrift Dam of 2,5 million m^3/a,
  - an estimated yield of 5,5 million m^3/a from farm dams and run-of-river abstractions,
  - the impact of afforestation on yield of 4,7 million m^3/a,
  - the impact on yield of water use by alien vegetation of 3,0 million m^3/a,
  - giving a total of 15,7 million m^3/a.

TABLE 6.3.2.1: SURFACE WATER RESOURCES

CATCHMENT					INCREMENTAL CATCHMENT AREA (km^2)	MEAN ANNUAL PRECIPITATION (mm/a)	MEAN ANNUAL EVAPORATION (mm/a)	NATURAL MAR (million m^3/a)		INCREMENTAL YIELD (1:50 YEAR)	
PRIMARY		SECONDARY		TERTIARY/QUATERNARY				INCREMENTAL	CUMULATIVE	UTILISED IN 1995 (million m^3/a)	TOTAL POTENTIAL (million m^3/a)
No.	Description	No.	Description	No.							
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	846	695	1 400	86,6	86,6	50,5	50,5
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	1 18	856	1 400	457,8	544,4	15,7	104,7
		TOTAL IN KROM/TSITSIKAMMA			**2 64**	**792**	**1 400**	**544,4**	**544,4**	**66,2**	**155,2**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	20 07	230	2 150	142,5	142,5	17,0	29,0
		L3 to L7	Lower Groot	L30 to L70	7 55	266	1 870	66,9	209,4	8,0	13,0
		L8	Kouga	L81, L82	4 53	541	1 600	193,9	193,9	119,7	119,7
		L9	Gamtoos	L90A to C	1 201	576	1 560	87,6	490,9	5,5	5,5
		TOTAL IN GROOT/GAMTOOS BASIN			**34 816**	**323**	**1 840**	**490,9**	**490,9**	**150,2**	**167,2**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	**2 630**	**550**	**1 550**	**147,0**	**147,0**	**11,8**	**11,8**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	3 673	352	1 900	43,7	43,7	15,0	15,0
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	13 175	297	1 850	173,9	217,6	56,0	56,0
		N4	Lower Sundays	N40	4 400	416	1 630	62,3	279,9	14,0	14,0
		TOTAL IN SUNDAYS BASIN			**21 248**	**324**	**1 820**	**279,9**	**279,9**	**85,0**	**85,0**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	**5 322**	**570**	**1 520**	**173,6**	**173,6**	**17,1**	**53,0**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	4 324	359	1 790	60,5	60,5	2,0	11,0
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	4 498	406	1 740	65,9	65,9	9,0	12,0
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C Q30, Q50A, Q44C	8 045	333	1 820	89,2	215,6	2,0	16,0
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	1 871	422	1 770	34,8	38,8	20,0	20,0
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	3 345	415	1 700	55,7	310,1	5,7	15,0
		Q9 (Part)	Koonap	Q92	3 334	535	1 630	76,4	76,4	20,0	37,0
		Q9 (Part)	Kat	Q94	1 715	668	1 580	70,0	70,0	23,0	36,0
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	3 111	470	1 520	62,0	518,5	13,0	35,0
		TOTAL IN GREAT FISH BASIN			**30 243**	**425**	**1 720**	**518,5**	**518,5**	**94,7**	**182,0**
TOTAL IN WMA					**97 023**	**420**	**1 750**	**2154,3**	**2154,3**	**425,0**	**654,2**

- In the Upper Groot River Catchment:
  - the yield of Beervlei Dam of 12,0 million m^3/a,
  - run-of-river yield of 5,0 million m^3/a (but data in WR90 indicates that the yield may be less than 1 million m^3/a).
  - giving a total of 17,0 million m^3/a.

- In the Lower Groot River Catchment:
  - the yield of Klipplaat Dam of 0,8 million m^3/a,
  - an estimated yield of 7,2 million m^3/a from farm dams and run-of-river abstractions (but the deficient flow-duration-frequency curves in WR90 show that the yield may be less than 1 million m^3/a),
  - giving a total of 8,0 million m^3/a.

- In the Kouga River Catchment:
  - the yield of Kouga Dam of 74,5 million m^3/a,
  - the yield of Haarlem Dam of 3,8 million m^3/a,
  - an estimated yield of 30,5 million m^3/a (from DWAF, 1994) from farm dams and run-of-river abstractions,
  - the estimated impact on utilisable yield of alien vegetation of 10,9 million m^3/a,
  - giving a total of 119,7 million m^3/a.

- In the Gamtoos River incremental catchment:
  - the yield of the Van Stadens River Dams of 0,1 million m^3/a,
  - the yield of Loerie Dam, assumed to be 1,0 million m^3/a,
  - an estimated yield of 2,8 million m^3/a from farm dams and run-of-river abstractions,
  - the estimated impact of afforestation on yield of 0,5 million m^3/a,
  - the estimated impact of alien vegetation on yield of 1,1 million m^3/a,
  - giving a total of 5,5 million m^3/a.

- In the Algoa Coast area:
  - the combined yields of Groendal Dam, Bulk River Dam and Sand River Dam of 9,8 million m^3/a,
  - an estimated yield from run-of-river abstractions of 1,4 million m^3/a,
  - the impact on yield of afforestation of 0,2 million m^3/a,
  - the estimated impact on yield of alien vegetation of 0,4 million m^3/a,
  - giving a total of 11,8 million m^3/a.

- In the Upper Sundays River Catchment:
  - the yield of Van Rynevelds Pass Dam of 4,5 million m^3/a,
  - an estimated yield of 10,5 million m^3/a from farm dams and run-of-river abstractions (reference to WR90 suggests that this estimate may be high and that 1,5 million m^3/a might be more realistic),
  - giving a total of 15,0 million m^3/a.

- In the Middle Sundays River Catchment:
  - assuming that under 1:50 year drought conditions, Darlington Dam operates purely as a balancing dam for water transferred from the Fish River, and has no yield from the Sundays River catchment, there is no yield from major dams,
  - the yield from farm dams and run-of-river abstractions has been assumed to be 56 million m^3/a, but the WR90 deficient flow-duration-frequency curves show that the yield could be as low as 6 million m^3/a,

- as the impacts on yield of alien vegetation and afforestation are negligible, the total utilised yield of this area has been assumed to be 56 million m^3/a.

- In the Lower Sundays River Catchment the only major dams are balancing dams for irrigation and urban supplies, and their yields are negligible. The yield from farm dams and run-of-river abstractions has been assumed to be 14 million m^3/a, but data obtained from WR90 shows that it could be as low as 2,5 million m^3/a.

- In the Albany Coast area :
  - the combined yields of Nuwejaars, Howiesons Poort, Settlers, Jamieson and Sarel Hayward Dams of 6,8 million m^3/a,
  - an estimated yield from farm dams and run-of-river abstractions of 8,0 million m^3/a,
  - the estimated impact on yield of alien vegetation of 2,3 million m^3/a,
  - giving a total yield of 17,1 million m^3/a.

- In the Upper Fish River Catchment :
  - no yield from major dams as Grassridge Dam is assumed to have negligible yield from local runoff under 1:50 year drought conditions and to act purely as a balancing dam for water imported from the Orange River,
  - an estimated run-of-river yield from the upper reaches of the tributaries upstream of Grassridge Dam of 2,0 million m^3/a,
  - giving a total of 2,0 million m^3/a.

- In the Tarka River Catchment above Lake Arthur :
  - the yield from Commando Drift Dam of 7,0 million m^3/a (Lake Arthur has negligible 1:50 year yield),
  - an estimated yield from farm dams and run-of-river abstractions of 2,0 million m^3/a,
  - giving a total of 9,0 million m^3/a.

- In the portion of the Middle Fish Catchment above Elandsdrift Dam :
  - estimated run-of-river yield of 2,0 million m^3/a.

- In the portion of the Middle Fish Catchment below Elandsdrift Weir :
  - an estimated yield from farm dams and run-of-river abstractions of 5,7 million m^3/a (but the WR90 deficient flow-duration-frequency curves show that 2 million m^3/a might be more realistic).

- In the Little Fish Catchment above De Mistkraal Weir :
  - an estimated yield from farm dams and run-of-river abstractions of 20,0 million m^3/a (but the yield might be as low as 3 million m^3/a according to data obtained from WR90).

- In the Koonap River Catchment :
  - an estimated yield from farm dams and run-of-river abstractions of 20,0 million m^3/a (but the deficient flow-duration-frequency curves in WR90 indicate that it might be as low as 10 million m^3/a).

- In the Kat River Catchment :
  - a yield of 12,7 million m^3/a from the Kat River Dam,

- an estimated yield from farm dams and run-of-river abstractions of 10,3 million m^3/a,
- giving a total of 23,0 million m^3/a.

- In the Lower Fish
  - an estimated yield of 13 million m^3/a from farm dams and run-of-river abstractions (but the deficient flow-duration-frequency curves in WR90 indicate that there might be no yield).

Thus, the total utilised yield of the surface water resources in 1995 is estimated to have been 425 million m^3/a, distributed amongst key areas as shown in Table 6.3.2.1. This estimate is at a low level of confidence because of uncertainty regarding the true yield obtained from farm dams and run-of-river flow, estimated to have been 218 million m/a, but which may be as low as 93 million m^3/a. Estimates of the impact on yield of afforestation, amounting to 7,1 million m^3/a, and water use by alien vegetation totalling 21,6 million m^3/a are also of low reliability.

Several investigations of schemes to further develop portions of the surface water resources of the WMA have been carried out, but none of these was designed to obtain the maximum potential yield from the catchments, so they were not used for the purposes of determining maximum potential yield. Instead, as an aid to estimating the total potential yield available from the catchments within the WMA, future storage dams of a particular maximum net storage capacity have been postulated. The method used is extremely rough and the results are very approximate, merely giving an indication of the potential yield in each key area. These results should not be used for any study where accurate results are necessary. More detailed investigation in the specific area should be undertaken when more reliable results are required.

The capacities and yields of the hypothetical dams were derived as follows:

Estimates of the maximum feasible storage (expressed as a percentage of MAR) for dams in each WR90 hydro zone were derived for this project (DWAF, 1999c). Dams that will capture and regulate all the runoff from a catchment are not economical to build. In the drier areas where the runoff is more variable the sizes of such dams also become prohibitive. A simple technique, based on past experience, has therefore been developed whereby plausible estimates of maximum feasible dam sizes have been derived for the entire South Africa and which will provide consistent results throughout the country. The water situation assessment model (WSAM) will, however, be enhanced in future to contain additional functionality to allow users to optimise the likely maximum storage capacity.

The technique that was adopted introduces a limit line to the net storage-gross yield relationship for a 50 year recurrence interval, as shown in Diagram 6.3.2.1. The net total incremental quaternary catchment storage capacity used to estimate the potential contribution to the yield by a quaternary catchment has been determined from the intersection of the net storage-gross yield relationship for a 50 year recurrence interval for a particular hydrologic zone, and the limit line shown in Diagram 6.3.2.1. This is illustrated by means of the typical net storage-gross yield relationships shown in Diagram 6.3.2.1 for rivers of low, moderate and high flow variability, which generally correspond to rivers draining high, moderate and low rainfall catchment areas respectively. The net total incremental storage capacities derived by means of this method have been rounded off to 100%, 125%, 150%, 200%, or 300% of the MAR, as appropriate.

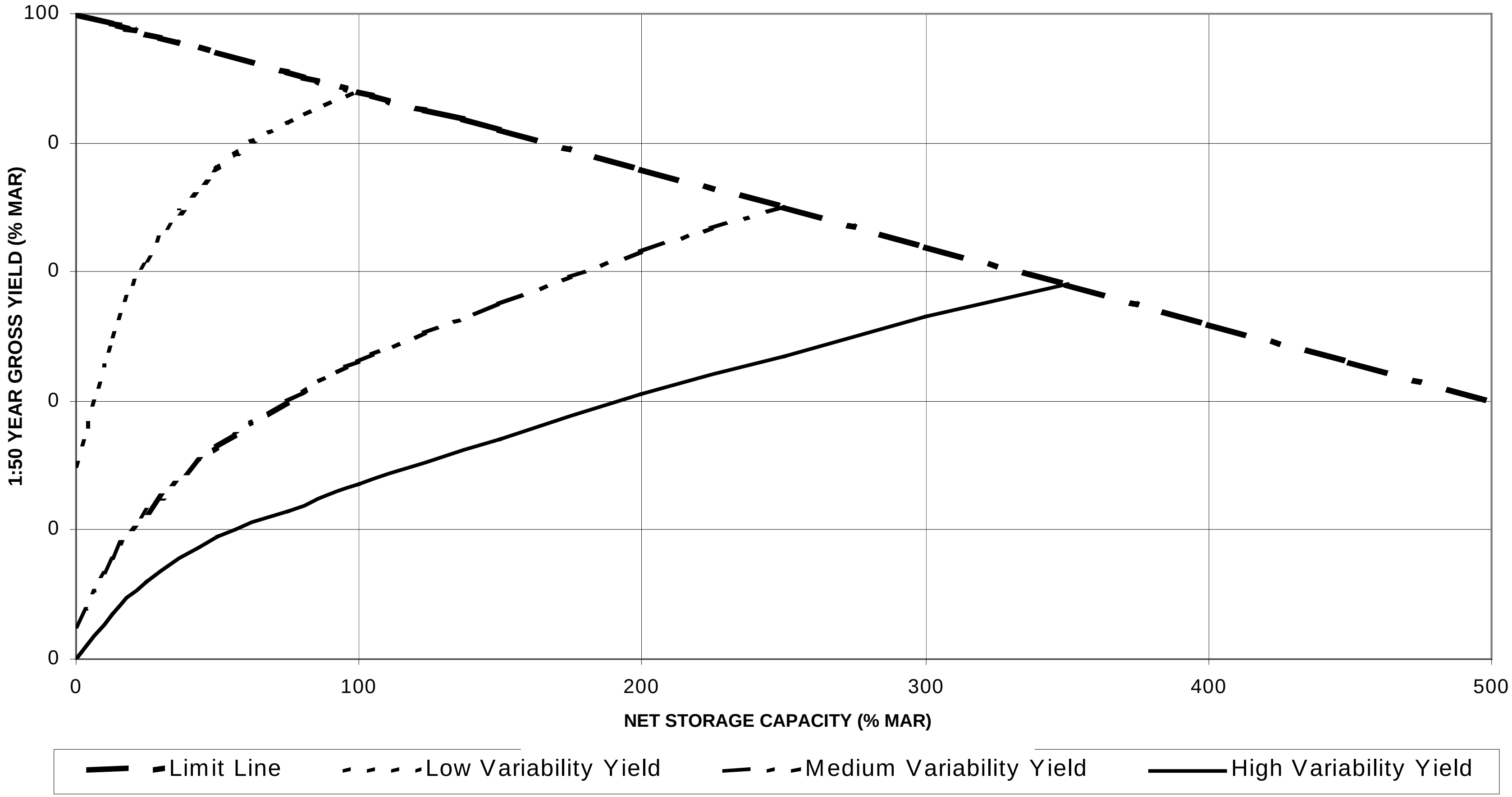

DIAGRAM 6.3.2.1: DAM STORAGE LIMITES

The relevant hydro zones and maximum storage values are summarised in Table 6.3.2.2. These range from 100% of the MAR in the higher rainfall quaternary catchments to 300% of the MAR in the drier quaternary catchments within the WMA.

The incremental instream flow requirement for the most downstream quaternary catchment in each key area was subtracted from the incremental MAR at that point. The remaining MAR was used to determine the maximum feasible storage capacity and corresponding 1:50 year gross yield from WR90. The values were estimated to be 3 909 million m^3 and 1 387 million m^3/a respectively for the WMA as a whole. These values are the sums of separate values calculated for each key area. The calculations are shown in Table 6.3.2.3.

TABLE 6.3.2.2: ESTIMATES OF MAXIMUM FEASIBLE STORAGE (EXPRESSED AS A PERCENTAGE OF MAR)

WR 90 HYDRO ZONE	PERCENTAGE OF MAR (1)	CATCHMENTS IN WMA LYING WITHIN HYDRO ZONE
B	100	K80A to K80D Tsitsikamma
F	150	K80E, K80F Tsitsikamma K90A, K90B Krom
H	200	L90A , L90C, L70C Gamtoos K90C to K90G Krom, Seekoei
N	250	L82A to L82J Kouga
P	200	Q30A Fish Q80A to Q80D Little Fish Q92B to Q92D Koonap
K	200	Q92A Upper Koonap Q94A to Q94C Upper Kat
Q	250	M10A to M10C Upper Zwartkops M20B Van Stadens
R	250	N40A, N40C Lower Sundays P10A, P10B, P10C, P10D Upper Bushmans P30A Upper Kariega P40A Upper Kowie
T	200	N11, N12, N13, N21, N30 Upper/Middle Sundays Q1, Q2, Q4, Q5, Q6, Q7 Fish
U	250	L81A to L81D Baviaanskloof N14, N22, N23, N24, N24 Middle Sundays
V	250	M20A Bakens
W	300	W92E to Q92G Koonap Q94F Lower Kat Q91C, Q93A to Q93C Lower Great Fish
X	300	N40B to N40F Lower Sundays M30A, M30B Coega
Z	300	L11 to L60, L70A to L70F Groot

(1) This information is extracted from a report by Stewart Scott prepared for DWAF for this study (DWAF 1999c).

The gross yields given by the WR90 curves have not had evaporation losses subtracted from them. The effects of evaporation losses were estimated by comparing the yields of representative existing dams (Churchill, Impofu, Kouga, Beervlei, Van Rynevelds Pass, Nuwejaars, Settlers, Howiesons Poort, Commando Drift and Kat River) as calculated in previous more detailed studies, with gross yields calculated using the WR90 curves. The ratios of net yields allowing for evaporation losses to gross yields, ranged from 0,21 for Beervlei Dam, through 0,63 for Churchill and Impofu Dams, to 0,90 for Kouga Dam.

The appropriate one of these ratios was applied to each of the gross yields calculated to obtain a yield adjusted for evaporation losses. This gave a potential maximum yield for the whole WMA of 748 million m^3/a, net of evaporation losses.

In order to determine the quantity of additional yield that would have to be developed to reach the full potential yield of the water resources, the 1:50 year yields in 1995 of existing major dams (totalling 179,9 million m^3/a for the WMA), farm dams and developed run-of-river yield (totalling 216,4 million m^3/a) and the impacts on yield of afforestation (totalling 7,1 million m^3/a) and water use by alien vegetation (totalling 21,6 million m^3/a) were subtracted from the estimated potential maximum yield of 748 million m^3/a.

The calculation was performed for each key area. In the Tsitsikamma coastal catchments, the utilisable portion of the undeveloped yield was assumed to be half of the full amount, it being assumed that the other half would be required to provide the freshwater ecological flow requirements of the estuaries. This adjustment was based on the figures for the existing Wolwedans Dam on the Great Brak River in the Gouritz WMA. In the Algoa Coastal catchments and the incremental catchment of the Gamtoos River (L90), studies previously carried out as part of the Algoa System Analysis (DWAF, 1994c) indicated that further development of the surface water resources of the Algoa catchments would not be viable because of the freshwater flow requirements of the estuaries and the lack of economical dam sites. Consequently, it has been assumed that there is no potential for further surface water development in those two key areas.

In the Upper Krom, the Upper Sundays, and the Middle Sundays key areas, the 1:50 year yields from farm dams and run-of-river abstractions estimated in consultation with officials of the DWAF Eastern Cape Regional Office result in the estimated total utilised 1:50 year yield in 1995 being higher than the subsequently estimated total potential 1:50 year yields which were derived from the WR90 storage-draft-frequency curves. These higher values have been retained as the potential maximum yields for this situation assessment because they are also the values that have been used for the first draft of the National Water Resources Strategy, but they require verification.

The potential maximum surface water yield for each key area in the WMA was calculated by adding the utilisable undeveloped potential yield to the developed yield in 1995. The calculations are summarised in Table 6.3.2.3, where it can be seen that the potential undeveloped surface water yield of the WMA is estimated to be 229 million m^3/a, and that, if developed, this would bring the total utilisable yield obtainable from the surface water resources of the WMA to 654 million m^3/a.

The natural MAR generated by each quaternary catchment is shown on Figure 6.3.1 and the maximum potential surface water yield is shown diagrammatically on Figure 6.3.2.

6.4 WATER QUALITY

6.4.1 Mineralogical Surface Water Quality

The purpose of this assessment is to provide an indication of where water quality problems can be expected rather than provide a comprehensive overview of water quality in the Water Management Area.

The mineralogical water quality of the surface water bodies is described in terms of total dissolved salts (TDS). Data for the assessment were obtained from the water quality database of the Department of Water Affairs and Forestry.

TABLE 6.3.2.3: CALCULATION OF POTENTIAL MAXIMUM SURFACE YIELD IN THE FISH TO TSITSIKAMMA WMA

Key Area		WR90 Hydro Zone	Maximum Feasible Storage Capacity	Incremental MAR	Incremental IFR fEMPi	Incre-mental MAR less IFR	Maximum Feasible Storage Capacity	1:50 year RI Gross Draft as % MAR (from WR90 Storage-Draft-Frequency	Gross Potential Maximum Yield (WR90 1:50 Yield)	Ratio used for allowance for evaporative losses (see Note 1 below)	Net Potential Maximum Yield (WR90 1:50 Yield)	Yield of Major Dams in 1995	Run of River & Minor Dam Yield in 1995	Impact of Afforestation on Yield	Impact of Alien Vegetation on Yield in 1995	Total Utilised Yield in 1995	Interim potential develop-able yield	Adjusted Potential Develop-able Yield (See Note 2 below)	Accepted Potential Develop-able Yield (-ve values zeroed)	Final Nett Potential Maximum Yield (WR90 1:50 Yield)
Description	**Catchments**		**% MAR**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**% MAR**	**$M.m^3/a$**		**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**	**$M.m^3/a$**
Upper Krom	K90A to D	F	150	86,6	9	78	117	0,82	64	0,63	40	44,4	2,6	0,0	3,5	50,5	-10,5	-	0,0	50,5 (3)
Tsitsikamma Coast	K80A to F, K90E to K90G	B	100	457,8	107	351	351	0,88	309	0,63	194	2,5	5,5	4,7	3,0	15,7	178,3	89,0	89,0	104,7
Upper Groot	L11, L12, L21, L22, L23	Z	300	142,5	13	130	390	0,63	82	0,35	29	12,0	5,0	0,0	0,0	17,0	12,0	-	12,0	29,0
Lower Groot	L30 - L70	Z	300	66,9	6	61	183	0,63	34	0,35	13	0,8	7,2	0,0	0,0	8,0	5,0	-	5,0	13,0
Kouga	L81, L82	N	250	193,9	20	174	435	0,70	122	0,90	110	78,3	30,5	0,0	10,9	119,7	-9,7	0,0 (3)	0,0	119,7 (3)
Gamtoos	L90	H	200	87,6	0	87	164	0,82	71	0,63	45	1,1	3,9	0,5	0,0	5,5	39,5	20,0	0,0 (4)	5,5
Algoa Coast	M10, M20, M30	Q	250	147,0	15	132	330	0,72	95	0,63	60	9,8	1,4	0,2	0,4	11,8	48,2	24,0	0,0 (4)	11,8
Upper Sundays	N11, N12	T	200	43,7	3	41	82	0,70	29	0,21	6	4,5	10,5	0,0	0,0	15,0	-9,0	0,0 (3)	0,0	15,0 (3)
Middle Sundays	N13, N14, N21-N23, N30	T	200	173,9	10	164	328	0,70	114	0,21	24	0,0	55,7	0,0	0,3	56,0	-32	0,0 (3)	0,0	56,0 (3)
Lower Sundays	N40	X	300	62,3	7	55	165	0,50	28	0,51	14	0,0	14,0	0,0	0,0	14,0	0,0	-	0,0	14,0
Albany Coastal Catchments	P10 - P40	R, V	250	173,6	15	159	398	0,66	105	0,51	53	6,8	8,0	0,0	2,3	17,1	35,9	-	35,9	53,0
Upper Fish	Q11, Q12, Q13A	T	200	60,5	5	56	112	0,70	39	0,28	11	0,0	2,0	0,0	0,0	2,0	9,0	-	9,0	11,0
Tarka	Q41, Q42, Q43, Q44A to Q44B	T	200	65,9	5	61	122	0,70	43	0,28	12	7,0	2,0	0,0	0,0	9,0	3,0	-	3,0	12,0
Upper Middle Fish	Q80A to Q80E	T	200	89,2	6	83	166	0,70	58	0,28	16	0,0	2,0	0,0	0,0	2,0	14,0	-	14,0	16,0
Upper Little Fish	Q80A to Q80E	P	200	38,8	4	35	70	0,78	27	0,28	8	0,0	20,0	0,0	0,0	20,0	-12,0	0,0 (3)	0,0	20,0 (3)
Middle Fish	Q50B, Q50C, Q60, Q70, Q80F, Q80G	T	200	55,7	4	52	104	0,64	32	0,48	15	0,0	5,7	0,0	0,0	5,7	9,3	-	9,3	15,0
Koonap	Q92	K, P, W	200	76,4	10	66	132	0,78	51	0,51	37	0,0	20,0	0,0	0,0	20,0	17,0	-	17,0	37,0
Kat	Q94	K, P, W	150	70,0	7	63	95	0,78	49	0,73	36	12,7	7,4	1,7	1,2	23,0	13,0	-	13,0	36,0
Lower Fish	Q91, Q93	W	300	62,0	7	55	165	0,64	35	0,73	25	0,0	13,0	0,0	0,0	13,0	22,0	-	22,0	35,0
TOTALS		**-**	**-**	**2154,3**	**253**	**1903**	**3909**	**-**	**1387**	**0,54**	**748**	**179,9**	**216,4**	**7,1**	**21,6**	**425,0**	**-**	**-**	**229,2**	**654,2**

Note 1 : Allowance for evaporation losses from Dams: One of eight ratios was taken, based on a comparison of the WR90 1:50 year yields with net yields obtained in studies of the following dams: Churchill and Impofu Dams combined = 0,63; Beervlei Dam = 0,35; Kouga Dam = 0,90; Van Rynevelds Pass Dam = 0,21; Nuwejaars, Settlers and Howiesons Poort Dams combined = 0,51; Commando Drift Dam = 0,28; Nuwejaars Dam = 0,48.

Note 2: For coastal catchments only, only half the potential yield was taken (but the full storage was kept). This is because, based on the numbers for the Groot Brak River in the Gouritz WMA, where the Wolwedans Dam was built in 1993, presumably to maximum capacity only approximately half of the potential yield will be available to users, because the rest will be required for estuarine flow requirements.

Note 3: The utilised 1:50 year yields in 1995 estimated in consultation with officials of the DWAF Eastern Cape Regional Office exceed the potential maximum yields subsequently estimated from WR90 data. The higher values have been used for this situation assessment but require verification.

Note 4: Studies caried out for the Algoa System Analysis (DWAF, 1994) indicated that further development of surface water resources would not be economical under present conditions because of poor dam sites and the ecological freshwater flow requirements of the estuaries.

The surface water quality monitoring stations that were used to provide the data are shown in Figure 6.4.1.1. There were 12 monitoring points on the K80 and K90 coastal catchments of which six were adequate for assessing the mineralogical status. The Krom, Salt and Upper Kariega catchments (L11, L12, L21, L22 and L23) were poorly monitored and the distribution of monitoring points was probably a reflection of the absence of perennial rivers in the area. There was a better distribution of monitoring points in the lower reaches of the Groot River (L60 and L70) and the Kouga River (L80) had a number of good monitoring points. The Sundays River catchment (N catchment) had a good distribution of monitoring points but the records in the middle reaches were inadequate for the assessment of the present status. The Fish River catchment (Q catchment) had a good distribution of monitoring points and many stations had adequate data records for assessing the mineralogical status. The Bushmans River catchment (P10 and P30) also had a good distribution of monitoring stations with adequate data records for characterising the present mineralogical status.

Only data sets that had data for the last five years (1994-1998) were used. The data sets were filtered to monthly data, and various techniques were used to fill in missing values where possible. The assessment method calls for only those data sets that span at least two years and contain at least 24 data points to be used for analysis. These should be used to derive the mean and maximum TDS concentrations. Owing to the poor status of water quality monitoring in the WMA, the whole 5 year data set of monthly TDS values was used in some cases to characterise the water quality because there were no monitoring points which fully met the criteria.

Details of the TDS and electrical conductivity (EC) for the various catchments are given in Appendix G.

The water quality is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements of other uses. The South African Water Quality Guidelines of the Department of Water Affairs and Forestry (DWAF, 1996) for these two uses were combined into a single classification system as shown in Table 6.4.1.1.

TABLE 6.4.1.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

CLASS	COLOUR CODE	DESCRIPTION	TDS RANGE (MG/ℓ)
0	Blue	Ideal water quality	<260
1	Green	Good water quality	260 - 600
2	Yellow	Marginal water quality	601 - 1800
3	Red	Poor water quality	1801 - 3400
4	Purple	Completely unacceptable water quality	>3400

Where water quality data were available, water quality was assessed at a quaternary catchment level of resolution. The final classification of the mineralogical surface water quality of a quaternary catchment was based on both average conditions and extreme conditions. For this purpose the data set was inspected for the worst two-year period observed. The average concentration and the maximum were used to determine the class of the water as shown in Table 6.4.1.2.

TABLE 6.4.1.2: OVERALL CLASSIFICATION

AVERAGE CONCENTRATION CLASS	MAXIMUM CONCENTRATION CLASS	OVERALL CLASSIFICATION
Blue	Blue Green Yellow Red Purple	Blue Green Green Yellow Purple
Green	Green Yellow Red Purple	Green Yellow Yellow Purple
Yellow	Yellow Red Purple	Yellow Red Purple
Red	Red Purple	Red Purple
Purple	Purple	Purple

The water quality of the Fish to Tsitsikamma Water Management Area is summarised in Table 6.4.1.3 and is shown on Figure 6.4.1.1.

TABLE 6.4.1.3: SUMMARY OF MINERALOGICAL SURFACE WATER QUALITY OF THE FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

SECONDARY CATCHMENT	NO OF QUATERNARY CATCHMENTS	NO OF QUATERNARY CATCHMENTS IN CLASS					
		BLUE	GREEN	YELLOW	RED	PURPLE	NO DATA
K80	6	1	0	0	0	0	5
K90	7	2	0	3	0	0	2
L10	11	0	0	0	0	0	11
L20	14	0	0	0	0	0	14
L30	4	0	0	1	0	0	3
L40	2	0	0	0	0	0	2
L50	2	0	0	0	0	0	2
L60	2	0	0	0	0	0	2
L70	7	0	0	0	2	5	0
L80	13	9	0	0	0	0	4
L90	3	0	3	0	0	0	0
M10	4	0	0	0	4	0	0
M20	2	0	1	0	0	0	1
M30	2	0	0	0	0	0	0
N10	12	0	0	0	5	0	7
N20	15	0	0	2	0	0	13
N30	3	0	0	0	3	0	0
N40	6	0	0	1	4	1	0
P10	7	0	0	0	0	4	3
P20	2	0	0	0	0	0	2
P30	3	0	0	0	0	3	0
P40	4	0	0	0	3	0	1
Q10	15	2	4	0	0	0	9
Q20	4	0	0	2	0	0	2
Q30	5	0	0	4	0	0	1
Q40	11	0	4	2	1	0	4
Q50	3	0	0	0	3	0	0
Q60	3	0	0	0	0	0	3
Q70	3	0	0	0	3	0	0
Q80	7	0	0	5	2	0	0
Q90	20	1	2	4	3	0	10

The mineralogical surface water quality of the Fish to Tsitsikamma Water Management Area was quite variable.

The water quality in the Tsitsikamma coastal catchments (K80) was classified as ideal for all uses for those quaternaries where adequate data was available. It is probable that the quality in the unclassified quaternaries of those catchments would also be ideal for all uses. Water quality in the upper Kromme River (K90A and B) was ideal and changed to marginal in a downstream direction (K90C-E). The underlying geology of these catchments is a mixture of sandstone and conglomerate but changes to mudstone north of Hankey (L70 and 90).

There was adequate data to classify the lower reaches of the Groot River where water quality was classified as poor (L70F and G) to completely unacceptable for most uses (L70A-E). The origin of the high salinity in the arid interior is the naturally high salinity of the groundwater and resulting high salinity in the base flow of the Groot River. High fluoride concentrations also occurred in the groundwater. Water quality was ideal in the Kouga River (L82) even though a downstream increase in TDS was observed. There is a high probability that water quality in the Baviaans River is also ideal. Below the confluence of the Kouga River with the Groot River, the river becomes the Gamtoos River and the water quality was classified as good, showing the beneficial impacts of the Kouga and Baviaans Rivers.

Water quality in the upper Swartkops River (M10A, M10B) was found to be ideal even though there was insufficient data for this study to classify the river status. However, water quality in the middle and lower reaches of the Swartkops River (M10C, M10D) was classified as poor as a result of man-made and geological impacts. The urban and industrial centre of Port Elizabeth/Uitenhage is located in the Swartkops catchment and treated sewage effluent return flows and the natural geology account for the deterioration in water quality in the middle and lower reaches. There are extensive informal settlements on the floodplain of the Swartkops River and its tributaries.

Water quality in the Sundays River was poor in the upper reaches (N11, N12). There was insufficient data to classify the middle reaches, Darlington Dam is classified as having marginal water quality (N23A and B) but quality deteriorated to a poor class in the lower reaches of the Sundays River. Water quality in the upper reaches of the Fish River (Q12, Q13) was classified as good to ideal. However, the TDS increases in a downstream direction and the middle reaches of the Fish are classified as marginal and the lower reaches as poor quality. The sources of salinity in the middle and lower reaches are the geology of the river valley as well as irrigation return flows. The relatively flat topography, low MAR and high evaporation and underlying mudstones generally give rise to saline groundwater and resulting saline baseflows in the Fish and Sundays Rivers. Releases of slugs of low TDS water from Gariep Dam into the Great Fish River show "slug flow" behaviour with intermittent periods of low TDS (transfer water) and high TDS (natural baseflows) (DWAF, 1999b). In the 1990s, a gradual decrease in salinity was observed as a result of additional transfers from the Orange River system to meet increasing demands in the Port Elizabeth area.

The Bushmans River water quality is classified as unacceptable in its upper reaches (P10A-D) but there is insufficient data to classify the lower reaches. Water quality in the Kowie River (P4A-C) is classified as poor and in the Kariega River (P3) the water quality is classified as completely unacceptable. The geology of the Bushmans, Kariega and Kowie River catchments results in highly saline baseflow which explains the poor water quality in the area.

6.4.2 Mineralogical Groundwater Quality

The groundwater quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality has been evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (Simonic, 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegter's maps (Vegter, 1995). The potability evaluation done by Simonic (2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998).

The portion of the groundwater resources considered to be potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) according to the classification system given in Section 6.4.1. Water classified as poor and unacceptable (Class 3 and 4) has been considered to be **not** potable.

In catchments where no information was available, estimates of the portion of potable groundwater were made using Vegter's maps (Vegter, 1995).

Figure 6.4.2.1 gives an evaluation of the mean TDS per quaternary catchment and Figure 6.4.2.2 gives an estimate of the percentage of potable groundwater per quaternary catchment.

6.4.3 Microbiological Water Quality

Background

A method was developed and applied to assess the risk of microbial contamination of surface water and groundwater resources in South Africa. (Refer to Appendix G2 for details of the study). Maps depicting the potential vulnerability of surface water and groundwater to microbial contamination were produced at a quaternary catchment resolution. The maps provide a comparative rating of the risk of faecal contamination of the surface water and groundwater resources. The information that has been provided is, however, intended for planning purposes only and is not suitable for detailed water quality assessments.

Mapping microbial contamination of surface water resources

As part of the National Microbiological Monitoring Programme a screening method was developed to identify the risk of faecal contamination in various catchments. This screening method uses a simple rule based weighting system to indicate the relative faecal contamination from different land use areas. It has been confirmed that the highest faecal contamination rate is derived from high population densities with poor sanitation services. The Programme produced a map, at quaternary catchment resolution, showing the potential faecal contamination in the selected catchments. Unfortunately, the map did not cover the entire country.

As part of this study, the same screening method was applied to produce a potential surface faecal contamination map for the whole of South Africa using national databases for population density and degree of sanitation. The portion applicable to the Fish to Tsitsikamma WMA is given in Figure 6.4.3.1. It shows that for most of the WMA, there is inadequate data to assess the potential for surface faecal contamination. However, for those areas where the data is adequate, most of the quaternaries have a low risk of contamination and there are no areas with a high risk of contamination. A medium risk was identified in the Port Elizabeth area (M20A); the middle reaches of the Swartkops River (M10C), around the Fort Beaufort area (Q94F) and in the Peddie area (Q93C and D).

Mapping aquifer vulnerability of groundwater resources

Certain aquifers are more vulnerable to contamination than others. The DRASTIC method used in this study is an acknowledged method for assessing aquifer vulnerability to contamination. The method is a weighting and rating technique that considers up to seven geologically and geohydrologically based factors to estimate groundwater vulnerability. The magnitudes or severities of pollution sources are, however, not considered. Three of the above factors were used in this study to estimate the vulnerability of groundwater to microbial contamination.

Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider groundwater depth, soil media and impact of the vadose zone media. Comparison of the different maps showed remarkable similarity and confirmed that the vulnerability is largely controlled by the selected three parameters. This similarity promotes confidence in the resultant microbial contamination vulnerability map.

A GIS model, which considered the three factors, was developed and a vulnerability rating of low, medium and high was calculated for each grid element in the GIS coverage. A numerical control was included to account for deep groundwater below 35 metres. At this depth it was assumed that the surface contamination rate would be low, irrespective of the other two factors.

Mapping microbial contamination of groundwater sources

The potential surface faecal contamination and aquifer vulnerability maps were then intersected to derive a potential groundwater faecal contamination map for South Africa at a quaternary scale. The portion applicable to the Fish to Tsitsikamma WMA is given in Figure 6.4.3.2. This map shows the degree of potential faecal contamination in groundwater using a rating scale, which ranges from low to medium to high. Figure 6.4.3.2 shows that there is a high risk of groundwater contamination in the upper reaches of the Groot River (most quaternary catchments of L11 and L21) and the Sundays River (N12A and B). The risk changes to medium in the middle parts of the WMA and the risk changes to low towards the coast. The exceptions are the highly populated areas at Port Elizabeth (M20A), the Zwartkops catchment (M10A to M10D) and around Paterson (N40D).

Conclusions and recommendations

A limitation of the study was the inability to validate results due to the limited information on groundwater contamination resulting from human wastes.

Once sufficient microbial data becomes available, the numerical methods and associated assumptions should be validated and the maps replotted. Monitoring data from selected areas should also be collected to assess the validity of the vulnerability assessment presented in this report.

6.4.4 Water Quality Issues

The following water quality issues, not related to salinity of the water, were identified (DWAF, 1999b):

Kouga and Tsitsikama catchments

- Intensive irrigation agriculture is practised alongside the Kouga River (Langkloof Valley) and Gamtoos River where vegetables, fruit and tobacco are produced. Pesticide residues are generally associated with the production of these crops and may be an issue.
- Iron and manganese problems and high dissolved organic carbon (DOC) levels which lead to trihalomethane (THM) compounds in drinking water, have been identified in the Kouga and Loerie Dams. This has lead to increased water treatment costs.
- Internal nutrient cycling has been identified as a problem in impoundments.
- Hypersaline conditions have been identified as a problem in the Krom River estuary.
- Concerns have been expressed about further impoundment of the Kouga River and the negative impact this would have on its dilution of high salinity in the Groot River.

Fish/Sundays/Groot River Catchments

- Salinity impacts appeared to be the main concern in these catchments.
- In the Scheepersvlakte Dam from which Port Elizabeth draws some of its raw water, problems have been experienced with corrosion of pumping equipment, taste and odours in treated water and THM compounds formed during the treatment process. Some of the problems are related to elevated levels of DOC. These problems have prompted complaints and petitions from domestic and industrial water users.

Zwartkops River Catchment

- High nutrient concentrations and organic compounds downstream of Uitenhage as a result of treated wastewater effluent being discharged to the river.
- Poor microbial water quality as a result of large informal settlements on the flood plains of the Chatty and Zwartkops Rivers.

Bushmans/Kariega, Kowie River Catchments

- High salinity appeared to be the main concerns in the Bushmans, Kariega and Kowie River catchments.

6.5 SEDIMENTATION

The relationship between the flow in a river and the quantity of sediment that it carries is not constant but varies with the availability of sediment in the catchment of the river. This, in turn, varies with factors such as the condition of natural vegetation, the area of land cultivated and type of crops grown, and the extent of human settlements. Nevertheless, the analysis of measurements taken by DWAF, over many years, of silt accumulation in existing reservoirs countrywide, has made it possible to calculate average sediment yields for the catchments of these reservoirs. The results of analysis of data for reservoirs in the Fish to Tsitsikamma WMA is shown in Table 6.5.1.

Data is available for 11 reservoirs in the WMA, and it can be seen that the yields vary considerably. The lowest yield is recorded for Nuwejaars Dam (4 t/km^2/a), which is situated high up in the catchment of the Bushman's River, with some agricultural development upstream. Four of the dams have yields of above 250 t/km^2/a.. These dams are Loerie, Lake Arthur, Darlington Dam and Kat River Dam. Lake Arthur with a sediment yield of 496 t/km^2/a from its catchment, has lost most of its storage capacity.

TABLE 6.5.1: RECORDED RESERVOIR SEDIMENTATION RATES FOR RESERVOIRS IN THE FISH TO TSITSIKAMMA WMA

QUATERNARY CATCHMENT NO.	RIVER	DAM NAME	ECA (km^2)	PERIOD	V_T (million m^3)	V_{50} (million m^3)	SEDIMENT YIELD (t/km^2/a)
K90B	Krom	Churchill	357	1943-1987	0,122	0,128	10
L82H	Kouga	Kouga	3 887	1969-1986	1,515	2,549	18
L90C	Loerie	Loerie	147	1971 - 1984	0,752	1,524	280
N12C	Sundays	Van Rynevelds Pass	3 544	1925 - 1978	31,397	27,500	210
N23B	Sundays	Darlington	12 987	1922 - 1978	135,670	130,140	271
P10B	Nuwejaars	Nuwejaars	531	1958 - 1981	0,057	0,081	4
Q13A	Groot Brak	Grassridge	4 325	1924 - 1984	41,252	38,610	241
Q41D	Tarka	Commando Drift	3 623	1956 - 1985	14,663	21,000	157
Q44B	Tarka	Lake Arthur	3 450	1924 - 1985	68,059	63,331	496
Q50B	Great Fish	Elandsdrift	8 042	1973 - 1981	2,459	7,912	27
Q94A	Kat	Katrivier	258	1969 - 1988	1,887	2,966	310

ECA = Total catchment area - catchment area of next major dam upstream
V_T = Sediment volume at end of period
V_{50} = Estimated sediment volume after fifty years at the same average yield.

Using the available data of this type on sediment accumulation in reservoirs and additional data on sediment loads in rivers, Rooseboom, *et al* in 1992 prepared a mean sediment yield map of South Africa. From this map and associated soil erodibility maps, an estimate of the average sediment yield from any desired area can be made. The Water Research Commission publication, *Surface Water Resources of South Africa, 1990 (WR90)*, presents estimates of the mean sediment yield for quaternary sub-catchments calculated from the sediment yield and soil erodibility maps. Mean values of sediment yield in the Gouritz WMA, calculated from the WR90 estimates range from a low of 3 t/km^2/a in the coastal catchments of the south-eastern corner of the WMA to 75 t/km^2/a in the central interior. Rooseboom also carried out statistical analyses of the recorded sediment yield data to obtain an indication of the confidence with which the sediment yield could be estimated for the various regions of South Africa. From these analyses he derived sets of curves which give multiples by which the estimated mean sediment yields should be multiplied to change the confidence level from the 50% confidence level of the mean yields. However, the data presented in this report is at the 50% confidence level.

Values of sediment yield in tonnes per year, and the 25-year sediment volume, expressed in million m^3 and adjusted to allow for consolidation of the sediment, are presented for each quaternary catchment in Appendix G. On Figure 6.5.1, the 25-year sediment volume is shown as a percentage of the natural incremental MAR for each quaternary catchment.

The information has been produced in this form for use in predicting the probable effects of sediment on the yields of dams in the WMA.

Research has shown that reservoirs with storage capacities in excess of 10% of the mean annual runoff will retain at least 70% of incoming sediments. It is only where reservoirs have storage capacities of very much less than 10% of mean annual runoff that it becomes possible to pass most of the incoming sediments through by designing the reservoirs so that high flow velocities are maintained through them during floods. Even so, a great deal of doubt exists regarding the accuracy with which the effective losses in the storage capacities of small reservoirs can be predicted. Only where adequate discharge facilities are provided and proper operational procedures are followed is it possible to ensure that a small reservoir will not lose virtually all its storage capacity, permanently or intermittently. Therefore, unless conditions for scouring are particularly favourable, it is not advisable to construct small storage dams on big rivers that carry high sediment loads. Where large dams are constructed, it is necessary to provide sufficient additional storage to accommodate the volume of sediment expected to accumulate during the economic life of the dam. Depending upon the characteristics of the dam site, it may be necessary either to construct the dam initially to provide the full volume of additional storage required to accommodate sediment, or to design the dam to be raised at a later stage if the accumulation of sediment begins to reduce the yield of the dam significantly.

CHAPTER 7: WATER BALANCE

7.1 METHODOLOGY

7.1.1 Water Situation Assessment Model

The Water Situation Assessment Model (WSAM) was developed with the purpose of providing a reconnaissance level decision support tool. The model is intended to provide a broad overview of the water situation in South Africa taking into account all significant water uses and resources. The model can produce output at a variable resolution, down to quaternary catchment scale.

The data input to the model was gathered by various organisations and individuals, but the Water Resources Situation Assessments (WRSA) were the main vehicle for providing data for the model. Appendix H lists the organisations responsible for the various components of the data. This list also gives the reader a good indication of the type of data in the database.

The intention was to use the WSAM to determine the water balance for the WRSA reports and also to use the WSAM reporting tools to produce as many of the tables in the WRSA reports as was practical. However, due to various unresolved developmental problems with the WSAM, another approach was adopted, as described in this section. For this reason, the WSAM is not described in any detail in this report. The reader is referred to the WSAM user manual for more information on this model.

7.1.2 Estimating the Water Balance

The water balance is simply the difference between the water resource and the sum of all the water requirements and losses. While the water requirements and losses are easily abstracted from the database, to estimate the water resource directly from the known yields of dams would be difficult and impractical. The main reason for this is that the run-of-river component of the resource is difficult to determine without some form of modelling, especially where there are multiple dams and abstractions and the different modes of operation of the dams influence the yields.

The water balance produced by the WSAM is not yet correct in all cases due to the following unresolved problems:

- The ecological Reserve has spurious impacts on the water balance, which do not appear to be correct;
- The impacts of afforestation and alien vegetation, as reported on the balance do not appear to be correct;
- It is not possible to model actual known river losses; and
- Return flows from irrigation are not modelled correctly.

The approach taken to determine the water balance was therefore to remove the above questionable components out of the WSAM modelling procedure. This is done relatively easily. The above impacts (ecological Reserve, etc.) were then determined external to the model and added or subtracted from the WSAM water balance as appropriate. This procedure achieved a resultant water balance that seemed to be in reasonable agreement with other estimates in most cases. However, in the case of the Fish to Tsitsikamma WMA, WSAM did not appear to determine the run-of-river yield, and hence the water balance, reliably. Therefore, these were determined external to the model, but making use of the database in the model.

7.1.3 Estimating the Water Requirements

The water requirements determined by the WSAM are mostly accepted to be correct. In order to facilitate the production of the WRSA reports, this data was abstracted from the WSAM into a spreadsheet and various worksheets set up, which reference this abstracted data. These worksheets were structured so a to present most of the information contained in the tables of this report. This is not only limited to water requirements but also lists land uses such as irrigated areas, afforested areas, etc.

The data were abstracted in two different formats: at key area resolution (incremental between key points) and at quaternary catchment resolution. The key area data has been aggregated by the WSAM except for a few parameters relating mainly to irrigation, which the WSAM did not aggregate correctly. In these cases, default values were used. A list of these parameters and the default values is attached as Appendix H. The data at quaternary catchment resolution was abstracted for information purposes only. It is attached in the Appendices to this report.

Water requirements or gains that the WSAM could not calculate were determined as follows:

Ecological Reserve

The impact of the ecological Reserve on the yield of a catchment depends on the storage in that catchment. It was accepted that the water required for the ecological Reserve follows the same general pattern of (i.e. mimics) the natural flow and that the storage/yield characteristics of the natural catchment could therefore also be used to estimate the yield of the catchment after allowing for the water requirements of the ecological Reserve. The estimates of the impact on the yield of a catchment were made separately for each of the incremental catchments between key points. The total storage within the incremental catchment was transposed to its outlet and formed the basis for determining the incremental yield of the catchment under natural conditions, both with and without provision for the ecological Reserve. The yields were estimated from the storage yield characteristics used in the WSAM for any particular recurrence interval of concern. The incremental impact of the ecological Reserve on the water resources of a particular key area was taken to be the difference between the impact at the downstream key point less the impact at the upstream key point.

The impact of the ecological Reserve on the run-of-river yield was accepted to be the annual equivalent of the lowest 4-month water requirement for the ecological Reserve. This value was used to establish the incremental impact of the ecological Reserve on the yield at a key point at which there was no significant storage in the incremental catchment.

Using the above method, negative impacts are sometimes possible. The reason for this is that the water required for the ecological Reserve at an upstream point may become available for use further downstream, if the ecological Reserve is less at the downstream point.

Water losses

The WSAM models losses as a function of the flow in the river. The water loss under natural flow conditions is used in the WSAM to calculate the water loss under the altered flow conditions. While this is conceptually correct, it is found to be very difficult to model the known loss under current conditions. For this reason, the WSAM was run with zero losses and the known losses taken into account external to the model when determining the water balance.

Irrigation return flows

The average return flow from irrigation in South Africa according to the WSAM is in the order of 3%. This is clearly erroneous and not in accordance with the 10% to 15% default agreed upon at various workshops. Irrigation return flows were therefore calculated external to the model and were usually assumed to be 10%. Where the consultant and/or other persons had more detailed information of the return flows that could be expected these were adopted instead.

7.1.4 Estimating the Water Resources

The water resources were estimated using data from other more detailed studies as described in Section 6.2 for groundwater and Section 6.3 for surface water. For areas where no suitable studies have been carried out, or the studies did not provide all of the data required, rough estimates of surface water resources were made as described in Section 6.3, using the regional data provided in the publication, the Surface Water Resources of South Africa, 1990 (Midgley *et al*, 1994). The impacts of afforestation and alien vegetation were estimated external to the model by the WSAM development team. These estimates are at a low level of confidence and require verification.

7.2 OVERVIEW

For purposes of considering the water balance situation within the WMA, the outlets of the key areas defined in Table 2.1.1 in Section 2.1, and used in most of the tables in this report, were used, and referred to as key points. For key areas comprising two or more separate rivers flowing into the sea, the water balances at the river mouths were combined to obtain a composite value for a hypothetical key point for the key area. The key points are shown in Table 7.2.1.

TABLE 7.2.1: KEY POINTS FOR YIELD DETERMINATION

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT	KEY AREA	KEY POINT QUATERNARY CATCHMENT	
K	Upper Krom	K90D	Impofu Dam
	Tsitsikamma Coast	K80A to K80F, K90F K90G, K90F	Hypothetical point for mouths of small coastal rivers and Krom River
L	Upper Groot	L12D, L23D	Beervlei Dam
	Lower Groot	L70G	Groot River confluence with Kouga River
	Kouga	L82H	Kouga River confluence with Groot River
	Gamtoos	L90C	Mouth of Gamtoos River
M	Algoa Coast	M10B, M20A, M20B, M30B	Hypothetical point for mouths of Zwartkops, Coega and Van Stadens Rivers and smaller rivers near Port Elizabeth
N	Upper Sundays	N12C	Vanrynevelds Pass Dam
	Middle Sundays	N23B	Darlington Dam
	Lower Sundays	N40F	Mouth of Sundays River
P	Albany Coastal Catchments	P10G, P20A, P20B, P30C, P40C, P40D	Hypothetical point for mouths of Kariega, Bushmans and Kowie Rivers and smaller coastal rivers
Q	Upper Fish	Q13A	Grassridge Dam
	Tarka	Q44B	Lake Arthur
	Upper Middle Fish	Q50A	Elandsdrift Weir
	Upper Little Fish	Q80E	De Mistkraal Weir
	Middle Fish	Q80G, Q70C	Fish River immediately downstream of its confluence with the Little Fish River
	Koonap	Q92G	Koonap River at its confluence with the Fish River
	Kat	Q94F	Kat River at its confluence with the Fish River
	Lower Fish	Q93D	Mouth of Fish River

In Table 7.2.2 the average water requirements at the key points are shown.

It can be seen from Table 7.2.2 that the total water requirement in the WMA in 1995 is estimated to have been 1 513 million m^3/a. This value includes the provision of 243 million m^3/a for the ecological Reserve and 112 million m^3/a for river losses in the Sundays and Great Fish River Basins, but excludes the non-consumptive 32 million m^3/a released into the Fish River from the Orange River Development Project for improving the water quality. A quantity of 114 million m^3/a, or 8% of the total requirements occurs in the coastal catchments surrounding Port Elizabeth. The requirement for the Fish River catchment is approximately 45% or 688 million m^3/a, and the Sundays River catchment requires 17%, or 264 million m^3/a. The coastal catchments to the west of Port Elizabeth (including the Kouga and the Gamtoos catchments) require 376 million m^3/a, or 25% of the total requirements, the Groot River catchment (excluding the Kouga and Gamtoos catchments) requires 1%, and the Albany Coastal Catchments 4% of the total requirements.

TABLE 7.2.2 : AVERAGE WATER REQUIREMENTS BY KEY AREA IN 1995 (in million m^3/a)

CATCHMENT					STREAMFLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENT						ECOLOGICAL RESERVE (5)	TOTAL (6)
PRIMARY		SECONDARY		TERTIARY/ QUATERNARY	AFFORESTATION	DRYLAND SUGAR CANE	ALIEN VEGETATION	RIVER LOSSES	BULK (1)	IRRIGA-TION (2)	RURAL (3)	URBAN (4)	HYDRO-POWER	WATER TRANSFERS OUT OF WMA		
No.	Description	No.	Description	No.												
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	0,08	0,00	4,66	0,00	0,00	4,70	0,30	0,20	0,00	0,00	9,20	19,14
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	39,86	0,00	25,57	0,00	0,00	7,80	0,79	2,72	0,00	0,00	107,00	183,74
		TOTAL IN KROM/TSITSIKAMMA			**39,94**	**0,00**	**30,23**	**0,00**	**0,00**	**12,50**	**1,09**	**2,92**	**0,00**	**0,00**	**107,00**	**193,68**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	0,00	0,00	0,05	0,00	0,00	16,40	1,50	0,36	0,00	0,00	13,00	31,31
		L3 to L7	Lower Groot	L30 to L70	0,00	0,00	1,87	0,00	0,00	17,30	0,93	0,66	0,00	0,00	18,20	38,96
		L8	Kouga	L81, L82	0,10	0,00	21,26	0,00	0,00	38,40	0,68	0,82	0,00	0,00	20,00	81,26
		L9	Gamtoos	L90A to C	6,70	0,00	1,12	0,00	0,00	52,70	0,24	1,03	0,00	0,00	39,00	100,79
		TOTAL IN GROOT/GAMTOOS BASIN			**6,80**	**0,00**	**24,30**	**0,00**	**0,00**	**124,80**	**3,35**	**2,87**	**0,00**	**0,00**	**39,00**	**201,12**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	**3,92**	**0,00**	**10,91**	**0,00**	**0,00**	**13,50**	**1,17**	**69,00**	**0,00**	**0,00**	**15,00**	**113,50**
N	Sundays	N1 (Part)	Upper Sundays (Van Rynevelds Pass Dam)	N11, N12	0,00	0,00	0,11	0,00	0,00	12,30	0,55	0,11	0,00	0,00	3,00	16,07
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	0,00	0,00	0,65	0,00	0,00	74,30	1,54	3,36	0,00	0,00	13,10	92,95
		N4	Lower Sundays	N40	0,00	0,00	0,46	18,00	0,00	130,40	1,51	1,31	0,00	0,00	19,80	171,48
		TOTAL IN SUNDAYS BASIN			**0,00**	**0,00**	**1,22**	**18,00**	**0,00**	**217,00**	**3,69**	**4,78**	**0,00**	**0,00**	**19,80**	**264,49**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	**0,14**	**0,00**	**17,32**	**0,00**	**0,00**	**9,30**	**2,30**	**8,32**	**0,00**	**0,00**	**15,30**	**52,68**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	0,00	0,00	0,01	6,00	0,00	67,30	0,75	0,61	0,00	0,00	4,50	79,17
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	0,00	0,00	0,00	0,00	0,00	24,30	1,08	0,14	0,00	0,00	4,60	30,12
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C, Q30, Q50A, Q44C	0,00	0,00	0,51	20,00	0,00	196,20	1,74	6,19	0,00	0,00	15,50	240,14
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	0,00	0,00	0,09	0,00	0,00	52,20	0,32	1,13	0,00	0,00	4,20	57,94
		Q5-Q9 (Part)	Middle Fish	Q50B, C, Q60, Q70, Q80F, G	0,00	0,00	0,15	33,00	0,00	124,50	0,77	0,30	0,00	0,00	23,20	181,92
		Q9 (Part)	Koonap	Q92	0,10	0,00	0,11	0,00	0,00	22,60	1,22	1,12	0,00	0,00	9,60	34,75
		Q9 (Part)	Kat	Q94	2,76	0,00	2,49	0,00	0,00	14,30	0,73	2,20	0,00	0,00	7,10	29,58
		Q9 (Part)	Lower Fish	Q91A, B, C, Q93A to D	0,00	0,00	1,08	35,00	0,00	18,80	0,99	0,34	0,00	0,00	46,80	103,01
		TOTAL IN GREAT FISH BASIN			**2,86**	**0,00**	**4,44**	**94,00**	**0,00**	**520,20**	**7,60**	**12,03**	**0,00**	**0,00**	**46,80**	**687,93**
TOTAL IN WMA					**53,66**	**0,00**	**88,42**	**112,00**	**0,00**	**897,30**	**19,21**	**99,92**	**0,00**	**0,00**	**242,90**	**1513,40**

(1) Requirements of wet industries, mines, thermal powerstations and any other bulk users supplied individually by a water board or DWAF.
(2) Includes conveyance and distribution losses.
(3) Requirements for rural household use, livestock and game watering, and subsistence irrigation, including losses.
(4) Requirements for urban residential, commercial, municipal and institutional use, and requirements of industries supplied by local authorities, all including water losses.
(5) Cumulative IFR requirements.
(6) IFR requirements included in these values are cumulative. Therefore only the values at outlets to the sea can be summed to obtain a total value for the WMA i.e. the sum of values for inland sub-catchments do not equal the value for the whole catchment.

As the water balance has been calculated on the basis of the 1:50 year yield of the water resources, it is necessary to consider the equivalent water requirements at 1:50 year assurance. These are shown in Table 7.2.3, where it can be seen that the total equivalent water requirements have reduced by 30% from 1 513 million m^3/a to 1 060 million m^3/a. The reduction has occurred mainly because the requirements of the ecological Reserve, afforestation and alien vegetation are expressed as impacts on the 1:50 year yield fo the system instead of actual quantities of water required. Similarly, irrigation requirements have been converted from the average quantity to the equivalent at 1:50 year assurance.

In the Fish to Tsitsikamma WMA, where 55% of the total developed yield in 1995 was estimated to be obtained from run of river yield and farm dams and 45% from major dams, the impacts of the ecological Reserve, afforestation and alien vegetation on the 1:50 year yield may be underestimated, as the method used for the estimates (See Section 7.1.4) may be more reliable for the impacts on the yields of major dams than for impacts on run of river yield. This aspect requires further investigation.

The yield balance shown in Table 7.2.4 is at a low level of confidence because of the uncertainty associated with the large run-of-river component of the utilised yield and the uncertainty, referred to above, as to the reliability of the estimates of the impacts on run-of-river yield of alien vegetation and afforestation and the ecological Reserve.

The table shows an overall excess in 1:50 year yield of 99 million m^3/a, but deficits occur in several key areas. The deficits all occur in areas that do not receive water imported from the Orange River. In general, they occur because the average requirements for irrigation in these areas are higher than the available 1:50 year yields. Agricultural practices have been adapted to deal with this situation by suiting the types and quantities of crops grown to the quantities of water available at different assurances of supply.

The excess yield shown in the Upper Krom area occurs because the yields of Churchill and Impofu Dams were not fully utilised by Port Elziabeth in 1995.

The Sundays and Great Fish River catchments would show significant overall deficits were it not for the water imported from the Orange River. The actual quantity of water imported is varied to suit requirements, and differs considerably from year to year, depending on the influence of weather conditions in the WMA on requirements for irrigation.

Actual transfers between 1986 and 1993 ranged from a minimum of 399 million m^3/a in 1988 to a maximum of 639 million m^3/a in 1990 (DWAF, 1997b).

Modelling of the system (DWAF, 1997b), with water requirements of 1994 levels applied to historical flow sequences for the period 1920 to 1993, showed a maximum transfer from the Orange River of 707 million m^3/a (for weather conditions that occurred in 1948) and a minimum of 259 million m^3/a. The mean for the 74 year period was 560 million m^3/a, and it is this value that has been used in Table 7.2.4.

The high surpluses in those parts of the Sundays River that do not receive Orange River water are surprising, and reinforce the concern that the assumed yields of run-of-river abstractions are unrealistically high for a 1:50 year assurance. The high surplus in the Lower Fish area may be ascribed to the comparison in the water balance of average imports from the Orange River with equivalent 1:50 year assurance water requirements. In practice, water imports are balanced with water requirements.

TABLE 7.2.3: WATER REQUIREMENTS IN 1995 AT 1:50 YEAR ASSURANCE (in million m^3/a)

CATCHMENT					STREAMFLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENT						ECOLOGICAL RESERVE (5)	TOTAL
PRIMARY		SECONDARY		TERTIARY/ QUATERNARY	AFFORES-TATION (5)	DRYLAND SUGAR CANE	ALIEN VEGETATION (5)	RIVER LOSSES	BULK (1)	IRRIGATION (2)	RURAL (3)	URBAN (4)	HYDRO-POWER	WATER TRANSFERS OUT OF WMA		
No.	Description	No.	Description	No.												
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	0,00	0,00	3,50	0,00	0,00	4,00	0,30	0,20	0,00	0,00	4,50	12,50
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F K90E to G	4,70	0,00	3,00	0,00	0,00	6,70	0,79	2,72	0,00	0,00	13,40	31,31
		TOTAL IN KROM/TSITSIKAMMA			**4,70**	**0,00**	**6,50**	**0,00**	**0,00**	**10,70**	**1,09**	**2,92**	**0,00**	**0,00**	**17,90**	**43,81**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12 L21, L22, L23	0,00	0,00	0,00	0,00	0,00	12,70	1,50	0,36	0,00	0,00	0,00	14,56
		L3 to L7	Lower Groot	L30 to L70	0,00	0,00	0,00	0,00	0,00	13,80	0,93	0,66	0,00	0,00	0,00	15,39
		L8	Kouga	L81, L82	0,00	0,00	10,90	0,00	0,00	33,40	0,68	0,82	0,00	0,00	2,30	48,10
		L9	Gamtoos	L90A to C	0,50	0,00	0,00	0,00	0,00	43,60	0,24	1,03	0,00	0,00	0,00	45,37
		TOTAL IN GROOT/GAMTOOS BASIN			**0,50**	**0,00**	**10,90**	**0,00**	**0,00**	**103,50**	**3,35**	**2,87**	**0,00**	**0,00**	**2,30**	**123,42**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	**0,20**	**0,00**	**0,40**	**0,00**	**0,00**	**11,50**	**1,17**	**69,00**	**0,00**	**0,00**	**1,50**	**83,77**
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld's Pass Dam)	N11, N12	0,00	0,00	0,00	0,00	0,00	9,80	0,55	0,11	0,00	0,00	1,10	11,56
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14 N21-24, N30	0,00	0,00	0,30	0,00	0,00	59,40	1,54	3,36	0,00	0,00	0,00	64,60
		N4	Lower Sundays	N40	0,00	0,00	0,00	18,00	0,00	104,30	1,51	1,31	0,00	0,00	3,70	128,82
		TOTAL IN SUNDAYS BASIN			**0,00**	**0,00**	**0,30**	**18,00**	**0,00**	**173,50**	**3,69**	**4,78**	**0,00**	**0,00**	**4,80**	**204,98**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	**0,00**	**0,00**	**2,30**	**0,00**	**0,00**	**7,60**	**2,30**	**8,32**	**0,00**	**0,00**	**0,00**	**20,52**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	0,00	0,00	0,00	6,00	0,00	58,50	0,75	0,61	0,00	0,00	1,20	67,06
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	0,00	0,00	0,00	0,00	0,00	21,10	1,08	0,14	0,00	0,00	1,30	23,62
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir	Q14, Q21, Q22, Q13B, C Q30, Q50A, Q44C	0,00	0,00	0,00	20,00	0,00	170,60	1,74	6,19	0,00	0,00	0,00	198,53
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	0,00	0,00	0,00	0,00	0,00	45,40	0,32	1,13	0,00	0,00	0,00	46,85
		Q5-Q9 (Part)	Middle Fish	Q50B, C Q60, Q70, Q80F, G	0,00	0,00	0,00	33,00	0,00	108,20	0,77	0,30	0,00	0,00	0,00	142,27
		Q9 (Part)	Koonap	Q92	0,00	0,00	0,00	0,00	0,00	19,60	1,22	1,12	0,00	0,00	0,00	21,94
		Q9 (Part)	Kat	Q94	1,70	0,00	1,20	0,00	0,00	12,80	0,73	2,20	0,00	0,00	1,30	19,93
		Q9 (Part)	Lower Fish	Q91A, B, C Q93A to D	0,00	0,00	0,00	35,00	0,00	16,30	0,99	0,34	0,00	0,00	0,00	52,63
		TOTAL IN GREAT FISH BASIN			**1,70**	**0,00**	**1,20**	**94,00**	**0,00**	**452,50**	**7,60**	**12,03**	**0,00**	**0,00**	**3,80**	**572,83**
TOTAL IN WMA					**7,10**	**0,00**	**21,60**	**112,00**	**0,00**	**759,30**	**19,20**	**99,92**	**0,00**	**0,00**	**30,30**	**1049,33** (6)

(1) Requirements of wet industries, mines, thermal powerstations and any other bulk users supplied individually by a water board or DWAF.
(2) Includes conveyance and distribution losses.
(3) Requirements for rural household use, livestock and game watering, and subsistence irrigation, including losses.
(4) Requirements for urban residential, commercial, municipal and institutional use, and requirements of industries supplied by local authorities, all including water losses.
(5) Impacts on the 1:50 year yield of the system.
(6) For correlation with Table 5.1.1, river losses of 112 million m^3/a should be added to the total requirement of 937,4 million m^3/a given in that table to obtain the total of 1 049,3 million m^3/a given in this table.

TABLE 7.2.4: WATER REQUIREMENTS AND AVAILABILITY IN 1995

CATCHMENT					AVAILABLE 1:50 YEAR YIELD IN 1995			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m^3/a)	YIELD BALANCE AT 1:50 YEAR ASSURANCE (million m^3/a)
PRIMARY		SECONDARY		TERTIARY/ QUATERNARY	SURFACE WATER (million m^3/a)	GROUNDWATER NOT CONTRIBUTING TO SURFACE WATER BASE FLOW (million m^3/a)	TOTAL (million m^3/a)	IMPORTS (million m^3/a)	EXPORTS (million m^3/a)	RE-USABLE (million m^3/a)	TO SEA (million m^3/a)		
No.	Description	No.	Description	No.									
K	Krom/Tsitsikamma	K9 (Part)	Upper Krom (Impofu Dam)	K90A to D	50,5	1,4	51,9	0,0	23,0 [1]	0,5	0,0	12,5	+16,9
		K8, K9 (Part)	Tsitsikamma Coast	K80A to F, K90E to G	15,7	4,3	20,0	0,0	0,0	1,9	0,0	31,3	-9,4
		TOTAL IN KROM/TSITSIKAMMA			**66,2**	**5,7**	**71,9**	**0,0**	**23,0 [1]**	**2,4**	**0,0**	**43,8**	**+7,5**
L	Groot/Gamtoos	L1, L2	Upper Groot (Beervlei Dam)	L11, L12, L21, L22, L23	17,0	2,6	19,6	0,0	12,0 [2]	0,1	0,0	14,6	-6,9
		L3 to L7	Lower Groot	L30 to L70	8,0	0,7	8,7	12,0 [5]	0,0	0,9	0,0	15,4	+6,2
		L8	Kouga	L81, L82	119,7	0,1	119,8	0,0	74,5 [3]	2,0	0,0	48,1	-0,8
		L9	Gamtoos	L90A to C	5,5	1,6	7,1	46,5 [5]	0,1 [1]	0,4	4,8	45,3	+8,6
		TOTAL IN GROOT/GAMTOOS BASIN			**150,2**	**5,0**	**155,2**	**0,0**	**28,1 [4]**	**3,4**	**4,8**	**123,4**	**+7,1**
M	Algoa Coast	M1, M2, M3	Zwartkops, Port Elizabeth, Coega	M10, M20, M30	**11,8**	**6,0**	**17,8**	**63,1 [10]**	**0,0**	**8,5**	**33,0**	**83,8**	**+5,6**
N	Sundays	N1 (Part)	Upper Sundays (Van Ryneveld's Pass Dam)	N11, N12	15,0	0,5	15,5	0,0	4,5 [2]	0,0	0,0	11,6	-0,6
		N1, N2, N3	Middle Sundays (Darlington Dam)	N13, N14, N21-24, N30	56,0	12,8	68,8	112,5 [11]	121,0 [2]	19,8	0,0	64,6	+15,5
		N4	Lower Sundays	N40	14,0	2,2	16,2	121,0 [5]	12,0 [1]	3,7	8,0	128,8	+0,1
		TOTAL IN SUNDAYS BASIN			**85,0**	**15,5**	**100,5**	**108,0 [13]**	**12,0 [1]**	**23,5**	**8,0**	**205,0**	**+15,0**
P	Albany Coastal	P1, P2, P3, P4	Bushmans, Kowie/Kariega	P10, P20, P30, P40	**17,1**	**1,6**	**18,7**	**0,8**	**0,0**	**2,9**	**0,6**	**20,5**	**+1,9**
Q	Great Fish	Q1 (Part)	Upper Fish (Grassridge Dam)	Q11, Q12, Q13A	2,0	0,3	2,3	560,0 [12]	495,0 [2]	0,2	0,0	67,1	+0,4
		Q4	Tarka (Lake Arthur)	Q41, Q42, Q43, Q44A, B	9,0	1,8	10,8	0,0	0,0	0,0	0,0	23,6	-12,8
		Q1 (Part) Q2 to 4 Q5 (Part)	Upper Middle Fish (Elandsdrift Weir)	Q14, Q21, Q22, Q13B, C, Q30, Q50A, Q44C	2,0	1,7	3,7	495,0 [15]	343,0 [6]	42,3	0,0	198,5	-0,5
		Q8 (Part)	Upper Little Fish (De Mistkraal Weir)	Q80A to E	20,0	0,7	20,7	148,0 [14]	133,0 [7]	11,0	0,0	46,9	-0,2
		Q5-Q9 (Part)	Middle Fish	Q50B, C, Q60, Q70, Q80F, G	5,7	1,3	7,0	220,0 [5]	110,0 [2]	25,2	0,0	142,3	-0,1
		Q9 (Part)	Koonap	Q92	20,0	0,2	20,2	0,0	0,0	1,4	0,0	21,9	-0,3
		Q9 (Part)	Kat	Q94	23,0	0,1	23,1	0,0	0,0	1,5	0,0	19,9	+4,7
		Q9 (Part)	Lower Fish	Q91A, B, C, Q93A to D	13,0	0,2	13,2	110,0 [5]	0,8 [8]	0,1	0,0	52,6	+69,9
		TOTAL IN GREAT FISH BASIN			**94,7**	**6,3**	**101,0**	**560,0 [12]**	**108,8 [9]**	**81,7**	**0,0**	**572,8**	**+61,1**
TOTAL IN WMA					**425,0**	**35,9**	**465,1**	**560,0 [12]**	**0,0**	**122,4**	**41,6**	**1049,3**	**+98,2**

1. Export to Port Elizabeth (Algoa Coast).
2. Yield used in the key area immediately downstream.
3. 23,0 million m^3/a exported to Port Elizabeth, 39,8 million m^3/a used in the key area (Gamtoos) immediately downstream, and 11,7 million m^3/a (equivalent quantity at 1:50 year assurance) canal losses.
4. 23,1 million m^3/a export to Port Elizabeth plus 5,0 million m^3/a canal losses.
5. Surplus yield from upstream key area.
6. 148 million m^3/a exported to Little Fish and 195 million m^3/a surplus yield to the downstream key area.
7. 108 million m^3/a exported to Sundays River and 25 million m^3/a surplus yield to the downstream key area.
8. 0,8 million m^3/a export to Grahamstown.
9. 108 million m^3/a to Sundays River and 0,8 million m^3/a to Grahamstown.
10. Imports of 28,1 million m^3/a (including 5,0 million m^3/a canal losses) from Groot/Gamtoos plus 23,0 million m^3/a from Krom plus 12 million m^3/a from Sundays.
11. Imports of 108 million m^3/a from Little Fish River plus 4,5 million m^3/a from Upper Sundays.
12. Import from Orange River.
13. Import from Little Fish River.
14. Import from Upper Middle Fish area.

In the modelling of the Fish/Sundays River System referred to above (DWAF, 1997b), the contribution of the local water resources to the portions of the catchment that receive Orange River water were investigated. It was found that, after allowing for river channel losses and canal conveyance losses, a yield of only 4 million m^3/a could be obtained at 1:50 year assurance. This very low yield was ascribed to the highly erratic nature of flow in the river in the area. The 1:50 year run-of-river yield included in Table 6.3.3 for the same area is 110 million m^3/a.

It is apparent from the above that, in order to improve the reliability of the water balance estimate, it is essential to obtain reliable information on the 1:50 year yields obtainable from run-of-river abstractions and farm dams in a system that requires more sophisticated modelling than the reconnaissance level techniques used for this study.

CHAPTER 8: COSTS OF WATER RESOURCE DEVELOPMENT

The yields of surface water resource schemes to develop the full potential of water resources within the WMA are given in Section 6.3, along with a description of how they were derived. The groundwater potential is discussed in Section 6.2, and estimates of the potential maximum yields of groundwater and surface water combined are given in Table 6.1.1 in Section 6.1. The utilised yield in 1995 is also shown in Table 6.1.1. In this chapter very rough estimates of the capital cost of developing the potential maximum yield of the water resources are provided.

In most of the key areas of the Fish to Tsitsikamma WMA the potential yield from groundwater not linked to surface water is greater than the maximum potential surface water yield. For purposes of estimating the capital cost of utilising the full undeveloped potential yield of the WMA, it has been assumed that, in these areas, it would be achieved solely through developing groundwater resources. The key areas to which this applies and the yields to be developed are:

• Upper Groot (L11, L12, L21, L22, L23)	60,7 million m^3/a
• Lower Groot (L30 to L70)	67,3 million m^3/a
• Kouga (L81, L82	8,7 million m^3/a
• Gamtoos (L90)	9,1 million m^3/a
• Algoa Coast (M10, M20, M30)	35,0 million m^3/a
• Middle Sundays (N13, N14, N21-N24, N30)	2,6 million m^3/a
• Lower Sundays (N40)	21,1 million m^3/a
• Upper Fish (Q11, Q12, Q13A)	20,1 million m^3/a
• Tarka (Q41, Q42, Q43, Q44A, Q44B)	19,8 million m^3/a
• Upper Middle Fish (Q80A to Q80E)	48,4 million m^3/a
• Middle Fish (Q50B, Q50C, Q60, Q70, Q80F, Q80G)	9,3 million m^3/a
Total yield	**302,1 million m^3/a**

Based on the data shown on Diagram 8.1, the total capital cost of developing this yield was estimated to be R1 272 million. The assumed average borehole yields and estimated costs for each key area are shown in Table 8.2.

Those catchments in which the surface water yield potential exceeds the groundwater yield potential are, with the exception of the Lower Fish River, the catchments in which conditions for the development of surface water yield are more favourable than they are in other areas. For purposes of estimating the cost of developing the full undeveloped potential yield in these areas, only surface water developments have been assumed. In practice, a combination of surface water and groundwater developments might be more economical, but it is beyond the scope of this study to investigate that. The relevant key areas and the yields to be developed are :

• Tsitsikamma Coast (K80A to K80F and K90E to K90G)	89,0 million m^3/a
• Albany Coast (P10 to P40)	35,9 million m^3/a
• Koonap (Q92)	16,8 million m^3/a
• Kat (Q94)	12,9 million m^3/a
• Lower Fish (Q91, Q93)	21,8 million m^3/a
Total	**176,4 million m^3/a**

The water resources of the only remaining key areas, namely the Upper Krom, the Upper Sundays, and the Upper Little Fish, are assumed to be fully developed.

The storage capacities used for calculating costs for surface water developments were derived as follows. The calculations are shown in Table 8.1.

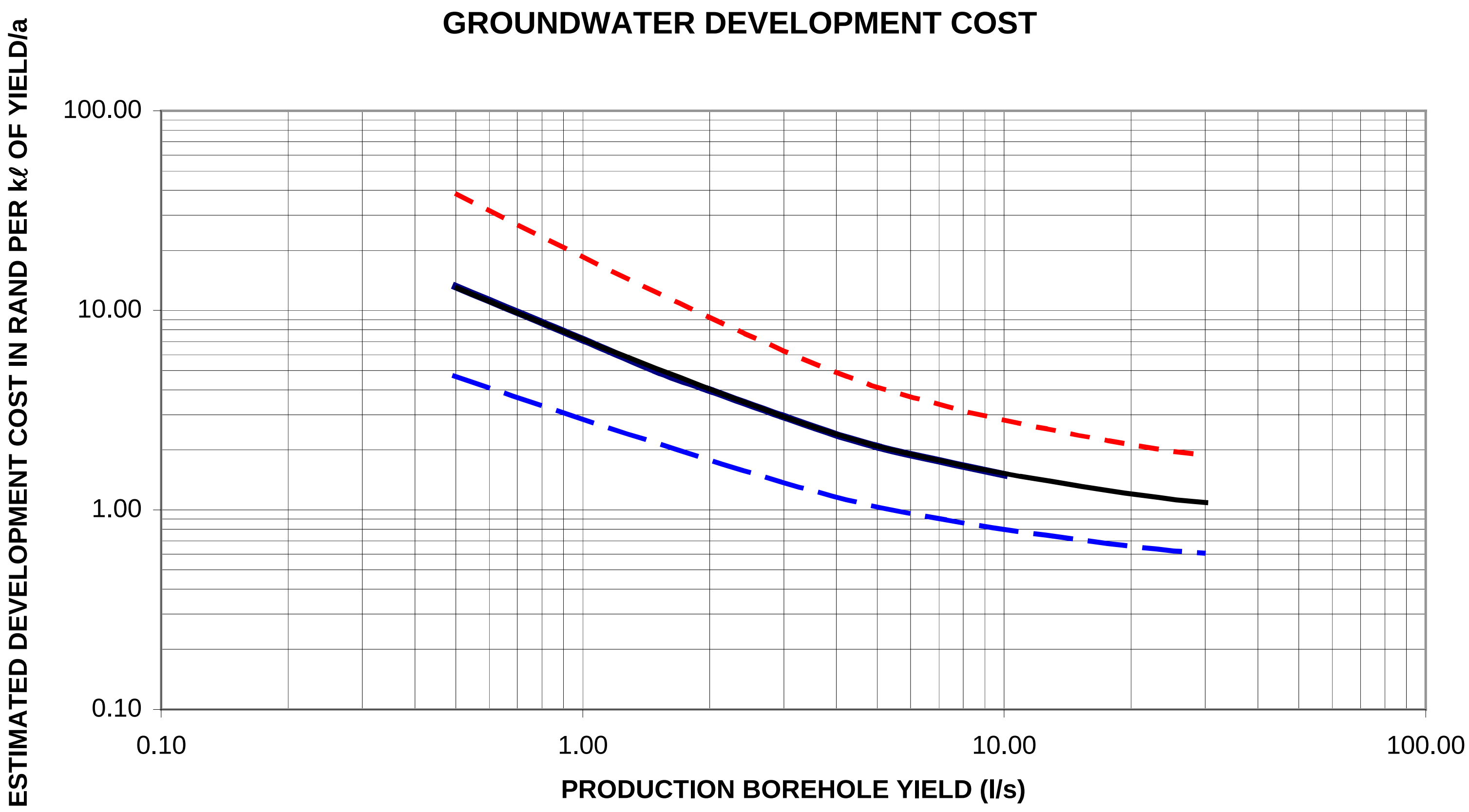

Diagram 8.1: Groundwater development cost

TABLE 8.1: CAPITAL COST OF DAMS

KEY POINT DESCRIPTION	MOST D/S QUAT	MAXIMUM FEASIBLE STORAGE CAPACITY	CAPACITIES OF EXISTING MAJOR DAMS	HYPOTHETICAL DAM CAPACITY (LIVE)	1 IN 25 YR SEDIMENT YIELD	HYPOTHETICAL DAM CAPACITY (GROSS)	COST OF HYPOTHETICAL DAMS
		(million m^3)	(million m^3)	(million m^3)	(million m^3)	(million m^3)	(R million)
Tsitsikamma Coast	-	351,0	3,0	348,0	1,7	349,7	605
Albany Coastal Catchments	-	398,0	13,4	384,6	23,7	408,3	651
Koonap	Q92G	132,0	0,0	132,0	16,9	148,9	406
Kat	Q94F	95,0	24,8	70,2	8,7	78,9	302
Lower Fish	Q93C	165,0	0,0	165,0	15,7	180,7	332
TOTALS	-	1 141,0	41,2	1099,8	66,7	1166,5	2296

The determination of the maximum feasible storage capacity of 1 140 million m^3 for the four key areas was described in Section 6.3. The capacities of the existing major dams per key area were subtracted from this capacity. This reduced the capacity to 1 099,8 million m^3.

An allowance for 1:25 year sediment accumulation in the dams was made, increasing the required capacity to 1 166,5 million m^3.

The cost curve derived for the purposes of this project is given in Diagram 8.2, and is based on the following equation: Total cost = 39,3 x capacity $^{(0,467)}$. As is evident from the large scattering of points through which the curve in Diagram 8.2 is drawn, this is a very rough estimate and the resulting cost estimates should be used appropriately. The estimated cost of providing 1 166,5 million m^3 of storage is R2 296 million at 2000 prices including 14% VAT.

The combined cost of developing groundwater and surface water resources to provide additional yield of 478 million m^3/a in the whole WMA is R3 568 million at 2000 prices including 14% VAT, made up as shown in Table 8.2.

The cost estimates to not make allowance for the poor quality of the groundwater in most of the WMA, nor do they allow for any treatment of groundwater or surface water, or for the costs of infrastructure to convey the water from the points of abstraction to users. These costs might be greater than the costs of developing the resource.

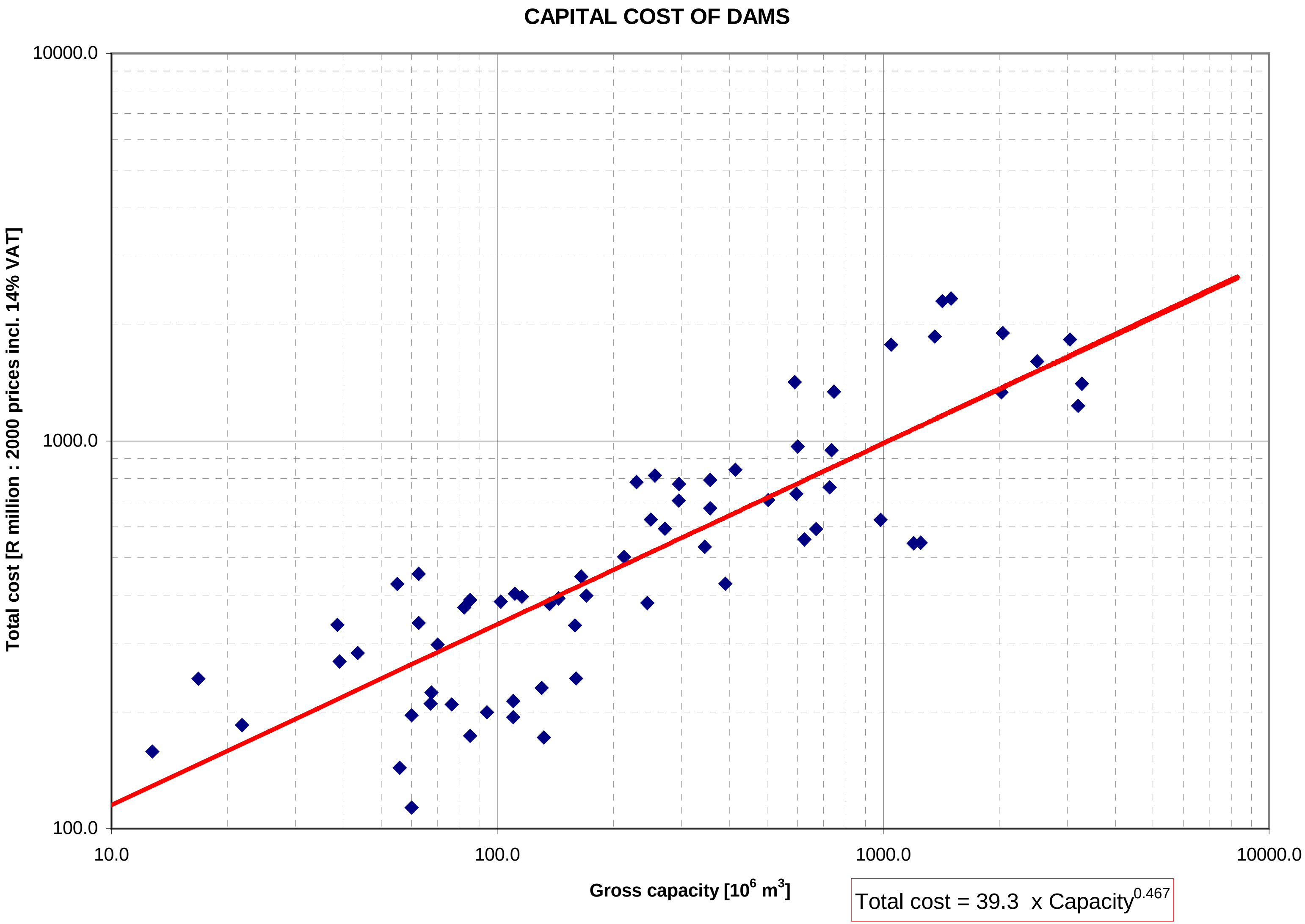

Diagram 8.2: Capital cost of dams

TABLE 8.2: COSTS OF FUTURE WATER RESOURCE DEVELOPMENT (AT YEAR 2000 PRICE LEVELS INCLUDING VAT)

KEY AREA	SURFACE WATER DEVELOPMENT		GROUNDWATER			CAPITAL COSTS		
	STORAGE VOLUME (million m^3)	INCREASE IN YIELD (million m^3)	INCREASE IN YIELD (million m^3)	ASSUMED AVERAGE BOREHOLE YIELD (ℓ/s)	COST PER kℓ /a OF YIELD (R)	DAMS (R Million)	WELLFIELDS (R Million)	TOTALS (R Million)
Upper Krom	-	-	-	-	-	-	-	-
Tsitsikamma Coast	350	89,0	-	-	-	605	-	605
Upper Groot	-	-	60,7	1,7	4,50	-	273	273
Lower Groot	-	-	67,3	1,7	4,50	-	303	303
Kouga	-	-	8,7	2,5	3,50	-	30	30
Gamtoos	-	-	9,1	1,6	5,00	-	46	46
Algoa Coast	-	-	35,0	1,4	5,50	-	193	193
Upper Sundays	-	-	-	-	-	-	-	-
Middle Sundays	-	-	2,6	2,8	3,00	-	8	8
Lower Sundays	-	-	21,1	1,4	5,50	-	116	116
Albany Coastal Catchments	408	35,9	--	-	-	651	-	651
Upper Fish	-	-	20,1	3,8	2,50	-	50	50
Tarka	-	-	19,8	2,7	3,00	-	59	59
Upper Middle Fish	-	-	48,4	2,0	4,00	-	194	194
Upper Little Fish	-	-	-	-	-	-	-	-
Middle Fish	-	-	9,3	-	-	-	-	-
Koonap	149	16,8	-	-	-	406	-	406
Kat	79	12,9	-	-	-	302	-	302
Lower Fish	181	21,8	-	-	-	332	-	332
TOTALS	**1 167**	**176,4**	**302,1**	**-**	**-**	**2296**	**1272**	**3568**

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

The main characteristics of the Fish to Tsitsikamma WMA, as determined from the information gathered in this situation assessment, are listed below:

(i) The Fish to Tsitsikamma WMA covers an area of 97 023 km^2 in which the mean annual precipitation ranges from 150 mm in the north-western interior, where the climate is semi-arid, and rainfall generally occurs in the period from March to May, to more than 1 100 mm along the coast in the south-west, where rainfall occurs throughout the year. Mean annual gross Symons Pan evaporation ranges from 2 300 mm to 1 500 mm.

(ii) The geology of the WMA consists of Karoo sediments in the interior and sandstones, quartzites and conglomerates of the Cape Supergroup along the coast. Thus, water can be expected to have naturally elevated TDS concentrations in the interior and low concentrations along the coast.

(iii) The small rivers of the coastal catchments are of high to very high ecological importance and sensitivity, and consequently have high ecological flow requirements. The Koonap River and Kat River and their tributaries are also of high ecological importance. Most of the other rivers are of moderate ecological importance and sensitivity and have correspondingly lower ecological flow requirements.

(iv) The population of the WMA in 1995 was approximately 1 623 000 people. Some 13% of the population lived in rural areas, and 87% of the total population lived in the towns of the WMA. About 64% of the population lives in the Algoa Coastal area, mainly within the boundaries of the Nelson Mandela Metropolitan Municipality.

(v) Much of the economic activity is concentrated in the south-western portion of the WMA, with the Port Elizabeth/Uitenhage area contributing 82% of the GGP in 1997. The GGP of the whole WMA was R21,8 billion in 1997, with the most important economic sectors, in terms of their contributions to GGP, being Manufacturing (28,3%), Trade (18,0%), and Government (16,6%). Transport and Manufacturing have comparative advantages relative to other WMAs.

(vi) Land-use is predominantly for rough grazing for livestock. Some 950 km^2, or 1% of the surface area of the WMA is used for irrigated crops, but only about 700 km^2 of land is irrigated in average years, with larger areas irrigated occasionally when rainfall and runoff is favourable in the semi-arid areas. Afforestation, mainly in the south-western coastal strip covers 417 km^2, and 3 705 km^2 of land consists of nature reserves. Alien vegetation other than the afforestation covered an equivalent condensed area of 940 km^2.

(vii) There were about 886 000 head of livestock in the WMA in 1995. Sheep and goats made up 61% of the livestock numbers, with sheep predominating.

(viii) Water related infrastructure is well developed, particularly in the southern half of the WMA and along the Great Fish River where most of the water requirements occur and where an average quantity of 560 million m^3/a of water is imported from the Orange River by means of the Orange/Fish Transfer Scheme.

(ix) Town bulk water supply schemes were generally adequate in 1995, but the requirements from many of them were approaching their capacities and supplies are likely to require augmentation soon.

(x) Many of the towns can be economically supplied with raw water imported from the Orange River, but some of the bigger towns where this is not the case, and where raw water supplies will require augmentation in the near future, are Adelaide, Fort Beaufort, Port Alfred, Kenton-on-Sea, Bushman's River Mouth, and Alexandria. The supply to Nelson Mandela Metropolitan Municipal Area could be augmented from the Orange River or from local sources.

(xi) Allocations of water for irrigation from Government Water Supply Schemes total 915 million m^3/a. Of this quantity, 722 million m^3/a, or 79%, is allocated from the Orange/Fish Transfer Scheme. From the information gathered in this study, it appears that only about 63% of the allocation from the Orange/Fish Transfer Scheme is used, but this is in conflict with the information gathered in earlier studies and should be verified.

(xii) On the basis of (xi) above, water used for irrigation from Government Water Supply Schemes amounts to 651 million m^3/a (excluding losses), and accounts for 86% of the average field edge irrigation water requirement of the WMA of 759 million m^3/a. Therefore, only 14% of the irrigation water requirements in the WMA are provided from what were "private" sources prior to 1998. With the exception of the Kouga River catchment, information on the capacities of these sources and the quantities of water used from them is not well documented, but may be required in the future for specific areas where the need to further develop the water resources occurs.

(xiii) Water requirements in 1995 were estimated to total 1 158 million m^3/a, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. The major water user sector was agriculture, which required 911 million m^3/a, or 79% of the total consumptive requirement (i.e. excluding the ecological Reserve). The next biggest water user was the urban and rural domestic sector, at 9% of the total consumptive requirement, followed by alien vegetation (7%) and afforestation (5%). The estimate of water use by alien vegetation is at a low level of confidence. With the requirements of the ecological Reserve added, and river channel losses of 112 million m^3/a associated with the Orange/Fish Transfer Scheme, the total water requirement becomes 1 513 million m^3/a.

(xiv) The equivalent water requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by alien vegetation and afforestation all included as impacts on yield, was 937 million m^3/a. Adding Orange/Fish Transfer Scheme river channel losses of 112 million m^3/a to this brings the total to 1 049 million m^3/a. The estimates of the impacts on yield are at a low level of confidence.

(xv) The natural MAR of the Fish to Tsitsikamma WMA was 2 154 million m^3/a and the yield utilised from surface water resources in 1995 was 425 million m^3/a at 1:50 year assurance. Some 50% of the utilised yield was from farm dams and run-of-river abstractions, and 43% from major dams. The balance of 7% was the impact of alien vegetation and afforestation on the yield. In addition, boreholes with an estimated yield of 40 million m^3/a had been developed, bringing the total developed yield to 465 million m^3/a at 1:50 year assurance.

(xvi) Natural water quality is good in some of the mountainous areas of the WMA, but in most other areas the base flows in the rivers are of high salinity, caused by the geological strata. For the same reason, only about 60% of the groundwater exploitation potential is estimated to be potable. The salinities of the base flows in many of the rivers are increased by irrigation return flows. In the Zwartkops River near Port Elizabeth, the impacts of urban development have resulted in high microbial pollution and elevated levels of nutrients in the water.

(xvii) Comparison of the equivalent 1:50 year assurance water requirements of 937 million m^3/a with the developed yield of 465 million m^3/a shows a deficit of 472 million m^3/a, but re-used return flows of 122 million m^3/a reduce the deficit to 350 million m^3/a. Imports of 560 million m^3/a from the Orange River, which incur river channel losses of 112 million m^3/a, result in an overall surplus of 98 million m^3/a. There is considerable doubt about the validity of this surplus, as discussed below.

(xviii) The yield balance is at a low level of confidence because of uncertainty regarding the true run-of-river yields and the true impacts of the ecological Reserve, afforestation and alien vegetation on the 1:50 year yields of the various key areas. Reference to the deficient flow-duration-frequency curves in WR90 suggests that the total of the 1:50 year run-of-river yield in the WMA may be up to 125 million m^3/a less than assumed for the yield balance. If this were the case, the yield balance would show a slight deficit in the Gamtoos River catchment and deficits in the Fish and Sundays River catchments which would need to be offset by increased imports from the Orange River. There would also be a significant deficit in the Koonap catchment. (The higher estimates of run-of-river yield have been retained in this report because they are the values used in the draft of the National Water Resource Strategy).

(xix) The maximum potential utilisable yield of the WMA is estimated to be 943 million m^3/a, which is 478 million m^3/a more than the utilised yield in 1995. (The total exploitable groundwater resource that does not contribute to surface base flow is estimated to be 752 million m^3/a, which appears to be a substantial over-estimate. The total potential surface water yield is estimated to be 654 million m^3/a. However, the interaction between groundwater and surface water is not known, except for the estimates of base flow interaction. Therefore the maximum potential utilisable yield in each key area was assumed to be the greater of the maximum surface water potential, or the maximum potential groundwater yield not connected to surface water base flow. The values for the key areas were combined to obtain the estimated maximum water resource potential of 943 million m^3/a. The adoption of the potential groundwater yield not connected to surface base flow rather than the full potential groundwater yield is conservative and is based on the assumption that a significant portion of the groundwater contribution to surface base flow is required for the ecological Reserve and is not, therefore, available for other water requirements.).

(xx) Surface water resources could provide a maximum yield of 229 million m^3/a additional to the surface water yield utilised in 1995, but the total potential yields in many areas could possibly not be economically developed. In some instances it might be more economical to develop groundwater resources to provide part of this.

(xxi) The capital cost of developing the additional yield of 476 million m^3/a was estimated to be R3 568 million at year 2000 prices including 14% VAT. However, the quality of groundwater and of surface water base flows in the WMA is variable, with high salinities in some areas. Therefore, the viability of developing the full potential yield may be affected by water quality as well as the high cost of constructing dams, and it is likely that only a small portion of this yield could be economically developed.

(xxii) On the basis of the data used for estimating the costs of development of the full potential yield of the water resources, the cost of developing groundwater resources is only half that of developing the same quantity of surface water yield. Therefore, it is surprising that only 5% of the potential groundwater yield had been developed by 1995. The reasons for this, which may be factors such as high distribution, operation and maintenance costs, which are not included in the cost estimates, should be determined.

It is concluded from the above that there is insufficient reliable data on the Fish to Tsitsikamma WMA to enable the water balance to be determined with confidence. The available data on the following aspects is inadequate:

- The 1:50 year yields from farm dams and run-of-river yield for all areas of the WMA.
- The quantity of water from the Orange/Fish Transfer Scheme that is used for irrigation.
- The distribution, types and areas of crops irrigated from "private" sources and their water requirements.
- Ecological flow requirements of both rivers and estuaries and their impacts on the utlised yields of the water resources.
- The impacts of alien vegetation and afforestation on the yield of the water resources.
- The reasons for the limited utilisation of the groundwater resource in relation to its apparent total potential and low cost of development.

Although not apparent from the above, it was also found during the assessment that information is lacking on the following aspects:

- The capacities of the raw water supplies of some of the towns (this data should be obtained for information on urban water supply infrastructure to be comprehensive, but is not of high priority and should be available from the water services development plans prepared by the towns).
- The numbers and types of game in the WMA. (This is not of high priority because the numbers, and hence the water requirements, are likely to be small. Nevertheless, the information should be obtained for completeness of the data on the water requirements of livestock and game).
- Updated estimates of the yields of Beervlei, Commando Drift, and Kat River Dams, and the dams supplying Grahamstown at assurances of 1:50 years and at lower assurances typically used for irrigation, as these have not been recently determined.

Ideally, all the information referred to above should be available to facilitate the efficient management of the water resources of the Fish to Tsitsikamma WMA and the planning of their further development. However, a considerable amount of work will be required to obtain all the information, and it is unlikely that the task could be completed in a short time. Therefore, a phased approach is recommended, in which the required information is collected for particular areas as it becomes necessary to address water resources problems, or as the Reserve is implemented.

It is recommended that the run-of-river and farm dam yields in the Fish and Sundays River catchments be determined by using and modifying as necessary the system yield model that was developed for those rivers for the Orange River Development Project Re-planning Study to also take account of actual operating procedures.

With regard to the potential groundwater yields, the fact that groundwater has not been utilised to a greater extent casts some doubt on the reliability of the estimates of groundwater yield. It is recommended that the data be verified, starting with the Zwartkops Catchment, where the data shows the groundwater to be under-utilised, but a Government Subterranean Water Control Area was declared because the resource has appeared in the past to be stressed. The estimates of total potential yield given in this report should therefore be used with caution until the investigation confirms the assumed groundwater yields, or otherwise.

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APPENDICES

LIST OF CONTENTS

NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

ABBREVIATIONS AND ACRONYMS

AEMC	Suggested Ecological Management Class
CMA	Catchment Management Agency
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management Class
DESC	Default Ecological Sensitivity Class
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Class
GIS	Geographical Information System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act No. 36 of 1998)
PESC	Present Ecological Status Class
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TRC	Transitional Rural Council
WMA	Water Management Area
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model
ha	hectare
km^2	square kilometres
m^3	cubic metre
10^6m^3	million cubic metres
$10^6m^3/a$	million cubic metres per year
%	percent

APPENDIX A

DEMOGRAPHIC DATA

Listing of urban, rural and total populations per quaternary catchment as contained in the database of the Water Situation Assessment Model.

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX A

DEMOGRAPHIC DATA PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	oPOPi URBAN POPULATION	oPORi RURAL POPULATION	TOTAL POPULATION
	Number	Number	Number
K80A	0	1327	1327
K80B	250	1540	1790
K80C	0	1673	1673
K80D	0	2269	2269
K80E	0	885	885
K80F	1800	614	2414
K90A	0	259	259
K90B	2250	192	2442
K90C	0	277	277
K90D	0	373	373
K90E	0	489	489
K90F	19600	1770	21370
K90G	10800	696	11496
L11A	0	75	75
L11B	0	99	99
L11C	0	470	470
L11D	0	547	547
L11E	0	789	789
L11F	0	296	296
L11G	0	354	354
L12A	0	171	171
L12B	0	97	97
L12C	700	194	894
L12D	0	199	199
L21A	0	91	91
L21B	0	203	203
L21C	0	261	261
L21D	0	233	233
L21E	0	184	184
L21F	3900	181	4081
L22A	0	262	262
L22B	0	106	106
L22C	0	170	170
L22D	0	117	117
L23A	0	107	107
L23B	0	210	210
L23C	0	210	210
L23D	0	209	209
L30A	6550	95	6645
L30B	0	84	84
L30C	0	52	52
L30D	0	289	289
L40A	0	180	180
L40B	0	279	279
L50A	0	253	253
L50B	0	268	268
L60A	3650	187	3837
L60B	0	248	248
L70A	0	246	246
L70B	3400	176	3576
L70C	0	278	278

QUATERNARY CATCHMENT	oPOPi URBAN POPULATION	oPORi RURAL POPULATION	TOTAL POPULATION
	Number	Number	Number
L70D	0	262	262
L70E	0	535	535
L70F	0	180	180
L70G	0	429	429
L81A	0	241	241
L81B	0	197	197
L81C	0	266	266
L81D	0	324	324
L82A	1950	929	2879
L82B	0	2723	2723
L82C	1000	3173	4173
L82D	4650	2673	7323
L82E	0	336	336
L82F	0	185	185
L82G	0	282	282
L82H	0	262	262
L82J	0	171	171
L90A	4000	4896	8896
L90B	9200	1949	11149
L90C	1350	2384	3734
M10A	0	169	169
M10B	0	483	483
M10C	182500	6301	188801
M10D	23600	1325	24925
M20A	809800	4686	814486
M20B	0	7017	7017
M30A	0	631	631
M30B	0	1172	1172
N11A	0	346	346
N11B	0	443	443
N12A	1450	345	1795
N12B	0	411	411
N12C	0	424	424
N13A	0	410	410
N13B	0	393	393
N13C	34100	384	34484
N14A	0	201	201
N14B	5950	129	6079
N14C	0	345	345
N14D	0	209	209
N21A	0	279	279
N21B	0	160	160
N21C	0	257	257
N21D	0	164	164
N22A	0	339	339
N22B	0	365	365
N22C	0	271	271
N22D	0	198	198
N22E	0	249	249
N23A	0	324	324
N23B	0	229	229
N24A	0	188	188
N24B	0	204	204
N24C	4700	321	5021
N24D	0	200	200
N30A	3700	342	4042
N30B	0	387	387
N30C	0	290	290

QUATERNARY CATCHMENT	oPOPi URBAN POPULATION	oPORi RURAL POPULATION	TOTAL POPULATION
	Number	Number	Number
N40A	0	1548	1548
N40B	0	1953	1953
N40C	10800	7015	17815
N40D	0	3627	3627
N40E	5900	4302	10202
N40F	0	2619	2619
P10A	0	246	246
P10B	650	972	1622
P10C	0	282	282
P10D	5950	904	6854
P10E	3250	1594	4844
P10F	0	2517	2517
P10G	4200	2497	6697
P20A	12050	3999	16049
P20B	0	1434	1434
P30A	0	1119	1119
P30B	0	3325	3325
P30C	0	562	562
P40A	59350	2378	61728
P40B	0	1772	1772
P40C	22000	2014	24014
P40D	1450	1289	2739
Q11A	0	353	353
Q11B	0	341	341
Q11C	0	248	248
Q11D	0	412	412
Q12A	0	483	483
Q12B	7900	596	8496
Q12C	0	410	410
Q13A	2850	904	3754
Q13B	0	310	310
Q13C	0	761	761
Q14A	0	208	208
Q14B	17400	938	18338
Q14C	0	524	524
Q14D	0	320	320
Q14E	0	219	219
Q21A	0	156	156
Q21B	0	565	565
Q22A	0	272	272
Q22B	0	137	137
Q30A	0	301	301
Q30B	0	488	488
Q30C	0	538	538
Q30D	0	751	751
Q30E	28600	603	29203
Q41A	0	390	390
Q41B	0	687	687
Q41C	5400	363	5763
Q41D	0	231	231
Q42A	0	457	457
Q42B	0	392	392
Q43A	0	581	581
Q43B	0	714	714
Q44A	0	260	260
Q44B	0	307	307
Q44C	0	714	714
Q50A	0	1844	1844

QUATERNARY CATCHMENT	oPOPi URBAN POPULATION	oPORi RURAL POPULATION	TOTAL POPULATION
	Number	Number	Number
Q50B	0	1060	1060
Q50C	0	480	480
Q60A	0	581	581
Q60B	0	629	629
Q60C	0	189	189
Q70A	5200	501	5701
Q70B	0	1315	1315
Q70C	0	331	331
Q80A	0	243	243
Q80B	0	350	350
Q80C	0	361	361
Q80D	16500	675	17175
Q80E	0	534	534
Q80F	0	521	521
Q80G	0	438	438
Q91A	0	631	631
Q91B	0	936	936
Q91C	0	1212	1212
Q92A	0	866	866
Q92B	0	950	950
Q92C	0	1318	1318
Q92D	11550	563	12113
Q92E	0	623	623
Q92F	10150	772	10922
Q92G	0	2241	2241
Q93A	0	592	592
Q93B	0	3701	3701
Q93C	15050	10560	25610
Q93D	0	5442	5442
Q94A	2700	1950	4650
Q94B	0	3472	3472
Q94C	0	4447	4447
Q94D	0	3464	3464
Q94E	0	930	930
Q94F	23350	17180	40530
TOTALS	1413100	209621	1622721

APPENDIX B

SUPPLEMENTARY ECONOMIC DATA

APPENDIX B.1

GRAPHS: GROSS GEOGRAPHIC PRODUCT, LABOUR AND SHIFT-SHARE

APPENDIX B.1
DESCRIPTION OF GRAPHS

Diagram No	Graphic Illustration	Description
	• **Gross Geographic Product**:	
B.1	➾ Contribution by Magisterial District to Fish to Tsitsikamma Economy, 1997 (%)	Each WMA comprises a number of Magisterial Districts. This graph illustrates the percentage contribution of each MD to the WMA economy as a whole. It shows which are the most important sub-economies in the region.
B.2	➾ Contribution by sector to National Economy, 1988 and 1997 (%)	This graph illustrates the percentage contribution of each sector in the WMA economy, e.g. agriculture, to the corresponding sector in the national economy.
	• **Labour Force Characteristics**:	
B.3	➾ Composition of Fish to Tsitsikamma Labour Force 1994 (%)	The total labour force may be divided into three main categories, namely formal employment, informal employment and unemployment, as outlined in this graph.
B.4	➾ Contribution by Sector to Fish to Tsitsikamma Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.5	➾ Contribution by Sectors of Fish to Tsitsikamma Employment to National Sectoral Employment, 1980 and 1994 (%)	Similar to the production function (i.e. GGP), this graph illustrates the percentage contribution of each sector in the WMA economy, e.g. mining, to the corresponding sector in the national economy.
B.6	➾ Compound Annual Employment Growth by Sector of Fish to Tsitsikamma versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.
	• **Shift-Share**:	
B.7	➾ Shift-Share Analysis, 1997	Compares the contribution of each sector in the WMA economy to its recent growth performance. This serves as an instrument to identify sectors of future importance (towards top right hand side of the graph) and sectors in distress (towards the bottom left hand side of the graph).

Figure B.1: Contribution by Magisterial District to Fish to Tsitsikamma economy, 1997 (%)

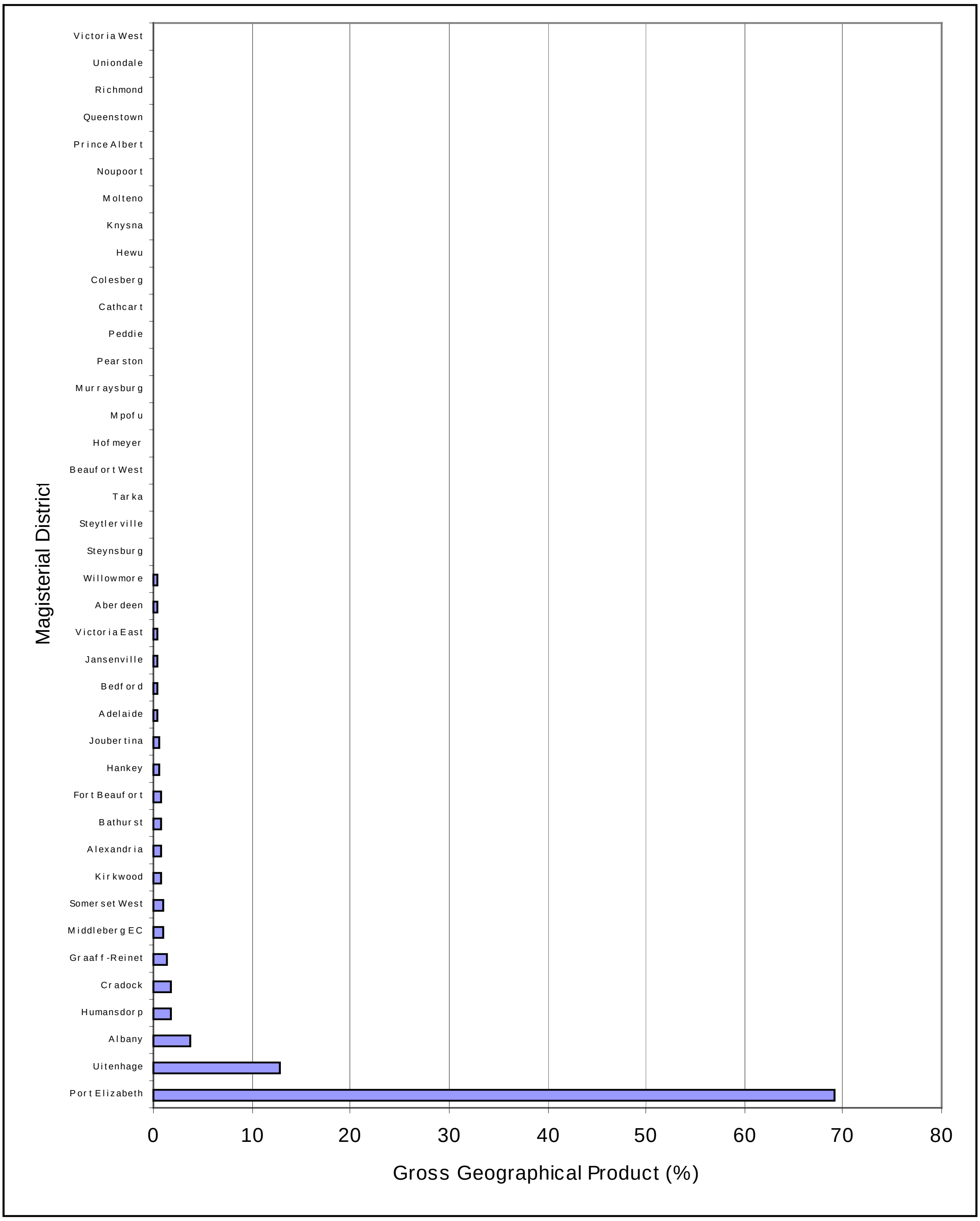


Figure B.2: Contribution by Sector to National Economy, 1988 and 1997 (%)

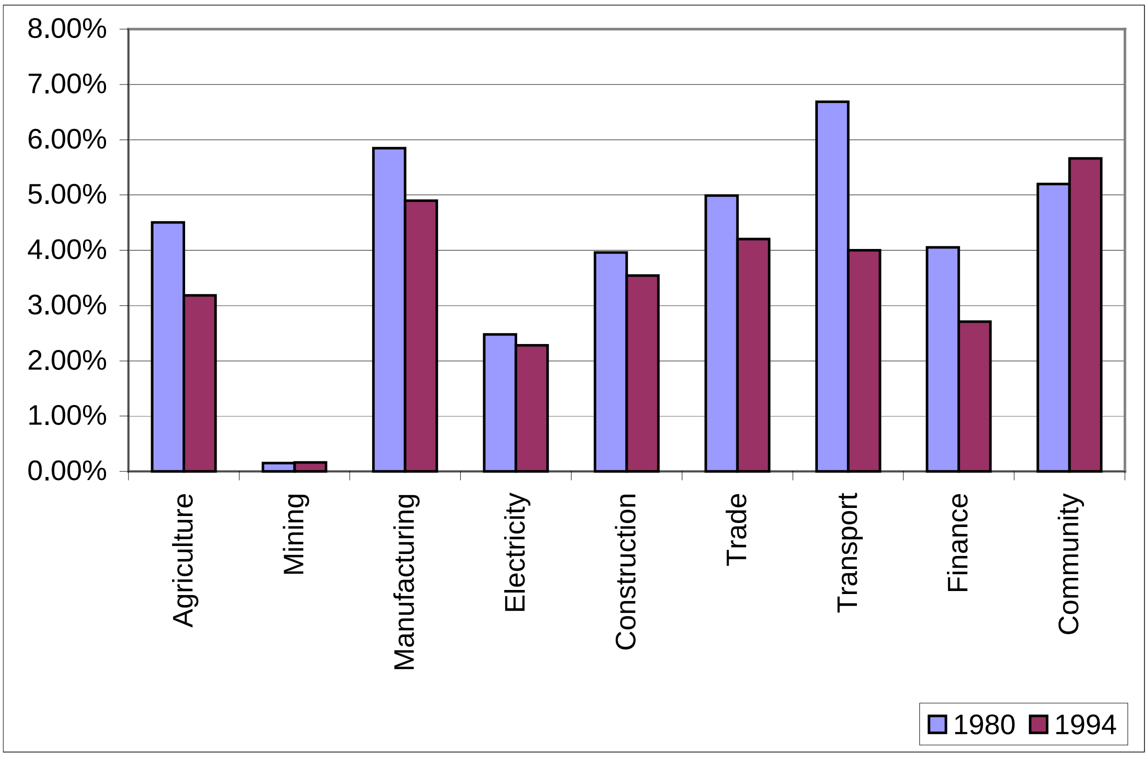


Figure B.3: Composition of Fish to Tsitsikamma Labour Force, 1994 (%)

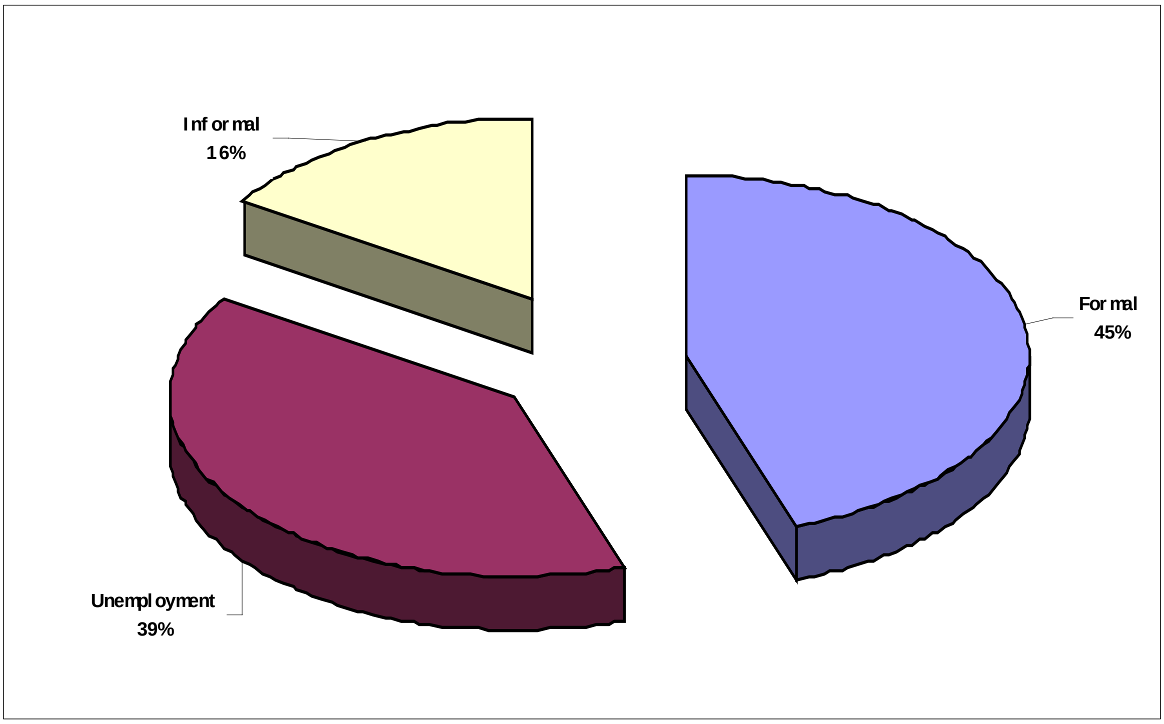


Figure B.4: **Contribution by Sector to Fish to Tsitsikamma Employment, 1980 and 1994(%)**

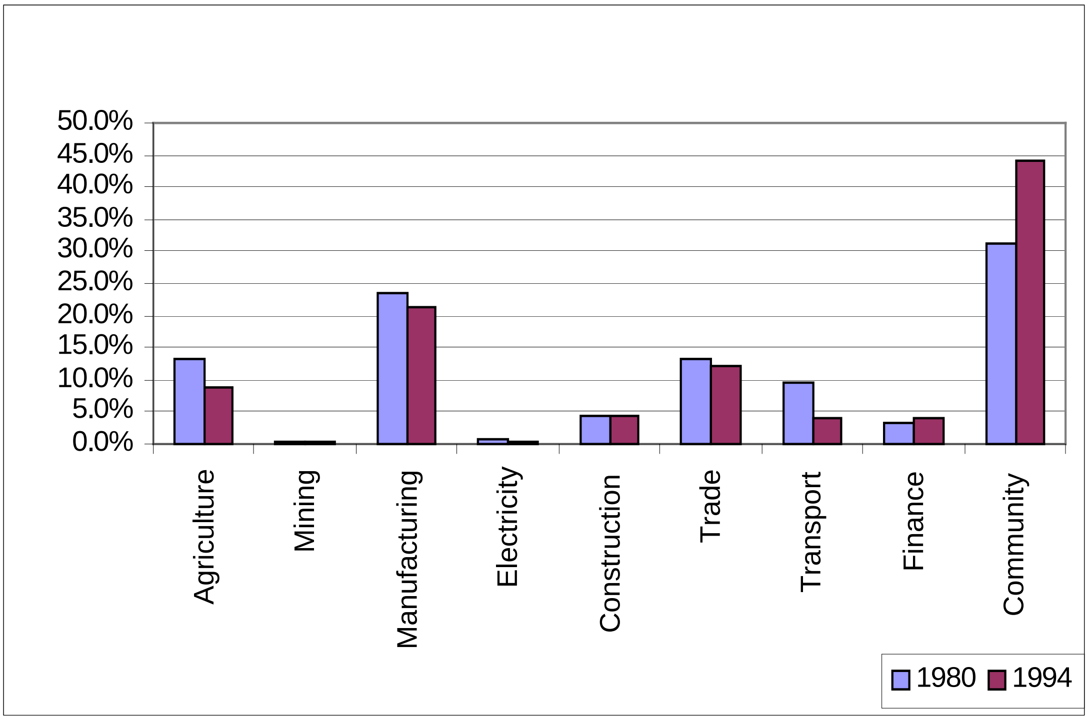


Figure B.5: **Contribution by Sectors of Fish to Tsitsikamma Employment to National Sectoral Employment, 1980 and 1994 (%)**

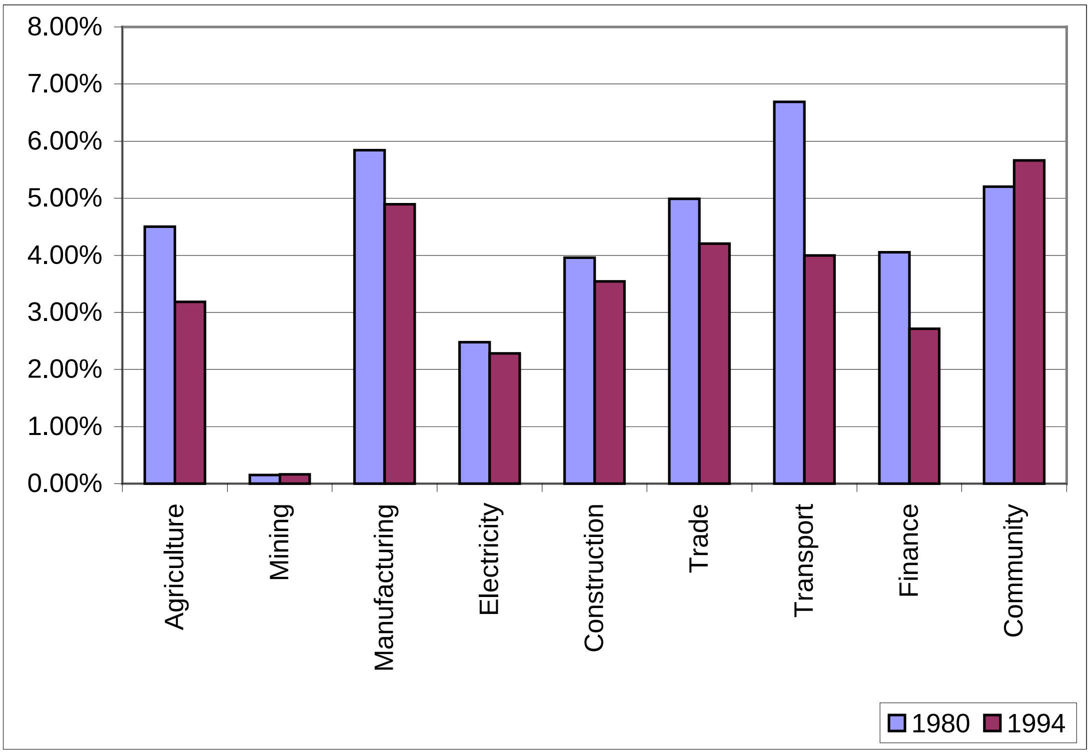


Figure B.6: Average Annual Employment Growth by Sector of Fish to Tsitsikamma versus South Africa, 1980 to 1994 (%)

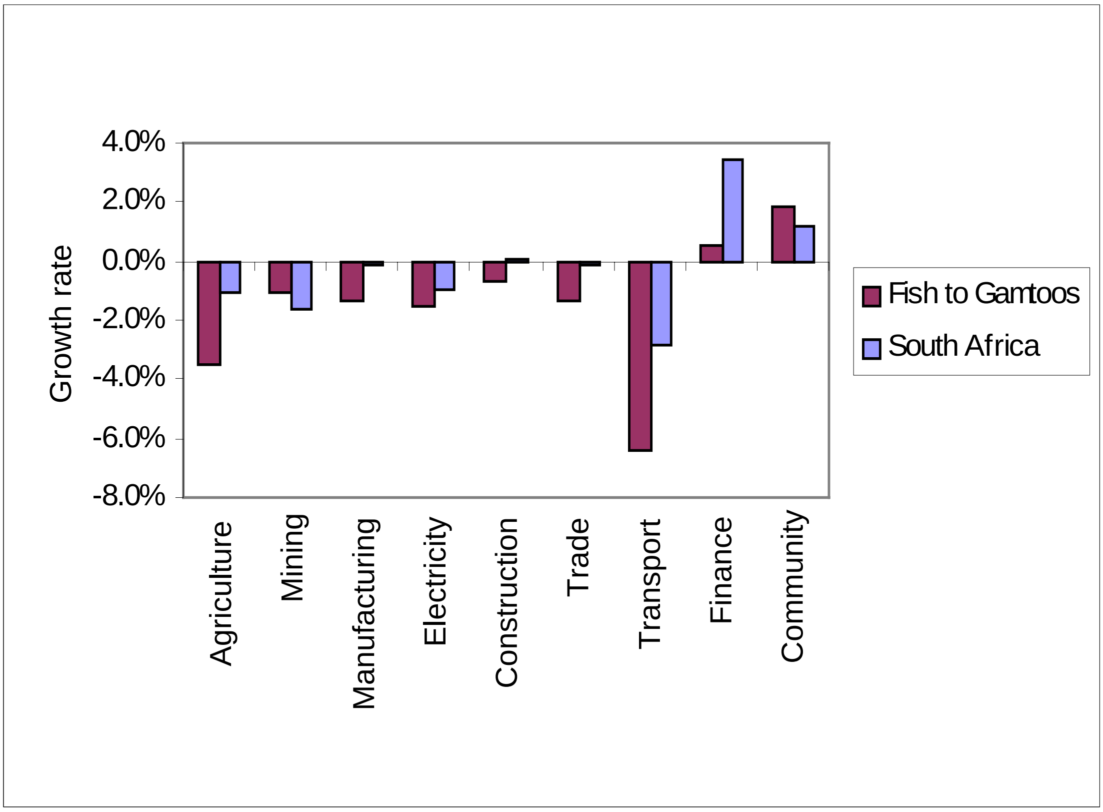
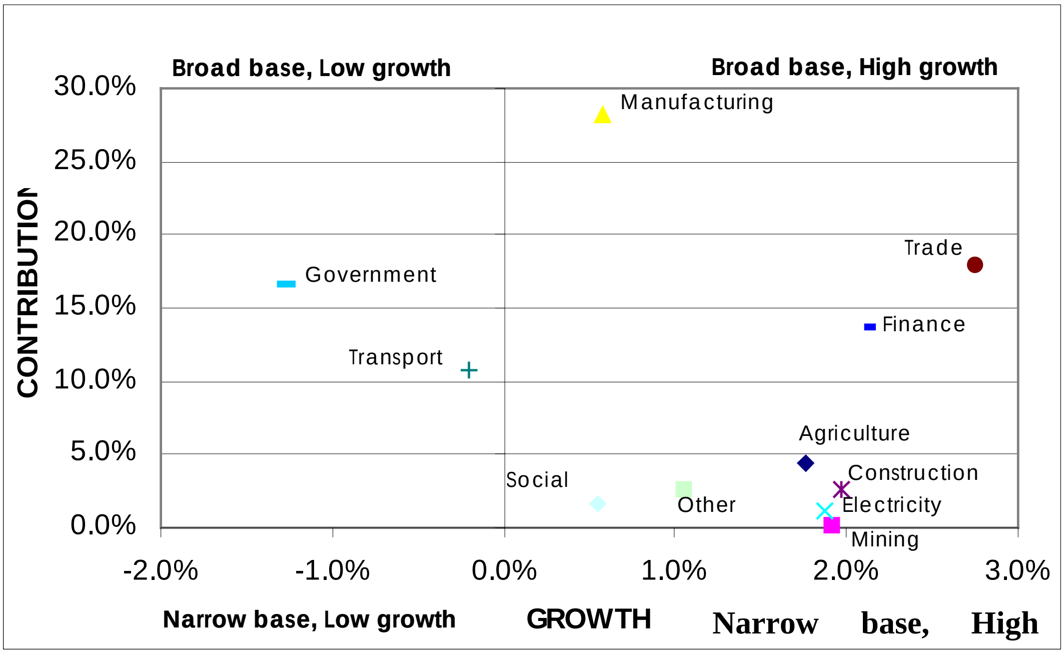


Figure B.7: Shift-Share Analysis, 1997



APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

B.1 INTRODUCTION

The purpose of this section is to illustrate the relative importance of the nineteen different water management areas (WMAs) in South Africa. The following aspects are outlined:

- Contribution by WMA to national economy
- Contribution by WMA to formal employment
- Economic growth by WMA.

B.2 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL ECONOMY

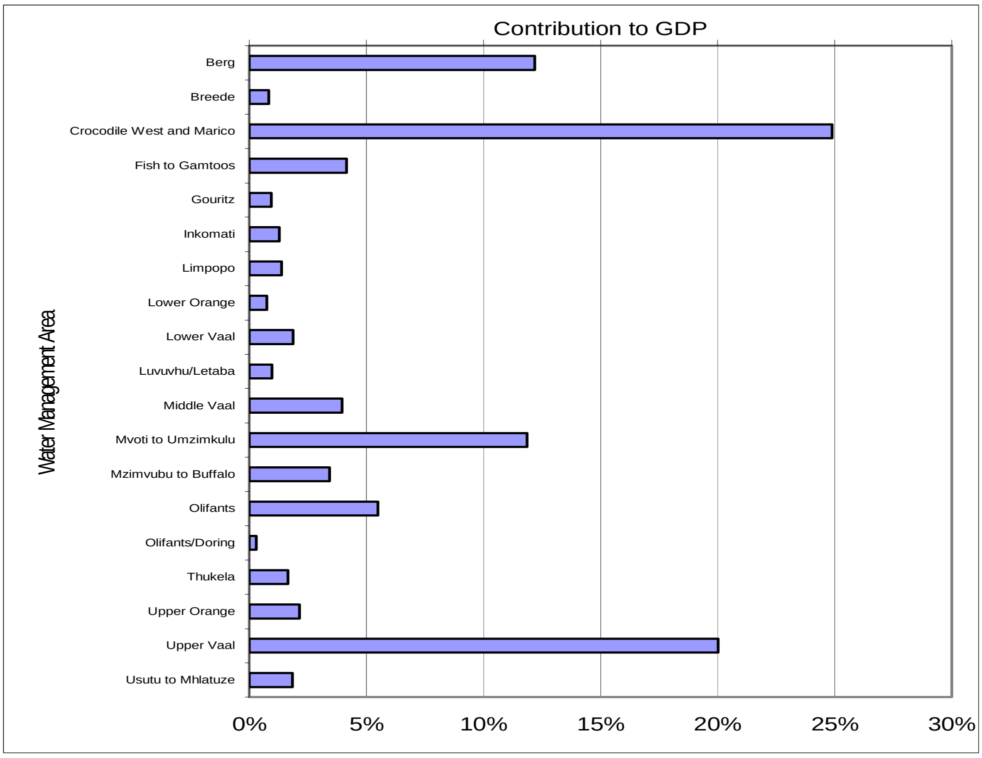
- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.

- The second largest WMA to the national economy, is the Upper Vaal, which contributes 16.6% to GDP. This WMA comprises mainly portions of Johannesburg, Vereeniging and Vanderbijlpark.

- The Berg WMA contributes 11.25% to the GDP of the national economy and comprises mainly the Cape Metropolitan Area (CMA).

- Mvoti to Umzimkulu WMA makes the fourth largest contribution of 10.72% to the GDP of the national economy. This WMA includes the Durban-Pinetown Metropolitan Area.

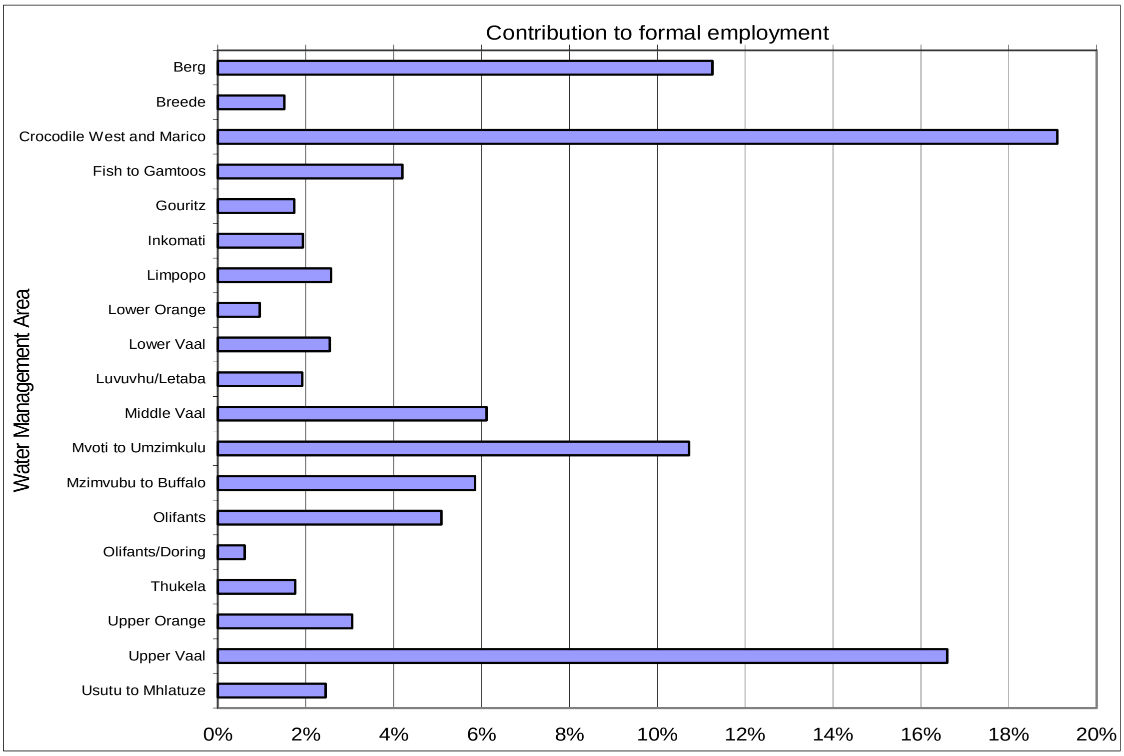
Figure B.1: Total GGP by Water Management Area (% of Country)



B.3 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL EMPLOYMENT

- Contribution to formal employment corresponds to economic production and is mainly concentrated in the four dominant WMAs.

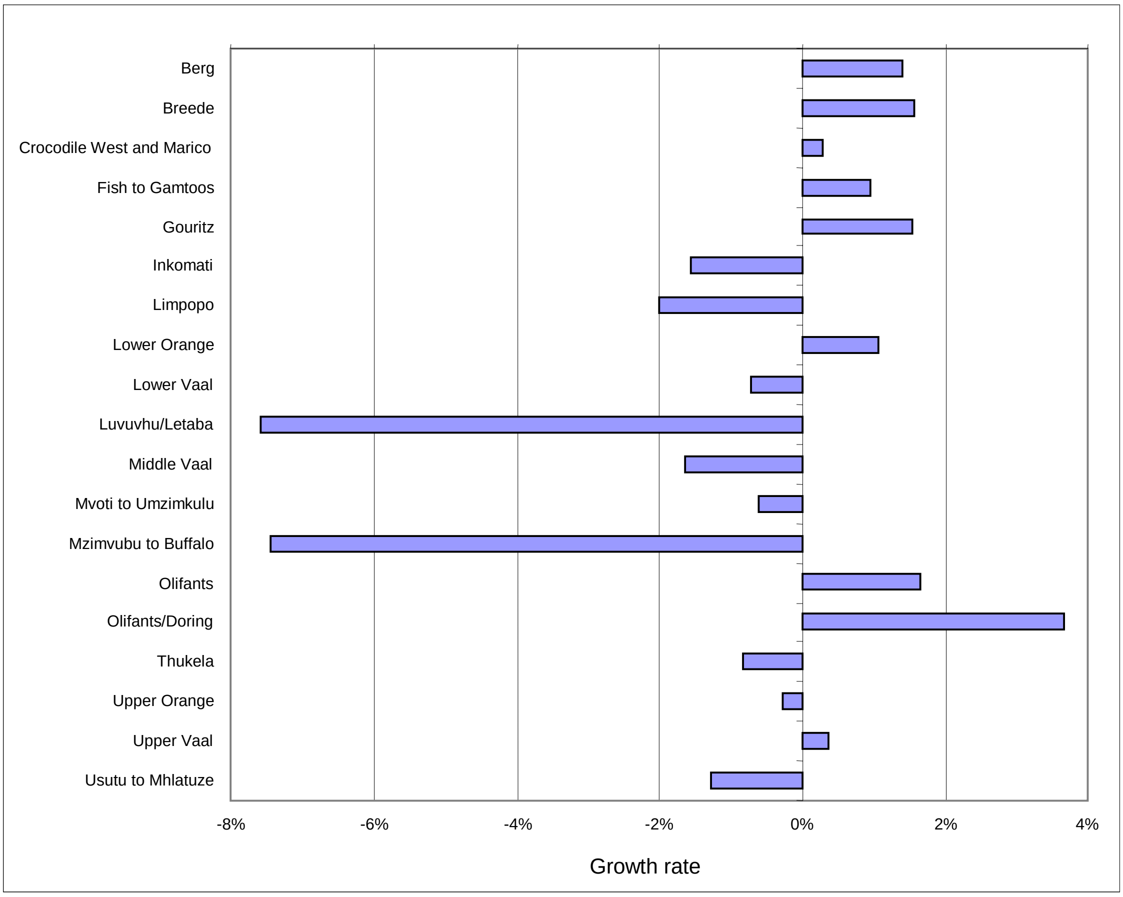
Figure B.2: Formal Employment by Water Management Area (% of country)



B.4 ECONOMIC GROWTH BY WATER MANAGEMENT AREA

- In terms of economic growth, three of the dominant four WMAs recorded positive economic growth between 1988 and 1997: the Berg grew at 1.4% per annum, Crocodile West and Marico at 0.28% per annum and Upper Vaal at 0.36% per annum. Marginal negative growth was recorded over the nine year period in the Mvoti to Umzimkulu WMA: -0.62% per annum.

Figure B.3: Average Annual Economic Growth by Water Management Area, 1988-1997 (%)



APPENDIX B.3
ECONOMIC SECTOR DESCRIPTION

ECONOMIC SECTOR DESCRIPTION

- **Agriculture:** This sector includes agriculture, hunting and related services. It comprises activities such as growing of crops, market gardening, horticulture, mixed farming, production of organic fertiliser, forestry, logging and related services and fishing, operation of fish hatcheries and fish farms.

- **Mining:** This section entails the mining and quarrying of metallic minerals (coal, lignite, gold, cranium ore, iron ore, etc); extraction of crude petroleum and natural gas, service activities incidental to oil and gas extraction; stone quarrying; clay and sand pits; and the mining of diamonds and other minerals.

- **Manufacturing:** Manufacturing includes, inter alia, the manufacturing of food products, beverages and tobacco products; production, processing and preserving of meat, fish, fruit, vegetables, oils and fats, dairy products and grain mill products; textile and clothing; spinning and weaving; tanning and dressing of leather; footwear; wood and wood products; paper and paper products; printing and publishing; petroleum products; nuclear fuel; and other chemical substances.

- **Electricity, Water and Gas:** Utilities comprise mainly three elements, namely electricity, water and gas. The services rendered to the economy include the supply of electricity, gas and hot water, the production, collection and distribution of electricity, the manufacture of gas and distribution of gaseous fuels through mains, supply of steam and hot water, and the collection, purification and distribution of water.

- **Construction:** This sector includes construction; site preparation building of complete constructions or parts thereof; civil engineering; building installation; building completion; and the renting of construction or demolition equipment with operators all form part of the construction sector.

- **Trade:** Trade entails wholesale and commission trade; retail trade; repair of personal household goods; sale, maintenance and repair of motor vehicles and motor cycles; hotels, restaurants, bars canteens, camping sites and other provision of short-stay accommodation.

- **Transport:** The transportation sector comprises land transport; railway transport; water transport; transport via pipelines; air transport; activities of travel agencies; post and telecommunications; courier activities; and storage.

- **Business and Financial Services:** The economic activities under this category include, inter alia, financial intermediation; insurance and pension funding; real estate activities; renting of transport equipment; computer and related activities; research and development; legal; accounting, book-keeping and auditing activities; architectural, engineering and other technical activities; and business activities not classified elsewhere.

- **Government and Social services (Community Services)**: This sector includes public administration and defence, social and related community services (education, medical, welfare and religious organisations), recreational and cultural services and personal and household services.

- **Other:** Private households, extraterritorial organisations, representatives of foreign governments and other activities not adequately defined.

APPENDIX B.4
ECONOMIC INFORMATION SYSTEM

ECONOMIC INFORMATION SYSTEM
for Department of Water Affairs and Forestry

1. Background

The Economic Information System was developed for the Department of Water Affairs and Forestry due to a need for a comprehensive source of readily available economic data that can be utilised as a management tool for decision making.

Relevant information required for planning the allocation and utilisation of scarce resources such as water has always been a difficult process due to:

- **Inaccessibility of information**
- **Incompatibility of information**
- **No framework of reference for analysis**

The purpose of the Economic Information System was thus to combine all readily available economic information into a single computer package that would be readily accessible, easy to use and could be distributed without restrictions.

2. The System

The characteristics of the Economic Information System can be summarised as follows:

- Provides immediate access to a comprehensive economic database.
- Stand alone software programme that can be loaded onto a personal computer.
- System provides not only the existing data but also allows first degree transformation of data both geographically and functionally.
- Allows multidimensional access and presentation of information, that is, on a sectoral, geographical and functional basis.
- Provides time series information to enable users to determine trends and make projections.

Urban-Econ collected existing data from a range of secondary sources. The following data were combined in a single database which can be queried spatially, thematically and temporally *via* a user-friendly computer interface.

Diagram 1 depicts the economic information system in a flow chart format. It is possible to display the data in:

- Tables
- Graphs
- Thematic maps (this provides a better perspective of the spatial context and significance of other spatial features relevant to the data.

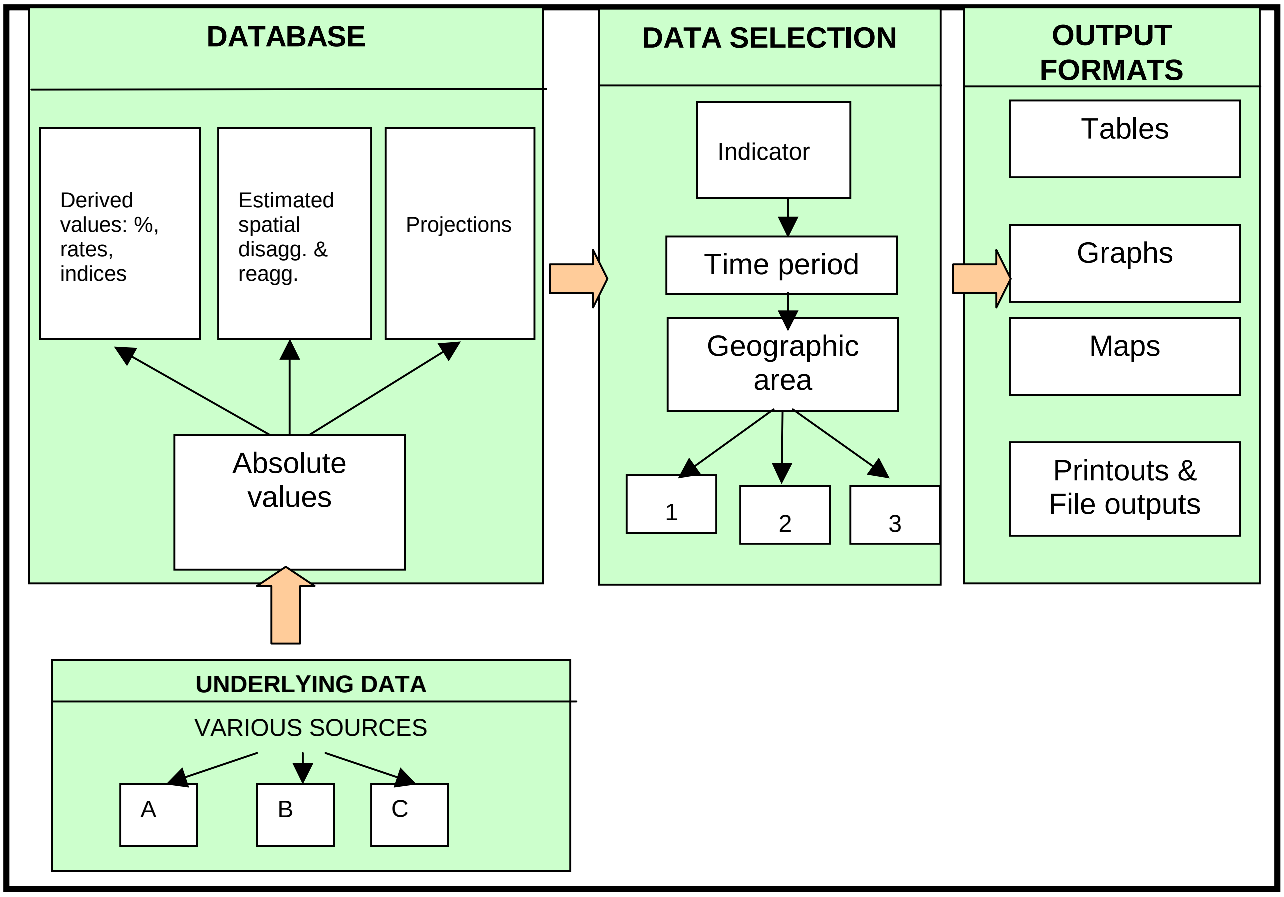
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service council area
Electricity connections	Economic sectors, domestic	1988-1997	Local authority area, service council area
Remuneration*	Economic sectors	1993-1998	Magisterial districts
Turnover*	Economic sectors	1993-1998	Magisterial districts
Number of firms*	Economic sectors	1992-1998	Magisterial districts
Tax revenue	Company, Personal, VAT	1992-1997	Tax office area
Buildings completed	Residential, office, shops, industrial	1991-1996	Local authority area, service council area
Telephone connections	Business, residence	1998 1976-1997	Magisterial district Province
Vehicle sales	Commercial, passenger	1980-1997	Towns

* Figures complete for totals, but incomplete for economic sectors

On-line documentation is provided which gives information on:

- The definition of an indicator
- How the figures were obtained
- How reliable the figures are
- How complete the figures are
- To what detail the figures are available
- What the relevance or limitations of the figures are for analytical purposes.

Diagram 1: Overview of Economic Information System



3. Examples of utilisation

- A user can select a main area for analysing the spatial variations of an indicator. Within that area, any level of geographic detail, i.e. magisterial district level or town level in the case of data relating to a local authority area can be assessed.
- It is possible to compare changes over time between different areas. This may indicate whether patterns of economic activity are changing, for example that it is growing in one area and declining in another area, which will have an impact on, for example, human settlement and the demand for water.
- A user can select more than one indicator to ascertain how the trends of the different indicators are correlated in different areas or over time. If indicators are correlated, there may be a causal relationship between the two, or it may reveal that changes in both indicators are a consequence of some other factor. If these causal relationships can be determined, it may also become known whether the causal factors are changing permanently or temporarily, which will inform the user whether there should be a long-term planning response or not.

APPENDIX C

LEGAL ASPECTS

Not used

APPENDIX D

LAND USE DATA

APPENDIX D.1	**Listing per quaternary catchment of land use data contained in the database of the Water Situation Assessment Model.**
APPENDIX D.2	**Conversion of mature livestock and game populations to Equivalent Large Stock Units.**
APPENDIX D.3	**Tree species in commercial forests.**

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX D.1

LISTING PER QUATERNARY CATCHMENT OF LAND USE DATA CONTAINED IN THE DATABASE OF THE WATER SITUATION ASSESSMENT MODEL

	aAAAi	aFCAi	aFINi	aISAi	a NAEi	oRSUi
QUATERNARY CATCHMENT	AREA UNDER ALIEN VEGETATION	AREA UNDER AFFORESTATION	INDIGENOUS FOREST AREA	FIELD AREA IRRIGATED	URBAN (1) AREAS	NUMBER OF LARGE STOCK UNITS
K80A	2.65	39.38	0.74	1.01	0.00	1821
K80B	8.53	45.30	0.00	1.48	0.00	2784
K80C	9.71	51.00	16.39	1.64	0.00	2524
K80D	15.47	25.53	6.77	1.01	0.00	2312
K80E	10.82	20.48	3.46	1.48	0.00	3556
K80F	27.25	0.00	0.00	0.00	0.65	2950
K90A	7.93	0.00	0.00	2.00	0.00	2644
K90B	7.79	0.53	0.81	1.37	0.76	2001
K90C	8.24	0.00	0.00	2.26	0.00	3570
K90D	8.56	0.02	0.63	1.27	0.00	2881
K90E	33.87	0.00	0.00	1.17	0.90	2316
K90F	6.49	1.84	0.00	1.72	6.87	3339
K90G	1.93	0.00	0.00	1.95	4.03	3830
L11A	0.00	0.00	0.00	0.60	0.00	650
L11B	0.56	0.00	0.00	0.50	0.00	600
L11C	0.21	0.00	0.00	0.40	0.00	415
L11D	0.03	0.00	0.00	0.00	0.00	749
L11E	0.00	0.00	0.00	0.80	1.20	265
L11F	0.00	0.00	0.00	0.30	0.00	432
L11G	0.00	0.00	0.00	0.30	0.00	1185
L12A	1.03	0.00	0.00	0.00	0.00	519
L12B	0.00	0.00	0.00	1.75	0.00	301
L12C	0.00	0.00	0.00	3.51	1.03	869
L12D	0.00	0.00	0.00	0.00	0.00	780
L21A	0.05	0.00	0.00	0.00	0.00	615
L21B	0.00	0.00	0.00	0.00	0.00	985
L21C	0.04	0.00	0.00	1.10	0.00	1536
L21D	0.40	0.00	0.00	1.10	0.00	841
L21E	0.00	0.00	0.00	0.00	1.51	698
L21F	0.00	0.00	0.00	0.00	0.00	555
L22A	0.00	0.00	0.00	0.00	0.00	1007
L22B	0.00	0.00	0.00	0.90	0.00	444
L22C	0.00	0.00	0.00	1.30	0.00	765
L22D	0.00	0.00	0.00	0.00	0.00	600
L23A	0.00	0.00	0.00	0.70	0.00	615
L23B	0.00	0.00	0.00	1.00	0.00	987
L23C	0.00	0.00	0.00	1.10	0.00	1035
L23D	0.00	0.00	0.00	0.00	0.00	661
L30A	0.00	0.00	0.00	0.13	1.98	339
L30B	0.00	0.00	0.00	0.84	0.00	354
L30C	0.00	0.00	0.00	1.88	0.00	222
L30D	0.00	0.00	0.00	0.40	0.00	516
L40A	0.00	0.00	0.00	0.32	0.00	920
L40B	0.00	0.00	0.00	0.27	0.00	595
L50A	0.31	0.00	0.00	0.47	0.00	455
L50B	0.00	0.00	0.00	2.53	0.00	683
L60A	0.00	0.00	0.00	0.05	2.70	763
L60B	0.00	0.00	0.00	0.04	0.00	764
L70A	0.39	0.00	0.00	0.00	0.00	710

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aFCAi AREA UNDER AFFORESTATION	aFINi INDIGENOUS FOREST AREA	aISAi FIELD AREA IRRIGATED	a NAEi URBAN (1) AREAS	oRSUi NUMBER OF LARGE STOCK UNITS
L70B	0.00	0.00	0.00	1.32	2.08	562
L70C	2.96	0.00	0.00	0.73	0.00	845
L70D	0.58	0.00	0.00	1.32	0.00	679
L70E	0.00	0.00	0.00	0.00	0.00	1907
L70F	7.03	0.00	0.00	0.13	0.00	914
L70G	23.12	0.00	0.00	2.20	0.00	1339
L81A	6.37	0.00	0.00	0.71	0.00	340
L81B	14.95	0.00	0.00	0.00	0.00	244
L81C	38.02	0.00	0.00	0.28	0.00	312
L81D	35.25	0.00	0.00	0.42	0.00	311
L82A	83.12	0.53	0.00	5.89	0.00	0
L82B	43.12	1.29	0.00	12.97	0.00	428
L82C	14.74	0.00	0.00	9.66	0.11	797
L82D	17.08	0.00	0.00	12.92	2.01	1331
L82E	14.81	0.00	0.00	6.26	0.00	3095
L82F	11.25	0.00	0.00	2.32	0.00	1935
L82G	12.54	0.00	0.00	3.65	0.00	2884
L82H	4.93	0.00	0.00	3.21	0.00	564
L82J	0.15	0.00	0.00	1.72	0.00	1776
L90A	3.45	0.00	0.00	24.02	0.86	2941
L90B	1.65	28.67	0.00	17.09	3.07	1258
L90C	4.74	59.79	0.00	14.86	0.00	1356
M10A	0.20	0.00	0.00	0.00	0.00	1298
M10B	18.17	33.05	0.00	2.30	0.00	2344
M10C	20.39	1.78	0.00	4.30	25.43	4818
M10D	10.28	0.00	0.00	1.80	41.13	6177
M20A	12.22	0.00	0.00	2.10	124.60	9768
M20B	29.25	25.72	0.00	1.80	0.18	5055
M30A	13.54	0.00	0.00	1.00	0.00	1360
M30B	9.52	0.00	0.00	1.20	4.98	7729
N11A	0.37	0.00	0.00	2.15	0.00	2304
N11B	1.20	0.00	0.00	2.75	0.00	2547
N12A	1.32	0.00	0.00	0.71	0.61	2413
N12B	0.04	0.00	0.00	0.00	0.00	2330
N12C	0.61	0.00	0.00	3.42	0.00	2160
N13A	0.09	0.00	0.00	2.82	0.00	1797
N13B	0.00	0.00	0.00	8.84	0.00	1485
N13C	16.55	0.00	0.00	11.06	9.34	1617
N14A	0.00	0.00	0.00	0.00	0.00	611
N14B	0.05	0.00	0.00	0.00	2.91	467
N14C	0.00	0.00	0.00	0.00	0.00	804
N14D	0.00	0.00	0.00	3.90	0.00	716
N21A	3.45	0.00	0.00	4.97	0.00	1111
N21B	0.00	0.00	0.00	0.84	0.00	1273
N21C	0.00	0.00	0.00	1.27	0.00	1222
N21D	0.00	0.00	0.00	0.34	0.00	1842
N22A	0.00	0.00	0.00	0.55	0.00	648
N22B	0.00	0.00	0.00	0.06	0.00	678
N22C	0.00	0.00	0.00	0.00	0.00	418
N22D	0.00	0.00	0.00	0.00	0.00	378
N22E	0.00	0.00	0.00	2.16	0.00	366
N23A	0.00	0.00	0.00	2.56	0.00	1575
N23B	0.00	0.00	0.00	2.23	0.00	581
N24A	0.00	0.00	0.00	1.16	0.00	803
N24B	0.06	0.00	0.00	2.56	0.00	1194
N24C	0.29	0.00	0.00	1.66	0.06	837
N24D	0.08	0.00	0.00	0.85	1.72	404
N30A	0.17	0.00	0.00	3.00	1.92	1012

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aFCAi AREA UNDER AFFORESTATION	aFINi INDIGENOUS FOREST AREA	aISAi FIELD AREA IRRIGATED	a NAEi URBAN (1) AREAS	oRSUi NUMBER OF LARGE STOCK UNITS
N30B	0.00	0.00	0.00	2.68	0.00	966
N30C	0.00	0.00	0.00	0.81	0.00	939
N40A	0.00	0.00	0.00	0.45	0.00	3586
N40B	0.03	0.00	0.00	5.40	0.52	7030
N40C	1.66	0.00	0.00	42.91	3.05	5784
N40D	1.58	0.00	0.00	23.70	0.01	16396
N40E	0.00	0.00	0.00	35.00	0.28	4266
N40F	7.78	0.00	0.00	18.50	0.38	17449
P10A	5.27	2.14	0.00	0.22	0.00	849
P10B	4.51	0.00	0.00	0.83	0.72	3436
P10C	0.00	0.00	0.00	0.47	0.00	822
P10D	0.26	0.00	0.00	0.94	0.30	2535
P10E	0.78	0.00	0.00	0.77	0.44	9982
P10F	11.20	0.00	0.00	0.77	0.00	7392
P10G	0.41	0.00	0.00	0.55	0.35	8851
P20A	51.10	0.00	0.00	0.00	1.44	12476
P20B	57.19	0.00	0.00	0.00	0.00	9812
P30A	22.12	3.40	0.00	0.53	0.00	1188
P30B	5.49	0.00	0.00	1.19	0.00	4082
P30C	0.38	0.00	0.00	0.20	0.08	1861
P40A	40.11	0.75	0.00	0.06	11.86	3211
P40B	5.62	0.00	0.00	0.03	0.26	6994
P40C	10.98	0.00	0.00	0.06	7.71	9469
P40D	13.51	0.00	0.00	0.03	1.30	6797
Q11A	0.00	0.00	0.00	0.00	0.00	1795
Q11B	0.00	0.00	0.00	1.09	0.00	953
Q11C	0.00	0.00	0.00	0.00	0.00	654
Q11D	0.03	0.00	0.00	4.03	0.00	910
Q12A	0.00	0.00	0.00	0.80	0.00	2735
Q12B	0.15	0.00	0.00	5.07	1.48	3732
Q12C	0.00	0.00	0.00	25.69	0.00	1153
Q13A	0.00	0.00	0.00	2.90	0.49	2347
Q13B	0.00	0.00	0.00	5.79	0.00	1044
Q13C	0.00	0.00	0.00	18.68	0.00	2391
Q14A	0.53	0.00	0.00	6.92	0.00	921
Q14B	3.51	0.00	0.00	6.39	4.07	1340
Q14C	0.00	0.00	0.00	3.44	0.00	1581
Q14D	0.00	0.00	0.00	2.17	0.00	772
Q14E	0.00	0.00	0.00	2.29	0.00	658
Q21A	0.12	0.00	0.00	0.12	0.00	3122
Q21B	1.38	0.00	0.00	6.75	0.00	2065
Q22A	0.11	0.00	0.00	1.79	0.00	1259
Q22B	0.00	0.00	0.00	1.91	0.00	453
Q30A	0.00	0.00	0.00	0.00	0.00	2132
Q30B	0.00	0.00	0.00	2.82	0.00	2628
Q30C	0.08	0.00	0.00	5.72	0.00	2276
Q30D	1.43	0.00	0.00	3.55	1.83	1695
Q30E	7.97	0.00	0.00	17.51	5.57	1779
Q41A	0.00	0.00	0.00	1.93	0.00	1613
Q41B	0.00	0.00	0.00	2.98	0.00	2884
Q41C	0.00	0.00	0.00	0.33	0.81	2226
Q41D	0.00	0.00	0.00	0.40	0.00	1714
Q42A	0.00	0.00	0.00	0.25	0.00	2934
Q42B	0.00	0.00	0.00	0.28	0.00	2511
Q43A	0.00	0.00	0.00	2.10	0.00	1595
Q43B	0.00	0.00	0.00	1.23	0.00	4198
Q44A	0.00	0.00	0.00	3.24	0.00	2324
Q44B	0.00	0.00	0.00	2.81	0.00	2355

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aFCAi AREA UNDER AFFORESTATION	aFINi INDIGENOUS FOREST AREA	aISAi FIELD AREA IRRIGATED	a NAEi URBAN (1) AREAS	oRSUi NUMBER OF LARGE STOCK UNITS
Q44C	0.14	0.00	0.00	8.15	0.00	1388
Q50A	3.48	0.00	0.00	21.42	0.00	3557
Q50B	0.00	0.00	0.00	9.59	0.00	1569
Q50C	0.00	0.00	0.00	12.17	0.00	1026
Q60A	0.00	0.00	0.00	0.33	0.00	2470
Q60B	0.00	0.00	0.00	0.00	0.00	2891
Q60C	0.04	0.00	0.00	0.31	0.00	1029
Q70A	0.79	0.00	0.00	7.94	0.87	1670
Q70B	2.66	0.00	0.00	28.99	0.67	2299
Q70C	0.00	0.00	0.00	5.36	0.00	1265
Q80A	0.00	0.00	0.00	2.87	0.00	1034
Q80B	0.37	0.00	0.00	2.67	0.00	1893
Q80C	0.00	0.00	0.00	1.20	0.00	822
Q80D	0.88	0.00	0.00	8.90	4.52	1225
Q80E	0.32	0.00	0.00	17.44	0.00	1068
Q80F	0.00	0.00	0.00	7.48	0.00	2032
Q80G	0.00	0.00	0.00	6.97	0.00	817
Q91A	0.00	0.00	0.00	1.74	0.00	3493
Q91B	0.00	0.00	0.00	3.33	0.00	3478
Q91C	6.55	0.00	0.00	4.34	0.49	3277
Q92A	0.53	0.00	0.00	4.50	0.00	3210
Q92B	0.00	0.00	1.43	5.00	0.00	4478
Q92C	0.00	0.00	0.68	4.57	0.67	7523
Q92D	0.71	3.06	2.17	1.62	0.86	2920
Q92E	0.00	0.00	0.00	2.61	0.63	3674
Q92F	0.00	0.00	0.00	0.83	1.49	5317
Q92G	0.00	0.00	0.00	0.49	0.00	7663
Q93A	0.00	0.00	0.00	0.43	0.00	2402
Q93B	5.50	0.00	0.00	0.87	0.00	2554
Q93C	1.52	0.00	0.00	1.38	2.09	698
Q93D	8.88	0.00	0.00	0.67	0.00	9181
Q94A	9.42	3.56	5.38	0.09	0.00	592
Q94B	2.33	11.62	8.10	0.00	0.00	
Q94C	5.82	30.03	5.43	0.47	0.00	830
Q94D	0.00	3.38	3.55	6.28	0.00	595
Q94E	4.21	24.73	9.09	0.00	0.00	1522
Q94F	0.00	0.00	0.77	6.68	2.72	5278
TOTALS	939.41	417.58	65.39	697.17	300.60	466581

(1) These are urban areas derived from 1:50 000 scale maps and do not include the smallholdings and rural villages included in Table 3.5.1.1 of Volume 1.

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX D.2

CONVERSION OF MATURE LIVESTOCK AND GAME POPULATIONS TO EQUIVALENT LARGE STOCK UNITS (ELSU)

SPECIES	GROUP *	NUMBER PER ELSU
Livestock :		
Cattle	L	0,85
Sheep	S	6,5
Goats	S	5,8
Horses	L	1
Donkeys / mules	S	1,1
Pigs	S	4
Game :		
Black Wildebeest	LA	3,3
Blesbuck	SA	5,1
Blou Wildebeest	LA	2,4
Buffalo	BG	1
Eland	BG	1
Elephant	BG	0,3
Gemsbok	LA	2,2
Giraffe	BG	0,7
Hippopotamus	BG	0,4
Impala	SA	7
Kudu	LA	2,2
Nyala	SA	3,3
Ostrich	--	2,7
Red Hartebeest	LA	2,8
Roan Antelope	LA	2
Sable Antelope	LA	2
Southern Reedbuck	SA	7,7
Springbok	SA	10,3
Tsessebe	LA	2,8
Warthog	O	5
Waerbuck	SA	2,4
Rhinoceros	BG	0,4
Zebra	O	1,6

* Groups (in terms of water consumption :
L = cattle and horses; S = small livestock; LA = large antelope; SA = small antelope; BG = big game;
O = other game.

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX D.3

TREE SPECIES IN COMMERCIAL FORESTS PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	aFCAi AREA UNDER AFFORESTATION km²	SPECIES
K80A	39.38	Eucalyptus (1%) & Pine (99%)
K80B	45.30	Pine
K80C	51.00	Eucalyptus (2%) & Pine (98%)
K80D	25.53	Pine
K80E	20.48	Eucalyptus (4%) & Pine (96%)
K80F	0.00	
K90A	0.00	
K90B	0.53	Pine
K90C	0.00	
K90D	0.02	Pine
K90E	0.00	
K90F	1.84	Pine
K90G	0.00	
L11A	0.00	
L11B	0.00	
L11C	0.00	
L11D	0.00	
L11E	0.00	
L11F	0.00	
L11G	0.00	
L12A	0.00	
L12B	0.00	
L12C	0.00	
L12D	0.00	
L21A	0.00	
L21B	0.00	
L21C	0.00	
L21D	0.00	
L21E	0.00	
L21F	0.00	

QUATERNARY CATCHMENT	aFCAi AREA UNDER AFFORESTATION km²	SPECIES
L22A	0.00	
L22B	0.00	
L22C	0.00	
L22D	0.00	
L23A	0.00	
L23B	0.00	
L23C	0.00	
L23D	0.00	
L30A	0.00	
L30B	0.00	
L30C	0.00	
L30D	0.00	
L40A	0.00	
L40B	0.00	
L50A	0.00	
L50B	0.00	
L60A	0.00	
L60B	0.00	
L70A	0.00	
L70B	0.00	
L70C	0.00	
L70D	0.00	
L70E	0.00	
L70F	0.00	
L70G	0.00	
L81A	0.00	
L81B	0.00	
L81C	0.00	
L81D	0.00	
L82A	0.53	Pine
L82B	1.29	Pine
L82C	0.00	
L82D	0.00	
L82E	0.00	
L82F	0.00	
L82G	0.00	

QUATERNARY CATCHMENT	aFCAi	SPECIES
	AREA UNDER AFFORESTATION	
	km²	
L82H	0.00	
L82J	0.00	
L90A	0.00	
L90B	28.67	Pine
L90C	59.79	Eucalyptus (1%) & Pine (99%)
M10A	0.00	
M10B	33.05	Pine
M10C	1.78	Eucalyptus (5%) & Pine (95%)
M10D	0.00	
M20A	0.00	
M20B	25.72	Eucalyptus (7%) , Pine (90%) and Wattle (3%)
M30A	0.00	
M30B	0.00	
N11A	0.00	
N11B	0.00	
N12A	0.00	
N12B	0.00	
N12C	0.00	
N13A	0.00	
N13B	0.00	
N13C	0.00	
N14A	0.00	
N14B	0.00	
N14C	0.00	
N14D	0.00	
N21A	0.00	
N21B	0.00	
N21C	0.00	
N21D	0.00	
N22A	0.00	
N22B	0.00	
N22C	0.00	
N22D	0.00	
N22E	0.00	
N23A	0.00	

QUATERNARY CATCHMENT	aFCAi AREA UNDER AFFORESTATION km²	SPECIES
N23B	0.00	
N24A	0.00	
N24B	0.00	
N24C	0.00	
N24D	0.00	
N30A	0.00	
N30B	0.00	
N30C	0.00	
N40A	0.00	
N40B	0.00	
N40C	0.00	
N40D	0.00	
N40E	0.00	
N40F	0.00	
P10A	2.14	Pine
P10B	0.00	
P10C	0.00	
P10D	0.00	
P10E	0.00	
P10F	0.00	
P10G	0.00	
P20A	0.00	
P20B	0.00	
P30A	3.40	Pine
P30B	0.00	
P30C	0.00	
P40A	0.75	Pine
P40B	0.00	
P40C	0.00	
P40D	0.00	
Q11A	0.00	
Q11B	0.00	
Q11C	0.00	
Q11D	0.00	
Q12A	0.00	

QUATERNARY CATCHMENT	aFCAi AREA UNDER AFFORESTATION km²	SPECIES
Q12B	0.00	
Q12C	0.00	
Q13A	0.00	
Q13B	0.00	
Q13C	0.00	
Q14A	0.00	
Q14B	0.00	
Q14C	0.00	
Q14D	0.00	
Q14E	0.00	
Q21A	0.00	
Q21B	0.00	
Q22A	0.00	
Q22B	0.00	
Q30A	0.00	
Q30B	0.00	
Q30C	0.00	
Q30D	0.00	
Q30E	0.00	
Q41A	0.00	
Q41B	0.00	
Q41C	0.00	
Q41D	0.00	
Q42A	0.00	
Q42B	0.00	
Q43A	0.00	
Q43B	0.00	
Q44A	0.00	
Q44B	0.00	
Q44C	0.00	
Q50A	0.00	
Q50B	0.00	
Q50C	0.00	
Q60A	0.00	
Q60B	0.00	

QUATERNARY CATCHMENT	aFCAi	SPECIES
	AREA UNDER AFFORESTATION	
	km²	
Q60C	0.00	
Q70A	0.00	
Q70B	0.00	
Q70C	0.00	
Q80A	0.00	
Q80B	0.00	
Q80C	0.00	
Q80D	0.00	
Q80E	0.00	
Q80F	0.00	
Q80G	0.00	
Q91A	0.00	
Q91B	0.00	
Q91C	0.00	
Q92A	0.00	
Q92B	0.00	Pine
Q92C	0.00	Pine
Q92D	3.06	Pine
Q92E	0.00	
Q92F	0.00	
Q92G	0.00	
Q93A	0.00	
Q93B	0.00	
Q93C	0.00	
Q93D	0.00	
Q94A	3.56	Pine (68%) and Wattle (32%)
Q94B	11.62	Pine
Q94C	30.03	Pine
Q94D	3.38	Eucalyptus (29%) & Pine (71%)
Q94E	24.73	Pine
Q94F	0.00	

APPENDIX E

WATER RELATED INFRASTRUCTURE

APPENDIX E.1	**Existing water supply schemes.**
APPENDIX E.2	**Main dams.**
APPENDIX E.3	**Farm dam data per quaternary catchment.**

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX E.1

EXISTING POTABLE WATER SUPPLY SCHEMES

SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED	WATER REQUIRED IN 1995 [2] (10^6 m³/a)	SCHEME CAPACITY			CATCH-MENT NO.
				10^6 m³/a	ℓ/c/d	Limiting Factor [1]	
Aberdeen	Boreholes	5 950	0,27	> 0,27	124	Borehole yield	N14B
Addo	Sundays River Irrigation Board	5 900	0,48	0,50	232	Treatment works	N40E
Adelaide	Koonap River	16 500	0,67	0,40	68	Source	Q92C
Alexandra	Sand dunes, boreholes	12 100	0,94	0,40	90	Sources	P20A
Albany Coast	Boreholes, sand dunes	16 300	1,12	1,20	202	Source	P10G, P20A
Algoa Scheme	Bulk River Dam, Sand River Dam, Van Stadens Dams, Loerie Dam, Churchill Dam, Impofu Dam, boreholes, springs, Gariep Dam via Fish/Sundays Rivers	1 050 000	72,0	102,1	266	Sources	K90A to G, L81A to D, L82B to H, M10A to D, M20A to D, M30B
Alicedale	Nuwejaars Dam	5 950	0,17	0,35	161	Treatment works	P10B, P10D
Bedford	Dam, mountain streams, boreholes, Fish River	10 200	0,47	0,60	161	Treatment works	Q92F
Boknes	Boreholes	250	0,04	>0,04	> 438	Borehole yield	P20A
Bushman's River Mouth	Albany Coast Scheme	Included under Albany Coast Scheme	--	--	--	--	P10G
Cannon Rocks	Boreholes	250	0,04	>0,04	> 438	Borehole yield	P20A
Cannonvale	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	N40F
Colchester	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	N40F
Cookhouse	Fish-Sundays Canal	5 200	0,30	0,48	253	Treatment works	Q70A
Cradock	Fish River	28 600	3,8	4,6	664	Treatment works	Q30E
Despatch	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	M10D
Enon	Sundays River Irrigation Board	1 000	0,10	0,17	466	Treatment works	N40C
Fort Beaufort	Kat River Dam	23 400	2,07	1,36	160	Treatment works	Q94F
Graaff-Reinet	Van Ryneveld Pass Dam Mimosadale Wellfield	34 100	2,67	5,2	418	Treatment works	N12C, N13A, N13C
Grahamstown	Settlers Dam, Howiesons Poort Dam, Fish River	59 400	5,75	4,7	217	Treatment works	P10A, P30A, P40A, Q99B
Hankey	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	L90B
Hofmeyr	Boreholes	2 850	0,19	<0,19	< 182	Borehole yield	Q13A
Humansdorp	Boreholes, Algoa Scheme	Included under Algoa scheme	--	--	--	--	K90F
Jansenville	Boreholes	4 700	0,27	> 0,27	> 157	--	N24D

SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED	WATER REQUIRED IN 1995 (2) (10^6 m^3/a)	SCHEME CAPACITY			CATCH-MENT NO.
				10^6 m^3/a	ℓ/c/d	Limiting Factor (1)	
Jeffrey's Bay	Boreholes, Algoa Scheme	Included under Algoa Scheme	--	--	--	--	K90G
Joubertina	Joubertina Dam	4 650	0,19	0,19	112	Treatment works	L82D
Kareedouw	Boreholes	2 250	0,25	>0,25	> 304	Borehole yield	K90B
Kenton-on-Sea	Albany Coast Scheme	Included under Albany Coast Scheme	--	--	--	--	P30C
Kirkwood	Sundays River Irrigation Board	10 800	0,83	0,67	170	Treatment works	N40B, N40C
Klipplaat	Klipfontein Dam	3 650	0,29	0,12	90	Treatment works	L60A
Loerie	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	L90C
Middleburg	Boreholes	17 400	2,4	> 2,4	> 378	Borehole yield	Q14B
Nieu Bethesda	Boreholes	1 450	0,10	>0,10	> 189	Borehole yield	N12A
Oesterbaai	Boreholes	1 800	0,24	<0,24	< 365	Borehole yield	K80F
Paradise Beach	Boreholes/Algoa Scheme	Included under Algoa Scheme	--	--	--	--	K90F
Patensie	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	L90A
Paterson	Boreholes	3 250	0,12	0,14	118	Borehole yield	P10E
Pearston	Boreholes	3 700	0,11	0,11	81	Borehole yield	N30A
Peddie	Nkwekaze Dam, Keiskamma River	15 100	0,35	1,9	344	Treatment works	Q93C
Port Alfred	Mansfield Dam, Sarel Hayward Dam, sand dunes	22 000	1,10	1,9	237	Treatment works	P40C
Port Elizabeth	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	M20D
Riebeeck Oos	Boreholes	700	0,01	> 0,01	> 39	Borehole yield	P10B
St Francis Bay	Boreholes/Algoa Scheme	Included under Algoa scheme	--	--	--	--	K90E
Seymour	Kat River Dam	2 700	0,15	0,22	102	Treatment works	Q94A
Somerset East	30 small dams, springs boreholes, Fish-Sundays Canal	16 500	1,14	1,5	249	Treatment works	Q80D
Steytlerville	Boreholes	3 400	0,13	0,13	105	Borehole yield	L70B
Tarkastad	Boreholes	5 400	0,10	> 0,10	> 51	Borehole yield	Q41C
Uitenhage	Algoa Scheme	Included under Algoa Scheme	--	--	--	--	M10C
Willowmore	Boreholes	6 550	0,25	> 0,25	> 105	Borehole yield	L30A
TOTALS		1 403 950	99,11	> 133,1	> 260	--	--

(1) Treatment work capacity assumed to be (peak design capacity)/1,25.
(2) From WSAM database.

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA
APPENDIX E.2: MAIN DAMS

NAME	LIVE CAPACITY (million m^3)	YIELD *				OWNER	CATCHMENT NO.	NOTES	SOURCE OF DATA
		DOMESTIC SUPPLIES (million m^3/a)	IRRIGATION (million m^3/a)	OTHER (million m^3/a)	TOTAL (million m^3/a)				
Grassridge	49,60	0	Balancing dam	0	0	DWAF	Q13A	Operating capacity is 45% of FSC, i.e. 22,3 million m^3 because of dam safety (spillway) requirements.	Hydrology and System Analysis - Eastern Cape Rivers - ORRS Sept 1997 DWAF Report No. P Q000/00/0597.
Commando Drift	55,7	0	7	0	7	DWAF	Q41D	1:20 yield 8,8 million m^3/a (From WR90 curves, equivalent 1:50 year yield is 7,3 million m^3/a)	1:20 year yield calculation by DWAF Eastern Cape Region.
Lake Arthur	10,95	0	Negligible	0	0	Great Fish Irrigation Board	Q44B	Average depth when full is 2,0 m, and 1,4 m when half full.	
Kat River	24,8	1,68	11	0	12,68	DWAF	Q94A	Assurance of yield not known.	Ciskei National Water Development Plan. HKS 1991.
Elandsdrift Weir	9,7	0	Diversion weir	0	0	DWAF	Q50B		
De Mistkraal Weir	3,1	0	Diversion weir	0	0	DWAF	Q80E		
Hermanuskraal Weir	1,2	0	Diversion weir	0	0	DWAF	Q91C		
Glen Melville	6,13	Balancing dam	0	0	0	DWAF	Q93B		
Glen Boyd	0,15	Balancing dam	0	0	0	DWAF	Q93B		
Nuwejaars	4,5	2,1	0	0	2,1	Alicedale TLC	P10B	1:10 year yield 3,28 million m^3/a (From WR90 curves, equivalent 1:50 year yield is 2,1 million m^3/a)	Van Wyk Louw, 1991 : Report to Regional Services Council.
Howiesons Poort Settlers	0,8 5,57	2,2	0,9	0	3,1	Grahamstown TLC	P30A P30B	Yield includes yields of Jameson Dam 0,46 million m^3/a capacity and Milner Dam 0,19 million m^3/a capacity. Assurance not known.	Van Wyk Louw, 1991 : Report to Regional Services Council.
Sarel Hayward ***	2,5	1,6	0	0	1,6	Port Alfred TLC	P40B	Water pumped from Kowrie River. Yield includes yield of Mansfield Dam (0,2 million m^3 capacity) and allows for flushing to improve water quality	Ninham Shand, 1987 : Report to Port Alfred Municipality.
Van Rynevelds Pass	47	3,3	1,2	0	4,5	Van Rynevelds Pass Irrigation Board	N12C	Capacity measured in 1998. 1:50 year yield but uncertainty regarding effects of farm dams upstream. Irrigation allocation bought by Graaff-Reinet.	Ninham Shand Files, 1999.
De Hoop	16	0	Negligible	0	0	Private	N14D	Thought to be silted up - no data found.	
Darlington	187	0	-	0	-	DWAF	N23B	Operating capacity is 21% of FSC, i.e. 39 million m^3 because of dam safety (spillway) requirements. Historical firm yield at full capacity is 28 million m^3/a.	Estimated by DWAF Eastern Cape Region
Koorhaansdrift Weir		0	Diversion weir	0	0	DWAF	N40A		
Groendal	12,3	4,1	2,4	0	6,50	Uitenhage TLC	M10A	1:50 year yield from stochastic analysis	Algoa Stochastic Analysis Report No. PM 000/00/0295.
Sand River Bulk River Van Stadens	2,67 0,65 0,37	3,3	0	0	3,3	Port Elizabeth TLC	M10B M10B L90C	1:50 year yield from stochastic analysis	Algoa Stochastic Analysis Report No. PM 000/00/0295.
Loerie Kouga	3,17 128	23,5	52	0	75,5	DWAF DWAF	L90C L82H	1:50 year yield from stochastic analysis	Algoa Stochastic Analysis Report No. PM 000.00/0295.
Klipfontein	1,8	0,83	0	0	0,83	Klipplaat TLC	L60A	Historical firm yield. Assurance not known.	Ninham Shand Files.
Beervlei	90	0	12	0	12	DWAF	L30C	1:50 year yield	DWAF Eastern Cape Region
Churchill Impofu	32,0 87,0	42,4	0	2,0	44,4	Port Elizabeth DWAF	K90B K90D	1:50 year yield from stochastic analysis.	Algoa Stochastic Analysis Report No. PM 000/00/0295.
Klippedrift	3	0	2,5	0	2,5	Klippedrift Irrigation Board	K80F	1:10 year yield 3,5 million m^3/a (From WR90 curves, equivalent 1;50 year yield is 2,5 million m^3/a).	Van Wyk and Louw, 1991 : Report to Regional Services Council
Joubertina	0,21	Not known	0	0	0	Joubertina TLC	L82D		
Haarlem	4,7	0,2	3,6	0	3,8	Haarlem Irrigation Board	L82A	Design yield of 4,5 million m^3/a at 1:10 year assurance (From WR90 curves, equivalent 1:50 year yield is 3,8 million m^3/a)	Ninham Shand Files, 1989.

* Approximately 1:50 year unless otherwise indicated
*** Off-channel dam

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX E.3

FARM DAM DATA
PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	oDISi	aDMIi	oDIEo
	FULL SUPPLY CAPACITY (million m^3)	**FULL SUPPLY AREA (km^2)**	**EVAPORATION LOSSES (million m^3)**
K80A	0.00	0.00	0.00
K80B	0.10	0.04	0.02
K80C	0.11	0.04	0.02
K80D	0.53	0.17	0.09
K80E	5.02	1.64	0.91
K80F	4.09	0.71	0.44
K90A	0.19	0.04	0.03
K90B	0.00	0.00	0.00
K90C	0.55	0.11	0.09
K90D	0.56	0.11	0.08
K90E	0.37	0.08	0.06
K90F	2.56	0.90	0.61
K90G	0.82	0.22	0.17
L11A	1.88	0.72	1.19
L11B	0.00	0.00	0.00
L11C	0.11	0.12	0.20
L11D	0.75	0.15	0.25
L11E	0.00	0.00	0.00
L11F	0.61	0.47	0.83
L11G	0.00	0.00	0.00
L12A	4.01	1.73	3.16
L12B	0.00	0.00	0.00
L12C	0.56	0.27	0.48
L12D	1.83	0.78	1.35
L21A	0.20	0.13	0.21
L21B	0.00	0.00	0.00
L21C	0.75	0.77	1.16
L21D	1.07	0.55	0.78
L21E	0.25	0.13	0.20
L21F	0.00	0.00	0.00

QUATERNARY CATCHMENT	oDISi	aDMIi	oDIEo
	FULL SUPPLY CAPACITY (million m^3)	**FULL SUPPLY AREA (km^2)**	**EVAPORATION LOSSES (million m^3)**
L22A	0.50	0.25	0.41
L22B	1.78	1.00	1.69
L22C	0.00	0.00	0.00
L22D	0.25	1.00	1.53
L23A	1.10	0.43	0.75
L23B	0.00	0.00	0.00
L23C	0.00	0.00	0.00
L23D	0.00	0.00	0.00
L30A	2.79	0.41	0.60
L30B	0.70	0.36	0.59
L30C	0.00	0.00	0.00
L30D	0.00	0.00	0.00
L40A	0.00	0.00	0.00
L40B	0.00	0.00	0.00
L50A	1.18	0.22	0.30
L50B	0.13	0.04	0.06
L60A	1.81	0.31	0.46
L60B	0.00	0.00	0.00
L70A	0.00	0.00	0.00
L70B	0.00	0.00	0.00
L70C	0.00	0.00	0.00
L70D	0.24	0.09	0.11
L70E	0.04	0.01	0.01
L70F	0.00	0.00	0.00
L70G	0.00	0.00	0.00
L81A	0.00	0.00	0.00
L81B	0.00	0.00	0.00
L81C	0.00	0.00	0.00
L81D	0.00	0.00	0.00
L82A	6.06	0.77	0.74
L82B	1.97	0.42	0.38
L82C	3.79	0.62	0.53
L82D	1.35	0.37	0.33
L82E	0.00	0.00	0.00
L82F	0.00	0.00	0.00
L82G	0.00	0.00	0.00

QUATERNARY CATCHMENT	oDISi FULL SUPPLY CAPACITY (million m^3)	aDMIi FULL SUPPLY AREA (km^2)	oDIEo EVAPORATION LOSSES (million m^3)
L82H	0.00	0.00	0.00
L82J	0.00	0.00	0.00
L90A	0.00	0.00	0.00
L90B	0.09	0.02	0.02
L90C	0.18	0.05	0.04
M10A	0.00	0.00	0.00
M10B	0.65	0.07	0.07
M10C	0.00	0.00	0.00
M10D	0.00	0.00	0.00
M20A	0.00	0.00	0.00
M20B	0.57	0.14	0.11
M30A	0.00	0.00	0.00
M30B	0.00	0.00	0.00
N11A	1.28	0.30	0.39
N11B	2.45	0.50	0.67
N12A	0.19	0.16	0.21
N12B	0.00	0.00	0.00
N12C	0.00	0.00	0.00
N13A	0.83	0.17	0.23
N13B	0.24	0.08	0.11
N13C	0.00	0.00	0.00
N14A	0.00	0.00	0.00
N14B	0.00	0.00	0.00
N14C	1.48	0.52	0.59
N14D	0.00	0.00	0.00
N21A	0.26	0.08	0.11
N21B	0.19	0.06	0.07
N21C	2.37	0.69	0.92
N21D	0.00	0.00	0.00
N22A	0.04	0.01	0.01
N22B	0.00	0.00	0.00
N22C	0.00	0.00	0.00
N22D	0.00	0.00	0.00
N22E	0.00	0.00	0.00
N23A	0.00	0.00	0.00
N23B	0.00	0.00	0.00

QUATERNARY CATCHMENT	oDISi	aDMIi	oDIEo
	FULL SUPPLY CAPACITY (million m³)	FULL SUPPLY AREA (km²)	EVAPORATION LOSSES (million m³)
N24A	0.24	0.05	0.07
N24B	0.36	0.19	0.26
N24C	0.19	0.06	0.08
N24D	0.00	0.00	0.00
N30A	0.24	0.09	0.11
N30B	0.00	0.00	0.00
N30C	0.00	0.00	0.00
N40A	0.00	0.00	0.00
N40B	0.28	0.09	0.11
N40C	0.47	0.11	0.12
N40D	0.82	0.13	0.13
N40E	0.12	0.04	0.04
N40F	0.00	0.00	0.00
P10A	1.56	0.43	0.37
P10B	0.56	0.16	0.15
P10C	0.06	0.07	0.08
P10D	0.21	0.06	0.06
P10E	0.00	0.00	0.00
P10F	0.82	0.19	0.17
P10G	0.08	0.02	0.02
P20A	0.00	0.00	0.00
P20B	0.00	0.00	0.00
P30A	1.38	0.31	0.26
P30B	11.92	3.31	2.86
P30C	0.00	0.00	0.00
P40A	0.89	0.20	0.16
P40B	0.60	0.16	0.14
P40C	0.41	0.13	0.10
P40D	0.32	0.04	0.03
Q11A	0.12	0.01	0.01
Q11B	0.00	0.00	0.00
Q11C	0.00	0.00	0.00
Q11D	0.00	0.00	0.00
Q12A	1.20	0.46	0.55
Q12B	0.00	0.00	0.00
Q12C	0.00	0.00	0.00

QUATERNARY CATCHMENT	oDISi FULL SUPPLY CAPACITY (million m³)	aDMIi FULL SUPPLY AREA (km²)	oDIEo EVAPORATION LOSSES (million m³)
Q13A	0.00	0.00	0.00
Q13B	0.00	0.00	0.00
Q13C	0.06	0.06	0.08
Q14A	0.00	0.00	0.00
Q14B	0.15	0.06	0.08
Q14C	1.79	0.35	0.46
Q14D	0.00	0.00	0.00
Q14E	0.32	0.09	0.12
Q21A	0.58	0.16	0.21
Q21B	0.12	0.04	0.05
Q22A	0.00	0.00	0.00
Q22B	0.00	0.00	0.00
Q30A	0.00	0.00	0.00
Q30B	0.10	0.03	0.04
Q30C	0.11	0.02	0.03
Q30D	0.08	0.04	0.05
Q30E	0.10	0.12	0.15
Q41A	0.35	0.15	0.16
Q41B	1.40	0.40	0.45
Q41C	0.06	0.03	0.03
Q41D	0.00	0.00	0.00
Q42A	0.21	0.02	0.02
Q42B	0.00	0.00	0.00
Q43A	0.45	0.10	0.12
Q43B	0.00	0.00	0.00
Q44A	0.00	0.00	0.00
Q44B	0.00	0.00	0.00
Q44C	0.00	0.00	0.00
Q50A	0.00	0.00	0.00
Q50B	0.12	0.02	0.02
Q50C	0.00	0.00	0.00
Q60A	0.24	0.09	0.10
Q60B	0.00	0.00	0.00
Q60C	0.00	0.00	0.00
Q70A	0.09	0.02	0.02
Q70B	0.06	0.02	0.02

QUATERNARY CATCHMENT	oDISi	aDMIi	oDIEo
	FULL SUPPLY CAPACITY (million m^3)	FULL SUPPLY AREA (km^2)	EVAPORATION LOSSES (million m^3)
Q70C	0.92	0.23	0.27
Q80A	0.00	0.00	0.00
Q80B	0.61	0.30	0.37
Q80C	0.00	0.00	0.00
Q80D	0.41	0.13	0.15
Q80E	0.00	0.00	0.00
Q80F	0.00	0.00	0.00
Q80G	0.36	0.15	0.17
Q91A	0.66	0.26	0.28
Q91B	0.40	0.22	0.22
Q91C	0.71	0.23	0.22
Q92A	0.09	0.04	0.04
Q92B	0.00	0.00	0.00
Q92C	1.15	0.36	0.36
Q92D	1.82	0.27	0.25
Q92E	0.00	0.00	0.00
Q92F	0.48	0.22	0.24
Q92G	0.42	0.14	0.14
Q93A	0.00	0.00	0.00
Q93B	0.61	0.17	0.16
Q93C	0.23	0.04	0.04
Q93D	0.54	0.15	0.12
Q94A	0.00	0.00	0.00
Q94B	0.00	0.00	0.00
Q94C	0.00	0.00	0.00
Q94D	0.00	0.00	0.00
Q94E	0.44	0.20	0.18
Q94F	0.00	0.00	0.00
TOTALS	100.52	30.27	35.65

APPENDIX F

WATER REQUIREMENTS

APPENDIX F.1	**Urban water requirements per quaternary catchment.**
APPENDIX F.2	**Rural water requirements per quaternary catchment.**
APPENDIX F.3	**Bulk water requirements per quaternary catchment.**
APPENDIX F.4	**Irrigation water requirements per quaternary catchment.**
APPENDIX F.5	**Streamflow reduction activity water requirements per quaternary catchment.**
APPENDIX F.6	**Notes on proceedings of the workshops on ecological flow requirements.**
APPENDIX F.7	**Assumed rural domestic per capita requirements**

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX F.1

URBAN WATER REQUIREMENTS PER QUATERNARY CATCHMENT

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
K80A		1.16	0.00	0	0.00	0.00	0.00		0.00
K80B		0.02	0.00	250	0.01	0.00	0.01		0.01
K80C		0.00	0.00	0	0.00	0.00	0.00		0.00
K80D		0.00	0.00	0	0.00	0.00	0.00		0.00
K80E		0.00	0.00	0	0.00	0.00	0.00		0.00
K80F		0.24	0.04	1800	0.11	0.06	0.10		0.06
K90A		0.00	0.00	0	0.00	0.00	0.00		0.00
K90B		0.25	0.05	2250	0.14	0.05	0.10		0.06
K90C		0.00	0.00	0	0.00	0.00	0.00		0.00
K90D		0.00	0.00	0	0.00	0.00	0.00		0.00
K90E		0.00	0.06	0	0.00	0.00	0.00		0.00
K90F		0.00	0.44	19600	0.50	0.35	0.48		0.29
K90G		1.34	0.25	10800	0.64	0.35	0.61		0.33
L11A		0.00	0.00	0	0.00	0.00	0.00		0.00
L11B		0.00	0.00	0	0.00	0.00	0.00		0.00
L11C		0.00	0.00	0	0.00	0.00	0.00		0.00
L11D		0.00	0.00	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
Areas		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
L11E		0.00	0.03	0	0.00	0.00	0.00		0.00
L11F		0.00	0.00	0	0.00	0.00	0.00		0.00
L11G		0.00	0.00	0	0.00	0.00	0.00		0.00
L12A		0.00	0.00	0	0.00	0.00	0.00		0.00
L12B		0.00	0.00	0	0.00	0.00	0.00		0.00
L12C		0.04	0.02	700	0.02	0.01	0.01		0.01
L12D		0.00	0.00	0	0.00	0.00	0.00		0.00
L21A		0.00	0.00	0	0.00	0.00	0.00		0.00
L21B		0.00	0.00	0	0.00	0.00	0.00		0.00
L21C		0.00	0.00	0	0.00	0.00	0.00		0.00
L21D		0.00	0.00	0	0.00	0.00	0.00		0.00
L21E		0.00	0.04	0	0.00	0.00	0.00		0.00
L21F		0.29	0.00	3900	0.16	0.06	0.09		0.07
L22A		0.00	0.00	0	0.00	0.00	0.00		0.00
L22B		0.00	0.00	0	0.00	0.00	0.00		0.00
L22C		0.00	0.00	0	0.00	0.00	0.00		0.00
L22D		0.00	0.00	0	0.00	0.00	0.00		0.00
L23A		0.00	0.00	0	0.00	0.00	0.00		0.00
L23B		0.00	0.00	0	0.00	0.00	0.00		0.00
L23C		0.00	0.00	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
L23D		0.00	0.00	0	0.00	0.00	0.00		0.00
L30A		0.25	0.06	6550	0.14	0.05	0.10		0.06
L30B		0.00	0.00	0	0.00	0.00	0.00		0.00
L30C		0.00	0.00	0	0.00	0.00	0.00		0.00
L30D		0.00	0.00	0	0.00	0.00	0.00		0.00
L40A		0.00	0.00	0	0.00	0.00	0.00		0.00
L40B		0.00	0.00	0	0.00	0.00	0.00		0.00
L50A		0.00	0.00	0	0.00	0.00	0.00		0.00
L50B		0.00	0.00	0	0.00	0.00	0.00		0.00
L60A		0.29	0.06	3650	0.15	0.06	0.09		0.07
L60B		0.00	0.00	0	0.00	0.00	0.00		0.00
L70A		0.00	0.00	0	0.00	0.00	0.00		0.00
L70B		0.13	0.05	3400	0.07	0.02	0.04		0.03
L70C		0.00	0.00	0	0.00	0.00	0.00		0.00
L70D		0.00	0.00	0	0.00	0.00	0.00		0.00
L70E		0.00	0.00	0	0.00	0.00	0.00		0.00
L70F		0.00	0.00	0	0.00	0.00	0.00		0.00
L70G		0.00	0.00	0	0.00	0.00	0.00		0.00
L81A		0.00	0.00	0	0.00	0.00	0.00		0.00
L81B		0.00	0.00	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
L81C		0.00	0.00	0	0.00	0.00	0.00		0.00
L81D		0.00	0.00	0	0.00	0.00	0.00		0.00
L82A		0.15	0.00	1950	0.08	0.03	0.05		0.04
L82B		0.00	0.00	0	0.00	0.00	0.00		0.00
L82C		0.12	0.01	1000	0.06	0.02	0.06		0.03
L82D		0.56	0.11	4650	0.30	0.11	0.26		0.14
L82E		0.00	0.00	0	0.00	0.00	0.00		0.00
L82F		0.00	0.00	0	0.00	0.00	0.00		0.00
L82G		0.00	0.00	0	0.00	0.00	0.00		0.00
L82H		0.00	0.00	0	0.00	0.00	0.00		0.00
L82J		0.00	0.00	0	0.00	0.00	0.00		0.00
L90A		0.29	0.04	4000	0.16	0.06	0.12		0.07
L90B		0.65	0.15	9200	0.35	0.13	0.20		0.16
L90C		0.10	0.00	1350	0.05	0.02	0.04		0.02
M10A		0.00	0.00	0	0.00	0.00	0.00		0.00
M10B		0.00	0.00	0	0.00	0.00	0.00		0.00
M10C		15.14	1.28	182500	5.00	1.80	4.80		2.30
M10D		3.29	1.94	23600	11.40	8.00	1.20		6.60
M20A		51.56	7.76	809800	15.00	10.30	29.50		8.60
M20B		0.00	0.01	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
M30A		0.00	0.00	0	0.00	0.00	0.00		0.00
M30B		0.00	0.22	0	0.00	0.00	0.00		0.00
N11A		0.00	0.00	0	0.00	0.00	0.00		0.00
N11B		0.00	0.00	0	0.00	0.00	0.00		0.00
N12A		0.10	0.02	1450	0.06	0.02	0.03		0.03
N12B		0.00	0.00	0	0.00	0.00	0.00		0.00
N12C		0.00	0.00	0	0.00	0.00	0.00		0.00
N13A		0.00	0.00	0	0.00	0.00	0.00		0.00
N13B		0.00	0.00	0	0.00	0.00	0.00		0.00
N13C		2.67	0.29	34100	1.15	0.81	1.23		0.67
N14A		0.00	0.00	0	0.00	0.00	0.00		0.00
N14B		0.27	0.08	5950	0.15	0.05	0.10		0.07
N14C		0.00	0.00	0	0.00	0.00	0.00		0.00
N14D		0.00	0.00	0	0.00	0.00	0.00		0.00
N21A		0.00	0.00	0	0.00	0.00	0.00		0.00
N21B		0.00	0.00	0	0.00	0.00	0.00		0.00
N21C		0.00	0.00	0	0.00	0.00	0.00		0.00
N21D		0.00	0.00	0	0.00	0.00	0.00		0.00
N22A		0.00	0.00	0	0.00	0.00	0.00		0.00
N22B		0.00	0.00	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
N22C		0.00	0.00	0	0.00	0.00	0.00		0.00
N22D		0.00	0.00	0	0.00	0.00	0.00		0.00
N22E		0.00	0.00	0	0.00	0.00	0.00		0.00
N23A		0.00	0.00	0	0.00	0.00	0.00		0.00
N23B		0.00	0.00	0	0.00	0.00	0.00		0.00
N24A		0.00	0.00	0	0.00	0.00	0.00		0.00
N24B		0.00	0.00	0	0.00	0.00	0.00		0.00
N24C		0.28	0.00	4700	0.15	0.05	0.10		0.07
N24D		0.00	0.04	0	0.00	0.00	0.00		0.00
N30A		0.20	0.07	3700	0.11	0.04	0.06		0.05
N30B		0.00	0.00	0	0.00	0.00	0.00		0.00
N30C		0.00	0.00	0	0.00	0.00	0.00		0.00
N40A		0.00	0.00	0	0.00	0.00	0.00		0.00
N40B		0.00	0.02	0	0.00	0.00	0.00		0.00
N40C		0.83	0.15	10800	0.45	0.16	0.30		0.21
N40D		0.00	0.00	0	0.00	0.00	0.00		0.00
N40E		0.48	0.01	5900	0.26	0.09	0.17		0.12
N40F		0.00	0.02	0	0.00	0.00	0.00		0.00
P10A		0.00	0.00	0	0.00	0.00	0.00		0.00
P10B		0.03	0.04	650	0.02	0.01	0.01		0.01

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
P10C		0.00	0.00	0	0.00	0.00	0.00		0.00
P10D		0.17	0.01	5950	0.09	0.03	0.06		0.04
P10E		0.20	0.02	3250	0.11	0.04	0.06		0.05
P10F		0.00	0.00	0	0.00	0.00	0.00		0.00
P10G		0.19	0.02	4200	0.09	0.05	0.08		0.05
P20A		0.94	0.10	12050	0.49	0.20	0.37		0.23
P20B		0.00	0.00	0	0.00	0.00	0.00		0.00
P30A		0.00	0.00	0	0.00	0.00	0.00		0.00
P30B		0.00	0.00	0	0.00	0.00	0.00		0.00
P30C		0.00	0.00	0	0.00	0.00	0.00		0.00
P40A		5.75	0.73	59350	2.76	1.48	2.38		1.44
P40B		0.00	0.01	0	0.00	0.00	0.00		0.00
P40C		1.10	0.46	22000	0.54	0.27	0.44		0.28
P40D		0.05	0.08	1450	0.02	0.01	0.02		0.01
Q11A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q11B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q11C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q11D		0.00	0.00	0	0.00	0.00	0.00		0.00
Q12A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q12B		0.43	0.06	7900	0.23	0.08	0.13		0.11

1	4	6	8	10	1		7	9	5
Areas		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
Q12C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q13A		0.19	0.02	2850	0.10	0.04	0.06		0.05
Q13B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q13C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q14A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q14B		2.44	0.14	17400	1.05	0.74	1.13		0.61
Q14C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q14D		0.00	0.00	0	0.00	0.00	0.00		0.00
Q14E		0.00	0.00	0	0.00	0.00	0.00		0.00
Q21A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q21B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q22A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q22B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q30A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q30B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q30C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q30D		0.00	0.06	0	0.00	0.00	0.00		0.00
Q30E		3.84	0.20	28600	1.66	1.17	1.71		0.96
Q41A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q41B		0.00	0.00	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
Q41C		0.14	0.04	5400	0.08	0.03	0.04		0.04
Q41D		0.00	0.00	0	0.00	0.00	0.00		0.00
Q42A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q42B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q43A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q43B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q44A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q44B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q44C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q50A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q50B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q50C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q60A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q60B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q60C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q70A		0.31	0.04	5200	0.17	0.06	0.09		0.08
Q70B		0.00	0.03	0	0.00	0.00	0.00		0.00
Q70C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q80A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q80B		0.00	0.00	0	0.00	0.00	0.00		0.00

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
Q80C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q80D		1.14	0.22	16500	0.62	0.23	0.44		0.29
Q80E		0.00	0.00	0	0.00	0.00	0.00		0.00
Q80F		0.00	0.00	0	0.00	0.00	0.00		0.00
Q80G		0.00	0.00	0	0.00	0.00	0.00		0.00
Q91A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q91B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q91C		0.00	0.02	0	0.00	0.00	0.00		0.00
Q92A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q92B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q92C		0.00	0.04	0	0.00	0.00	0.00		0.00
Q92D		0.67	0.05	11550	0.36	0.13	0.25		0.17
Q92E		0.00	0.03	0	0.00	0.00	0.00		0.00
Q92F		0.47	0.06	10150	0.26	0.09	0.13		0.12
Q92G		0.00	0.00	0	0.00	0.00	0.00		0.00
Q93A		0.00	0.00	0	0.00	0.00	0.00		0.00
Q93B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q93C		0.35	0.10	15050	0.19	0.07	0.09		0.09
Q93D		0.00	0.00	0	0.00	0.00	0.00		0.00
Q94A		0.15	0.00	2700	0.08	0.03	0.05		0.04

1	4	6	8	10	1		7	9	5
		gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo		oUTLo
Areas	Distribution loss factor	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Idirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	million m³/a	million m³/a	Number	million m³/a	million m³/a	million m³/a	million m³/a	million m³/a
Q94B		0.00	0.00	0	0.00	0.00	0.00		0.00
Q94C		0.00	0.00	0	0.00	0.00	0.00		0.00
Q94D		0.00	0.00	0	0.00	0.00	0.00		0.00
Q94E		0.00	0.00	0	0.00	0.00	0.00		0.00
Q94F		2.08	0.13	23350	0.90	0.63	0.79		0.52
TOTALS	---	101.32	16.01	1413100	46.52	28.11	48.20	0.00	25.33

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX F.2

RURAL WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
K80A		0	45	0.02	0.04	0.06	1327		0	1 821	0
K80B		0	45	0.02	0.06	0.08	1 540		0	2 784	0
K80C		0	45	0.02	0.06	0.08	1 673		0	2 524	0
K80D		0	45	0.09	0.05	0.15	2 269		0	2 312	0
K80E		0	45	0.01	0.08	0.09	885		0	3 556	0
K80F		0	45	0.01	0.07	0.08	614		0	2 950	0
K90A		0	45	0.01	0.06	0.07	259		0	2 644	0
K90B		0	45	0.00	0.04	0.05	192		0	2 001	0
K90C		0	45	0.01	0.08	0.09	277		0	3 570	0
K90D		0	45	0.02	0.06	0.08	373		0	2 881	0
K90E		0	45	0.01	0.05	0.06	489		0	2 316	0
K90F		0	45	0.03	0.07	0.10	1 770		0	3 339	0
K90G		0	45	0.01	0.08	0.10	696		0	3 830	0
L11A		0	45	0.00	0.05	0.05	75		0	650	0
L11B		0	45	0.00	0.05	0.05	99		0	600	0
L11C		0	45	0.01	0.03	0.04	470		0	415	0
L11D		0	45	0.01	0.07	0.08	547		0	749	0
L11E		0	45	0.01	0.02	0.04	789		0	265	0
L11F		0	45	0.01	0.04	0.05	296		0	432	0
L11G		0	45	0.01	0.11	0.12	354		0	1 185	0
L12A		0	45	0.00	0.05	0.05	171		0	519	0
L12B		0	45	0.00	0.03	0.03	97		0	301	0
L12C		0	45	0.01	0.07	0.08	194		0	869	0
L12D		0	45	0.01	0.06	0.07	199		0	780	0
L21A		0	45	0.00	0.04	0.04	91		0	615	0
L21B		0	45	0.01	0.06	0.06	203		0	985	0
L21C		0	45	0.01	0.09	0.09	261		0	1 536	0
L21D		0	45	0.01	0.06	0.07	233		0	841	0

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
L21E		0	45	0.00	0.05	0.05	184		0	698	0
L21F		0	45	0.00	0.04	0.04	181		0	555	0
L22A		0	45	0.01	0.07	0.08	262		0	1 007	0
L22B		0	45	0.01	0.03	0.04	106		0	444	0
L22C		0	45	0.01	0.05	0.06	170		0	765	0
L22D		0	45	0.01	0.04	0.05	117		0	600	0
L23A		0	45	0.01	0.04	0.05	107		0	615	0
L23B		0	45	0.01	0.06	0.08	210		0	987	0
L23C		0	45	0.01	0.07	0.08	210		0	1 035	0
L23D		0	45	0.01	0.05	0.06	209		0	661	0
L30A		0	45	0.00	0.03	0.03	95		0	339	0
L30B		0	45	0.00	0.03	0.03	84		0	354	0
L30C		0	45	0.00	0.02	0.02	52		0	222	0
L30D		0	45	0.01	0.04	0.05	289		0	516	0
L40A		0	45	0.01	0.06	0.07	180		0	920	0
L40B		0	45	0.01	0.04	0.06	279		0	595	0
L50A		0	45	0.01	0.03	0.05	253		0	455	0
L50B		0	45	0.01	0.05	0.06	268		0	683	0
L60A		0	45	0.00	0.05	0.05	187		0	763	0
L60B		0	45	0.01	0.05	0.05	248		0	764	0
L70A		0	45	0.01	0.05	0.06	246		0	710	0
L70B		0	45	0.00	0.04	0.04	176		0	562	0
L70C		0	45	0.01	0.06	0.07	278		0	845	0
L70D		0	45	0.01	0.04	0.06	262		0	679	0
L70E		0	45	0.03	0.09	0.12	535		0	1 907	0
L70F		0	45	0.01	0.04	0.05	180		0	914	0
L70G		0	45	0.02	0.04	0.06	429		0	1 339	0
L81A		0	45	0.01	0.02	0.03	241		0	340	0
L81B		0	45	0.00	0.02	0.02	197		0	244	0
L81C		0	45	0.00	0.02	0.03	266		0	312	0
L81D		0	45	0.01	0.02	0.04	324		0	311	0
L82A		0	45	0.01	0.00	0.01	929		0	0	0

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
L82B		0	45	0.11	0.01	0.12	2 723		0	428	0
L82C		0	45	0.04	0.02	0.06	3 173		0	797	0
L82D		0	45	0.03	0.04	0.07	2 673		0	1 331	0
L82E		0	45	0.02	0.07	0.09	336		0	3 095	0
L82F		0	45	0.01	0.04	0.05	185		0	1 935	0
L82G		0	45	0.01	0.07	0.08	282		0	2 884	0
L82H		0	45	0.01	0.01	0.02	262		0	564	0
L82J		0	45	0.01	0.04	0.05	171		0	1 776	0
L90A		0	45	0.06	0.06	0.13	4 896		0	2 941	0
L90B		0	45	0.03	0.03	0.05	1 949		0	1 258	0
L90C		0	45	0.03	0.03	0.06	2 384		0	1 356	0
M10A		0	45	0.01	0.05	0.06	169		0	1 298	0
M10B		0	45	0.02	0.08	0.10	483		0	2 344	0
M10C		0	45	0.08	0.12	0.20	6 301		0	4 818	0
M10D		0	45	0.02	0.12	0.14	1 325		0	6 177	0
M20A		0	45	0.07	0.17	0.24	4 686		0	9 768	0
M20B		0	45	0.09	0.09	0.18	7 017		0	5 055	0
M30A		0	45	0.03	0.05	0.08	631		0	1 360	0
M30B		0	45	0.02	0.14	0.16	1 172		0	7 729	0
N11A		0	45	0.02	0.11	0.12	346		0	2 304	0
N11B		0	45	0.02	0.12	0.14	443		0	2 547	0
N12A		0	45	0.01	0.11	0.12	345		0	2 413	0
N12B		0	45	0.02	0.11	0.13	411		0	2 330	0
N12C		0	45	0.02	0.10	0.12	424		0	2 160	0
N13A		0	45	0.02	0.08	0.10	410		0	1 797	0
N13B		0	45	0.02	0.07	0.09	393		0	1 485	0
N13C		0	45	0.01	0.07	0.08	384		0	1 617	0
N14A		0	45	0.01	0.04	0.05	201		0	611	0
N14B		0	45	0.00	0.03	0.03	129		0	467	0
N14C		0	45	0.02	0.05	0.07	345		0	804	0
N14D		0	45	0.01	0.04	0.05	209		0	716	0
N21A		0	45	0.01	0.06	0.07	279		0	1 111	0

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
N21B		0	45	0.01	0.06	0.07	160		0	1 273	0
N21C		0	45	0.01	0.06	0.08	257		0	1 222	0
N21D		0	45	0.01	0.08	0.09	164		0	1 842	0
N22A		0	45	0.02	0.04	0.05	339		0	648	0
N22B		0	45	0.02	0.04	0.06	365		0	678	0
N22C		0	45	0.01	0.03	0.04	271		0	418	0
N22D		0	45	0.01	0.02	0.03	198		0	378	0
N22E		0	45	0.01	0.02	0.03	249		0	366	0
N23A		0	45	0.02	0.06	0.08	324		0	1 575	0
N23B		0	45	0.01	0.02	0.04	229		0	581	0
N24A		0	45	0.01	0.05	0.06	188		0	803	0
N24B		0	45	0.01	0.06	0.07	204		0	1 194	0
N24C		0	45	0.02	0.05	0.07	321		0	837	0
N24D		0	45	0.00	0.02	0.03	200		0	404	0
N30A		0	45	0.01	0.06	0.06	342		0	1 012	0
N30B		0	45	0.02	0.05	0.07	387		0	966	0
N30C		0	45	0.01	0.04	0.05	290		0	939	0
N40A		0	45	0.07	0.11	0.18	1 548		0	3 586	0
N40B		0	45	0.04	0.24	0.28	1 953		0	7 030	0
N40C		0	45	0.09	0.13	0.23	7 015		0	5 784	0
N40D		0	45	0.06	0.26	0.32	3 627		0	16 396	0
N40E		0	45	0.06	0.11	0.17	4 302		0	4 266	0
N40F		0	45	0.05	0.30	0.34	2 619		0	17 449	0
P10A		0	45	0.01	0.02	0.04	246		0	849	0
P10B		0	45	0.02	0.10	0.11	972		0	3 436	0
P10C		0	45	0.01	0.03	0.05	282		0	822	0
P10D		0	45	0.02	0.08	0.10	904		0	2 535	0
P10E		0	45	0.03	0.16	0.19	1 594		0	9 982	0
P10F		0	45	0.11	0.14	0.25	2 517		0	7 392	0
P10G		0	45	0.04	0.14	0.18	2 497		0	8 851	0
P20A		0	45	0.06	0.19	0.24	3 999		0	12 476	0
P20B		0	45	0.07	0.15	0.21	1 434		0	9 812	0

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
P30A		0	45	0.05	0.03	0.08	1 119		0	1 188	0
P30B		0	45	0.14	0.09	0.23	3 325		0	4 082	0
P30C		0	45	0.02	0.03	0.05	562		0	1 861	0
P40A		0	45	0.03	0.07	0.11	2 378		0	3 211	0
P40B		0	45	0.03	0.11	0.14	1 772		0	6 994	0
P40C		0	45	0.03	0.15	0.18	2 014		0	9 469	0
P40D		0	45	0.02	0.10	0.13	1 289		0	6 797	0
Q11A		0	45	0.02	0.07	0.09	353		0	1 795	0
Q11B		0	45	0.02	0.04	0.06	341		0	953	0
Q11C		0	45	0.01	0.03	0.05	248		0	654	0
Q11D		0	45	0.02	0.05	0.07	412		0	910	0
Q12A		0	45	0.02	0.11	0.13	483		0	2 735	0
Q12B		0	45	0.01	0.13	0.15	596		0	3 732	0
Q12C		0	45	0.02	0.05	0.07	410		0	1 153	0
Q13A		0	45	0.02	0.12	0.14	904		0	2 347	0
Q13B		0	45	0.01	0.04	0.06	310		0	1 044	0
Q13C		0	45	0.04	0.10	0.13	761		0	2 391	0
Q14A		0	45	0.01	0.05	0.06	208		0	921	0
Q14B		0	45	0.01	0.07	0.08	938		0	1 340	0
Q14C		0	45	0.03	0.08	0.11	524		0	1 581	0
Q14D		0	45	0.02	0.04	0.06	320		0	772	0
Q14E		0	45	0.01	0.03	0.04	219		0	658	0
Q21A		0	45	0.01	0.13	0.14	156		0	3 122	0
Q21B		0	45	0.03	0.08	0.11	565		0	2 065	0
Q22A		0	45	0.01	0.06	0.07	272		0	1 259	0
Q22B		0	45	0.01	0.02	0.03	137		0	453	0
Q30A		0	45	0.02	0.09	0.10	301		0	2 132	0
Q30B		0	45	0.03	0.11	0.13	488		0	2 628	0
Q30C		0	45	0.03	0.09	0.12	538		0	2 276	0
Q30D		0	45	0.03	0.07	0.10	751		0	1 695	0
Q30E		0	45	0.01	0.07	0.08	603		0	1 779	0
Q41A		0	45	0.02	0.05	0.07	390		0	1 613	0

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
Q41B		0	45	0.03	0.09	0.13	687		0	2 884	0
Q41C		0	45	0.01	0.07	0.08	363		0	2 226	0
Q41D		0	45	0.01	0.06	0.08	231		0	1 714	0
Q42A		0	45	0.02	0.09	0.12	457		0	2 934	0
Q42B		0	45	0.02	0.08	0.10	392		0	2 511	0
Q43A		0	45	0.03	0.08	0.11	581		0	1 595	0
Q43B		0	45	0.04	0.15	0.19	714		0	4 198	0
Q44A		0	45	0.02	0.09	0.11	260		0	2 324	0
Q44B		0	45	0.02	0.10	0.11	307		0	2 355	0
Q44C		0	45	0.03	0.06	0.09	714		0	1 388	0
Q50A		0	45	0.08	0.14	0.22	1 844		0	3 557	0
Q50B		0	45	0.05	0.06	0.10	1 060		0	1 569	0
Q50C		0	45	0.02	0.03	0.05	480		0	1 026	0
Q60A		0	45	0.03	0.07	0.10	581		0	2 470	0
Q60B		0	45	0.03	0.08	0.11	629		0	2 891	0
Q60C		0	45	0.01	0.03	0.04	189		0	1 029	0
Q70A		0	45	0.01	0.05	0.06	501		0	1 670	0
Q70B		0	45	0.02	0.07	0.09	1 315		0	2 299	0
Q70C		0	45	0.02	0.04	0.06	331		0	1 265	0
Q80A		0	45	0.01	0.04	0.05	243		0	1 034	0
Q80B		0	45	0.02	0.08	0.09	350		0	1 893	0
Q80C		0	45	0.02	0.03	0.05	361		0	822	0
Q80D		0	45	0.01	0.05	0.06	675		0	1 225	0
Q80E		0	45	0.02	0.04	0.07	534		0	1 068	0
Q80F		0	45	0.03	0.08	0.11	521		0	2 032	0
Q80G		0	45	0.02	0.03	0.05	438		0	817	0
Q91A		0	45	0.03	0.10	0.13	631		0	3 493	0
Q91B		0	45	0.04	0.10	0.14	936		0	3 478	0
Q91C		0	45	0.02	0.09	0.11	1 212		0	3 277	0
Q92A		0	45	0.01	0.07	0.09	866		0	3 210	0
Q92B		0	45	0.04	0.12	0.17	950		0	4 478	0
Q92C		0	45	0.06	0.21	0.27	1 318		0	7 523	0

Areas	3	5	4			6	1		7	2	7
		gRIRo	gRSRo			gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consump-tion rate	1:50 Year Small scale irrigation	Large stock units consump-tion rate	Rural domestic water use	Livestock water use	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l /c/d	million m³/a	l /u/d	million m³/a	million m³/a	million m³/a	Number	million m³/a	million m³/a	Number	Factor
Q92D		0	45	0.03	0.08	0.10	563		0	2 920	0
Q92E		0	45	0.01	0.10	0.11	623		0	3 674	0
Q92F		0	45	0.02	0.15	0.17	772		0	5 317	0
Q92G		0	45	0.10	0.20	0.30	2 241		0	7 663	0
Q93A		0	45	0.01	0.11	0.12	592		0	2 402	0
Q93B		0	45	0.05	0.07	0.12	3 701		0	2 554	0
Q93C		0	45	0.13	0.02	0.15	10 560		0	698	0
Q93D		0	45	0.07	0.15	0.22	5 442		0	9 181	0
Q94A		0	45	0.02	0.02	0.04	1 950		0	592	0
Q94B		0	45	0.04	0.00	0.04	3 472		0		0
Q94C		0	45	0.06	0.02	0.07	4 447		0	830	0
Q94D		0	45	0.04	0.02	0.07	3 464		0	595	0
Q94E		0	45	0.01	0.03	0.04	930		0	1 522	0
Q94F		0	45	0.22	0.24	0.47	17 180		0	5 278	0
TOTALS	---	**0**	---	**4.97**	**14.23**	**19.20**	209 621	**0**	**0**	466 581	**0**

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX F.3

BULK WATER REQUIREMENTS PER QUATERNARY CATCHMENT

There are no bulk water requirements in the Fish to Tsitsikamma Water Management Area.

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA
APPENDIX F.4
IRRIGATION WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Max. area under high category crops	Max. area under low category crops	Max. area under medium category crops	Average land area irrigated	Conveyance losses for high category crops	Conveyance losses for low category crops	Conveyance losses for medium category crops	Application efficiency for high category crops	Application efficiency for low category crops	Application efficiency for medium category crops	Total average water use by irrigators
	km²	km²	km²	km²	Factor	Factor	Factor	Factor	Factor	Factor	million m³/a
K80A	0.00	0.00	1.01	1.01	0.00	0.00	0.15	0.00	0.00	0.75	0.69
K80B	0.00	0.00	1.48	1.48	0.00	0.00	0.15	0.00	0.00	0.75	1.01
K80C	0.00	0.00	1.64	1.64	0.00	0.00	0.15	0.00	0.00	0.75	1.12
K80D	0.00	0.00	1.01	1.01	0.00	0.00	0.15	0.00	0.00	0.75	0.69
K80E	0.00	0.00	1.48	1.48	0.00	0.00	0.15	0.00	0.00	0.75	1.01
K80F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K90A	0.00	0.00	2.00	2.00	0.00	0.00	0.15	0.00	0.00	0.75	1.37
K90B	0.00	0.00	1.37	1.37	0.00	0.00	0.15	0.00	0.00	0.75	0.94
K90C	0.00	0.00	2.26	2.26	0.00	0.00	0.15	0.00	0.00	0.75	1.54
K90D	0.00	0.00	1.27	1.27	0.00	0.00	0.15	0.00	0.00	0.75	0.87
K90E	0.00	0.00	1.17	1.17	0.00	0.00	0.15	0.00	0.00	0.75	0.80
K90F	0.00	0.00	1.72	1.72	0.00	0.00	0.15	0.00	0.00	0.75	1.17
K90G	0.00	0.00	1.95	1.95	0.00	0.00	0.15	0.00	0.00	0.75	1.33
L11A	0.00	0.00	1.40	0.60	0.00	0.00	0.15	0.00	0.00	0.75	0.88
L11B	0.00	0.00	1.30	0.50	0.00	0.00	0.15	0.00	0.00	0.75	0.74
L11C	0.00	0.00	0.90	0.40	0.00	0.00	0.15	0.00	0.00	0.75	0.59
L11D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L11E	0.00	0.00	1.80	0.80	0.00	0.00	0.15	0.00	0.00	0.75	1.18

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
L11F	0.00	0.00	0.70	0.30	0.00	0.00	0.15	0.00	0.00	0.75	0.44
L11G	0.00	0.00	0.76	0.30	0.00	0.00	0.15	0.00	0.00	0.75	0.44
L12A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L12B	0.00	0.00	1.75	1.75	0.00	0.00	0.15	0.00	0.00	0.75	0.44
L12C	0.00	0.00	3.51	3.51	0.00	0.00	0.15	0.00	0.00	0.75	1.03
L12D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21C	0.00	0.00	2.42	1.10	0.00	0.00	0.15	0.00	0.00	0.75	1.62
L21D	0.00	0.00	2.00	1.10	0.00	0.00	0.15	0.00	0.00	0.75	1.62
L21E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L22A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L22B	0.00	0.00	1.58	0.90	0.00	0.00	0.15	0.00	0.00	0.75	1.32
L22C	0.00	0.00	2.55	1.30	0.00	0.00	0.15	0.00	0.00	0.75	1.91
L22D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L23A	0.00	0.00	1.21	0.70	0.00	0.00	0.15	0.00	0.00	0.80	1.03
L23B	0.00	0.00	1.94	1.00	0.00	0.00	0.15	0.00	0.00	0.75	1.47
L23C	0.00	0.00	2.06	1.10	0.00	0.00	0.15	0.00	0.00	0.80	1.62
L23D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L30A	0.03	0.00	0.10	0.13	0.15	0.00	0.15	0.80	0.00	0.80	0.18

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
L30B	0.18	0.00	0.65	0.84	0.15	0.00	0.15	0.80	0.00	0.80	1.14
L30C	0.55	0.00	1.96	1.88	0.15	0.00	0.15	0.80	0.00	0.80	2.57
L30D	0.12	0.00	0.42	0.40	0.15	0.00	0.15	0.80	0.00	0.80	0.55
L40A	0.00	0.00	0.32	0.32	0.00	0.00	0.15	0.00	0.00	0.75	0.44
L40B	0.06	0.00	0.21	0.27	0.15	0.00	0.15	0.80	0.00	0.80	0.37
L50A	0.10	0.00	0.37	0.47	0.15	0.00	0.15	0.80	0.00	0.80	0.64
L50B	0.68	0.00	2.70	2.53	0.00	0.00	0.00	0.80	0.00	0.00	3.46
L60A	0.00	0.00	0.05	0.05	0.00	0.00	0.15	0.00	0.00	0.75	0.07
L60B	0.01	0.00	0.03	0.04	0.15	0.00	0.15	0.80	0.00	0.80	0.06
L70A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L70B	0.26	0.00	1.06	1.32	0.15	0.00	0.15	0.80	0.00	0.80	1.80
L70C	0.21	0.00	0.76	0.73	0.15	0.00	0.15	0.80	0.00	0.80	0.99
L70D	0.29	0.00	1.03	1.32	0.15	0.00	0.15	0.80	0.00	0.80	1.80
L70E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L70F	0.03	0.00	0.10	0.13	0.00	0.00	0.00	0.80	0.00	0.80	0.18
L70G	0.48	0.00	1.72	2.20	0.00	0.00	0.00	0.80	0.00	0.80	3.00
L81A	0.16	0.00	0.55	0.71	0.00	0.00	0.00	0.80	0.00	0.80	0.45
L81B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L81C	0.06	0.00	0.22	0.28	0.00	0.00	0.00	0.80	0.00	0.80	0.18
L81D	0.09	0.00	0.33	0.42	0.00	0.00	0.00	0.80	0.00	0.80	0.27
L82A	5.89	0.00	0.00	5.89	0.00	0.00	0.00	0.80	0.00	0.00	3.76

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
L82B	12.97	0.00	0.00	12.97	0.15	0.00	0.00	0.80	0.00	0.00	8.27
L82C	9.66	0.00	0.00	9.66	0.15	0.00	0.00	0.80	0.00	0.00	6.16
L82D	12.92	0.00	0.00	12.92	0.15	0.00	0.00	0.80	0.00	0.00	8.24
L82E	6.26	0.00	0.00	6.26	0.15	0.00	0.00	0.80	0.00	0.00	3.99
L82F	2.32	0.00	0.00	2.32	0.15	0.00	0.00	0.80	0.00	0.00	1.48
L82G	0.80	0.00	2.85	3.65	0.15	0.00	0.15	0.80	0.00	0.80	2.33
L82H	0.71	0.00	2.50	3.21	0.15	0.00	0.15	0.80	0.00	0.80	2.05
L82J	0.38	0.00	1.34	1.72	0.15	0.00	0.15	0.80	0.00	0.80	1.10
L90A	7.04	0.00	24.98	24.02	0.24	0.00	0.24	0.80	0.00	0.80	22.10
L90B	5.01	0.00	17.77	17.09	0.24	0.00	0.24	0.80	0.00	0.80	15.72
L90C	4.36	0.00	15.45	14.86	0.24	0.00	0.24	0.80	0.00	0.80	13.67
M10A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M10B	0.00	0.00	2.30	2.30	0.00	0.00	0.15	0.00	0.00	0.75	2.13
M10C	0.00	0.00	4.30	4.30	0.00	0.00	0.15	0.00	0.00	0.75	3.98
M10D	0.00	0.00	1.80	1.80	0.00	0.00	0.15	0.00	0.00	0.75	1.67
M20A	0.00	0.00	2.10	2.10	0.00	0.00	0.15	0.00	0.00	0.75	1.95
M20B	0.00	0.00	1.80	1.80	0.00	0.00	0.15	0.00	0.00	0.75	1.67
M30A	0.00	0.00	1.00	1.00	0.00	0.00	0.15	0.00	0.00	0.75	0.93
M30B	0.00	0.00	1.20	1.20	0.00	0.00	0.15	0.00	0.00	0.75	1.11
N11A	0.00	0.00	5.52	2.15	0.00	0.00	0.15	0.00	0.00	0.75	2.93
N11B	0.00	0.00	7.53	2.75	0.00	0.00	0.15	0.00	0.00	0.75	3.75

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
N12A	0.00	0.00	1.36	0.71	0.00	0.00	0.15	0.00	0.00	0.75	0.97
N12B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N12C	0.00	0.00	8.07	3.42	0.00	0.00	0.15	0.00	0.00	0.75	4.67
N13A	0.00	0.00	9.42	2.82	0.00	0.00	0.15	0.00	0.00	0.75	3.85
N13B	0.00	0.00	21.14	8.84	0.00	0.00	0.15	0.00	0.00	0.75	12.07
N13C	0.00	0.00	25.20	11.06	0.00	0.00	0.15	0.00	0.00	0.75	15.10
N14A	0.00	0.00	1.44	0.00	0.00	0.00	0.15	0.00	0.00	0.75	0.00
N14B	0.00	0.00	8.31	0.00	0.00	0.00	0.15	0.00	0.00	0.75	0.00
N14C	0.00	0.00	20.54	0.00	0.00	0.00	0.15	0.00	0.00	0.75	0.00
N14D	0.00	0.00	9.73	3.90	0.00	0.00	0.15	0.00	0.00	0.75	5.32
N21A	0.00	0.00	11.91	4.97	0.00	0.00	0.15	0.00	0.00	0.75	6.78
N21B	0.00	0.00	2.12	0.84	0.00	0.00	0.15	0.00	0.00	0.75	1.15
N21C	0.00	0.00	3.24	1.27	0.00	0.00	0.15	0.00	0.00	0.75	1.73
N21D	0.00	0.00	0.46	0.34	0.00	0.00	0.15	0.00	0.00	0.75	0.46
N22A	0.00	0.00	1.82	0.55	0.00	0.00	0.15	0.00	0.00	0.75	0.75
N22B	0.00	0.00	0.21	0.06	0.00	0.00	0.15	0.00	0.00	0.75	0.09
N22C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22E	1.07	0.00	0.59	2.16	0.15	0.00	0.15	0.85	0.00	0.85	2.95
N23A	0.00	0.00	2.56	2.56	0.00	0.00	0.15	0.00	0.00	0.75	3.49
N23B	1.20	0.00	1.04	2.23	0.15	0.00	0.15	0.85	0.00	0.85	3.04

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
N24A	0.00	0.00	1.16	1.16	0.00	0.00	0.15	0.00	0.00	0.75	1.58
N24B	0.00	0.00	6.87	2.56	0.00	0.00	0.15	0.00	0.00	0.75	3.49
N24C	0.00	0.00	3.89	1.66	0.00	0.00	0.15	0.00	0.00	0.75	2.27
N24D	0.00	0.00	1.17	0.85	0.00	0.00	0.15	0.00	0.00	0.75	1.16
N30A	0.00	0.00	8.35	3.00	0.00	0.00	0.15	0.00	0.00	0.75	4.10
N30B	0.00	0.00	2.68	2.68	0.00	0.00	0.15	0.00	0.00	0.75	3.66
N30C	0.43	0.00	0.38	0.81	0.15	0.00	0.15	0.85	0.00	0.85	1.11
N40A	0.24	0.00	0.21	0.45	0.15	0.00	0.15	0.85	0.00	0.85	0.47
N40B	2.90	0.00	2.50	5.40	0.15	0.00	0.15	0.85	0.00	0.85	5.59
N40C	23.51	0.00	18.40	42.91	0.15	0.00	0.15	0.85	0.00	0.85	44.41
N40D	12.40	0.00	10.70	23.70	0.15	0.00	0.15	0.85	0.00	0.85	24.53
N40E	18.80	0.00	16.20	35.00	0.15	0.00	0.15	0.85	0.00	0.85	36.23
N40F	9.90	0.00	8.60	18.50	0.15	0.00	0.15	0.85	0.00	0.85	19.15
P10A	0.00	0.00	0.44	0.22	0.00	0.00	0.15	0.00	0.00	0.75	0.30
P10B	0.00	0.00	1.65	0.83	0.00	0.00	0.15	0.00	0.00	0.75	1.14
P10C	0.00	0.00	0.94	0.47	0.00	0.00	0.15	0.00	0.00	0.75	0.65
P10D	0.00	0.00	1.87	0.94	0.00	0.00	0.15	0.00	0.00	0.75	1.29
P10E	0.00	0.00	1.54	0.77	0.00	0.00	0.15	0.00	0.00	0.75	1.06
P10F	0.00	0.00	1.54	0.77	0.00	0.00	0.15	0.00	0.00	0.75	1.06
P10G	0.00	0.00	1.10	0.55	0.00	0.00	0.15	0.00	0.00	0.75	0.76
P20A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
P20B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P30A	0.00	0.00	1.05	0.53	0.00	0.00	0.15	0.00	0.00	0.75	0.72
P30B	0.00	0.00	2.37	1.19	0.00	0.00	0.15	0.00	0.00	0.75	1.64
P30C	0.00	0.00	0.39	0.20	0.00	0.00	0.15	0.00	0.00	0.75	0.27
P40A	0.00	0.00	0.11	0.06	0.00	0.00	0.15	0.00	0.00	0.75	0.08
P40B	0.00	0.00	0.06	0.03	0.00	0.00	0.15	0.00	0.00	0.75	0.04
P40C	0.00	0.00	0.11	0.06	0.00	0.00	0.15	0.00	0.00	0.75	0.08
P40D	0.00	0.00	0.06	0.03	0.00	0.00	0.15	0.00	0.00	0.75	0.04
Q11A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q11B	0.00	0.00	1.51	1.09	0.00	0.00	0.25	0.00	0.00	0.75	1.86
Q11C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q11D	0.00	0.00	5.57	4.03	0.00	0.00	0.25	0.00	0.00	0.75	6.86
Q12A	0.00	0.00	1.10	0.80	0.00	0.00	0.25	0.00	0.00	0.75	1.35
Q12B	0.00	2.20	5.50	5.07	0.00	0.25	0.25	0.00	0.80	0.80	8.62
Q12C	0.00	12.40	30.39	25.69	0.00	0.25	0.25	0.00	0.80	0.80	43.71
Q13A	0.00	1.34	3.29	2.90	0.00	0.25	0.25	0.00	0.80	0.80	4.93
Q13B	0.00	2.70	6.70	5.79	0.00	0.25	0.25	0.00	0.80	0.80	9.85
Q13C	0.00	7.50	18.30	18.68	0.00	0.25	0.25	0.00	0.80	0.80	31.77
Q14A	0.00	0.00	9.56	6.92	0.00	0.00	0.25	0.00	0.00	0.75	11.77
Q14B	0.00	0.00	8.82	6.39	0.00	0.00	0.25	0.00	0.00	0.75	10.86
Q14C	0.00	0.00	4.75	3.44	0.00	0.00	0.25	0.00	0.00	0.75	5.85

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
Q14D	0.00	0.00	3.00	2.17	0.00	0.00	0.25	0.00	0.00	0.75	3.69
Q14E	0.00	0.00	3.16	2.29	0.00	0.00	0.25	0.00	0.00	0.75	3.89
Q21A	0.00	0.00	0.16	0.12	0.00	0.00	0.25	0.00	0.00	0.75	0.20
Q21B	0.00	3.20	7.80	6.75	0.00	0.25	0.25	0.00	0.80	0.80	11.49
Q22A	0.00	0.00	2.47	1.79	0.00	0.00	0.25	0.00	0.00	0.75	3.04
Q22B	0.00	0.00	2.64	1.91	0.00	0.00	0.25	0.00	0.00	0.75	3.25
Q30A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q30B	0.00	0.00	3.90	2.82	0.00	0.00	0.15	0.00	0.00	0.75	4.80
Q30C	0.00	3.20	6.00	5.72	0.00	0.25	0.25	0.00	0.80	0.80	9.73
Q30D	0.00	1.70	4.10	3.55	0.00	0.25	0.25	0.00	0.80	0.80	6.03
Q30E	0.00	8.48	19.80	17.51	0.00	0.25	0.25	0.00	0.80	0.80	29.79
Q41A	0.00	0.00	2.67	1.93	0.00	0.00	0.25	0.00	0.00	0.75	3.29
Q41B	0.00	0.00	4.12	2.98	0.00	0.00	0.25	0.00	0.00	0.75	5.07
Q41C	0.00	0.00	0.46	0.33	0.00	0.00	0.25	0.00	0.00	0.75	0.57
Q41D	0.00	0.14	0.48	0.40	0.00	0.25	0.25	0.00	0.80	0.80	0.68
Q42A	0.00	0.00	0.35	0.25	0.00	0.00	0.25	0.00	0.00	0.75	0.43
Q42B	0.00	0.13	0.32	0.28	0.00	0.25	0.25	0.00	0.80	0.80	0.48
Q43A	0.00	0.00	2.90	2.10	0.00	0.00	0.25	0.00	0.00	0.75	3.57
Q43B	0.00	0.00	1.70	1.23	0.00	0.00	0.25	0.00	0.00	0.75	2.09
Q44A	0.00	1.51	3.69	3.24	0.00	0.25	0.25	0.00	0.80	0.80	5.51
Q44B	0.00	1.31	3.21	2.81	0.00	0.25	0.25	0.00	0.80	0.80	4.79

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
Q44C	0.00	3.95	9.20	8.15	0.00	0.25	0.25	0.00	0.80	0.80	13.85
Q50A	0.00	10.40	24.20	21.42	0.00	0.25	0.25	0.00	0.80	0.80	36.43
Q50B	0.00	5.61	8.98	9.59	0.00	0.25	0.25	0.00	0.80	0.80	15.10
Q50C	0.00	7.12	11.36	12.17	0.00	0.25	0.25	0.00	0.80	0.80	19.17
Q60A	0.00	0.00	0.46	0.33	0.00	0.00	0.25	0.00	0.00	0.75	0.52
Q60B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q60C	0.00	0.18	0.29	0.31	0.00	0.25	0.25	0.00	0.80	0.80	0.49
Q70A	0.00	4.65	7.43	7.94	0.00	0.25	0.25	0.00	0.80	0.80	12.51
Q70B	0.00	16.97	27.15	28.99	0.00	0.25	0.25	0.00	0.80	0.80	45.66
Q70C	0.00	2.85	4.56	5.36	0.00	0.25	0.25	0.00	0.80	0.80	8.45
Q80A	0.00	0.00	3.97	2.87	0.00	0.00	0.15	0.00	0.00	0.75	4.53
Q80B	0.00	0.00	3.69	2.67	0.00	0.00	0.15	0.00	0.00	0.75	4.21
Q80C	0.00	0.00	1.66	1.20	0.00	0.00	0.15	0.00	0.00	0.75	1.89
Q80D	0.00	5.46	8.20	8.90	0.00	0.25	0.25	0.00	0.80	0.80	14.01
Q80E	0.00	10.20	15.30	17.44	0.00	0.25	0.25	0.00	0.80	0.80	27.47
Q80F	0.00	4.40	6.60	7.48	0.00	0.25	0.25	0.00	0.80	0.80	11.78
Q80G	0.00	4.50	7.00	6.97	0.00	0.25	0.25	0.00	0.80	0.80	10.97
Q91A	0.00	0.00	2.40	1.74	0.00	0.00	0.25	0.00	0.00	0.75	2.54
Q91B	0.00	0.00	4.60	3.33	0.00	0.00	0.25	0.00	0.00	0.75	4.87
Q91C	0.00	0.00	6.00	4.34	0.00	0.00	0.25	0.00	0.00	0.75	6.35
Q92A	0.00	0.00	6.22	4.50	0.00	0.00	0.25	0.00	0.00	0.75	5.15

Quaternary catchment	1	2	3	4	5	6	7	9	10	11	8
	aIHAi	**aILAi**	**aIMAi**	**aISAi**	**fIHCi**	**fILCi**	**fIMCi**	**fIPHi**	**fIPLi**	**fIPMi**	**gIARo**
	Max. area under high category crops	**Max. area under low category crops**	**Max. area under medium category crops**	**Average land area irrigated**	**Conveyance losses for high category crops**	**Conveyance losses for low category crops**	**Conveyance losses for medium category crops**	**Application efficiency for high category crops**	**Application efficiency for low category crops**	**Application efficiency for medium category crops**	**Total average water use by irrigators**
	km²	**km²**	**km²**	**km²**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**Factor**	**million m³/a**
Q92B	0.00	0.00	6.90	5.00	0.00	0.00	0.25	0.00	0.00	0.75	5.72
Q92C	0.00	0.00	6.31	4.57	0.00	0.00	0.25	0.00	0.00	0.75	5.23
Q92D	0.00	0.00	2.24	1.62	0.00	0.00	0.25	0.00	0.00	0.75	1.86
Q92E	0.00	0.00	3.60	2.61	0.00	0.00	0.25	0.00	0.00	0.75	2.98
Q92F	0.00	0.00	1.14	0.83	0.00	0.00	0.25	0.00	0.00	0.75	0.94
Q92G	0.00	0.00	0.67	0.49	0.00	0.00	0.25	0.00	0.00	0.75	0.56
Q93A	0.00	0.00	0.60	0.43	0.00	0.00	0.25	0.00	0.00	0.75	0.64
Q93B	0.00	0.00	1.20	0.87	0.00	0.00	0.25	0.00	0.00	0.75	1.27
Q93C	0.00	0.00	1.90	1.38	0.00	0.00	0.25	0.00	0.00	0.75	2.01
Q93D	0.00	0.00	0.93	0.67	0.00	0.00	0.25	0.00	0.00	0.75	0.98
Q94A	0.12	0.00	0.00	0.09	0.25	0.00	0.00	0.80	0.00	0.00	0.09
Q94B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q94C	0.65	0.00	0.00	0.47	0.25	0.00	0.00	0.80	0.00	0.00	0.50
Q94D	8.68	0.00	0.00	6.28	0.25	0.00	0.00	0.80	0.00	0.00	6.62
Q94E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q94F	9.23	0.00	0.00	6.68	0.25	0.00	0.00	0.75	0.00	0.00	7.04
TOTALS	160.77	122.10	725.93	697.17	---	---	---	---	---	---	897.49

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX F.5

STREAMFLOW REDUCTION ACTIVITY WATER REQUIREMENTS PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	vLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
K80A	2.65	0.00	39.38	0.74	1.19	0.00	8.98	0.00
K80B	8.53	0.00	45.30	0.00	3.38	0.00	10.30	0.00
K80C	9.71	0.00	51.00	16.39	4.11	0.00	11.78	0.00
K80D	15.47	0.00	25.53	6.77	5.92	0.00	5.81	0.00
K80E	10.82	0.00	20.48	3.46	2.46	0.00	2.86	0.00
K80F	27.25	0.00	0.00	0.00	4.57	0.00	0.00	0.00
K90A	7.93	0.00	0.00	0.00	1.37	0.00	0.00	0.00
K90B	7.79	0.00	0.53	0.81	1.54	0.00	0.07	0.00
K90C	8.24	0.00	0.00	0.00	0.75	0.00	0.00	0.00
K90D	8.56	0.00	0.02	0.63	1.00	0.00	0.00	0.00
K90E	33.87	0.00	0.00	0.00	3.09	0.00	0.00	0.00
K90F	6.49	0.00	1.84	0.00	0.69	0.00	0.14	0.00
K90G	1.93	0.00	0.00	0.00	0.18	0.00	0.00	0.00
L11A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L11B	0.56	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L11C	0.21	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L11D	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L11E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	vLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
L11F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L11G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L12A	1.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L12B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L12C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L12D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21A	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21C	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21D	0.40	0.00	0.00	0.00	0.02	0.00	0.00	0.00
L21E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L21F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L22A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L22B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L22C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L22D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L23A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L23B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L23C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L23D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L30A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L30B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aCAUi AREA UNDER DRYLAND SUGAR CANE	aFCAi AREA UNDER AFFORESTATION	aFINi AREA OF INDIGENOUS FORESTS	oARDo REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	oCDo REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	oFRDo REDUCTION IN RUNOFF DUE TO AFFORESTATION	vLRLi RIVER LOSSES
	km^2	km^2	km^2	km^2	million m^3/a	million m^3/a	million m^3/a	million m^3/a
L30C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L30D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L40A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L40B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L50A	0.31	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L50B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L60A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L60B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L70A	0.39	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L70B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L70C	2.96	0.00	0.00	0.00	0.06	0.00	0.00	0.00
L70D	0.58	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L70E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L70F	7.03	0.00	0.00	0.00	0.25	0.00	0.00	0.00
L70G	23.12	0.00	0.00	0.00	1.53	0.00	0.00	0.00
L81A	6.37	0.00	0.00	0.00	0.53	0.00	0.00	0.00
L81B	14.95	0.00	0.00	0.00	0.90	0.00	0.00	0.00
L81C	38.02	0.00	0.00	0.00	2.25	0.00	0.00	0.00
L81D	35.25	0.00	0.00	0.00	1.84	0.00	0.00	0.00
L82A	83.12	0.00	0.53	0.00	5.77	0.00	0.02	0.00
L82B	43.12	0.00	1.29	0.00	4.23	0.00	0.08	0.00
L82C	14.74	0.00	0.00	0.00	1.50	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aCAUi AREA UNDER DRYLAND SUGAR CANE	aFCAi AREA UNDER AFFORESTATION	aFINi AREA OF INDIGENOUS FORESTS	oARDo REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	oCDo REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	oFRDo REDUCTION IN RUNOFF DUE TO AFFORESTATION	vLRLi RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
L82D	17.08	0.00	0.00	0.00	1.50	0.00	0.00	0.00
L82E	14.81	0.00	0.00	0.00	1.14	0.00	0.00	0.00
L82F	11.25	0.00	0.00	0.00	0.68	0.00	0.00	0.00
L82G	12.54	0.00	0.00	0.00	0.68	0.00	0.00	0.00
L82H	4.93	0.00	0.00	0.00	0.25	0.00	0.00	0.00
L82J	0.15	0.00	0.00	0.00	0.01	0.00	0.00	0.00
L90A	3.45	0.00	0.00	0.00	0.27	0.00	0.00	0.00
L90B	1.65	0.00	28.67	0.00	0.21	0.00	1.86	0.00
L90C	4.74	0.00	59.79	0.00	0.64	0.00	4.83	0.00
M10A	0.20	0.00	0.00	0.00	0.02	0.00	0.00	0.00
M10B	18.17	0.00	33.05	0.00	1.83	0.00	2.06	0.00
M10C	20.39	0.00	1.78	0.00	2.21	0.00	0.13	0.00
M10D	10.28	0.00	0.00	0.00	0.42	0.00	0.00	0.00
M20A	12.22	0.00	0.00	0.00	1.05	0.00	0.00	0.00
M20B	29.25	0.00	25.72	0.00	4.67	0.00	1.73	0.00
M30A	13.54	0.00	0.00	0.00	0.44	0.00	0.00	0.00
M30B	9.52	0.00	0.00	0.00	0.27	0.00	0.00	0.00
N11A	0.37	0.00	0.00	0.00	0.02	0.00	0.00	0.00
N11B	1.20	0.00	0.00	0.00	0.01	0.00	0.00	0.00
N12A	1.32	0.00	0.00	0.00	0.06	0.00	0.00	0.00
N12B	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N12C	0.61	0.00	0.00	0.00	0.02	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	vLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km^2	km^2	km^2	km^2	million m^3/a	million m^3/a	million m^3/a	million m^3/a
N13A	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N13B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N13C	16.55	0.00	0.00	0.00	0.53	0.00	0.00	0.00
N14A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N14B	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N14C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N14D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N21A	3.45	0.00	0.00	0.00	0.12	0.00	0.00	0.00
N21B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N21C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N21D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N22E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N23A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N23B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N24A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N24B	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N24C	0.29	0.00	0.00	0.00	0.01	0.00	0.00	0.00
N24D	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aCAUi AREA UNDER DRYLAND SUGAR CANE	aFCAi AREA UNDER AFFORESTATION	aFINi AREA OF INDIGENOUS FORESTS	oARDo REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	oCDo REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	oFRDo REDUCTION IN RUNOFF DUE TO AFFORESTATION	vLRLi RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
N30A	0.17	0.00	0.00	0.00	0.01	0.00	0.00	0.00
N30B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N30C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N40A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
N40B	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.00
N40C	1.66	0.00	0.00	0.00	0.11	0.00	0.00	3.00
N40D	1.58	0.00	0.00	0.00	0.07	0.00	0.00	0.00
N40E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
N40F	7.78	0.00	0.00	0.00	0.29	0.00	0.00	4.00
P10A	5.27	0.00	2.14	0.00	0.38	0.00	0.05	0.00
P10B	4.51	0.00	0.00	0.00	0.26	0.00	0.00	0.00
P10C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P10D	0.26	0.00	0.00	0.00	0.01	0.00	0.00	0.00
P10E	0.78	0.00	0.00	0.00	0.03	0.00	0.00	0.00
P10F	11.20	0.00	0.00	0.00	0.61	0.00	0.00	0.00
P10G	0.41	0.00	0.00	0.00	0.02	0.00	0.00	0.00
P20A	51.10	0.00	0.00	0.00	4.89	0.00	0.00	0.00
P20B	57.19	0.00	0.00	0.00	3.95	0.00	0.00	0.00
P30A	22.12	0.00	3.40	0.00	1.65	0.00	0.08	0.00
P30B	5.49	0.00	0.00	0.00	0.30	0.00	0.00	0.00
P30C	0.38	0.00	0.00	0.00	0.01	0.00	0.00	0.00
P40A	40.11	0.00	0.75	0.00	3.17	0.00	0.02	0.00

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	vLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km^2	km^2	km^2	km^2	million m^3/a	million m^3/a	million m^3/a	million m^3/a
P40B	5.62	0.00	0.00	0.00	0.32	0.00	0.00	0.00
P40C	10.98	0.00	0.00	0.00	0.66	0.00	0.00	0.00
P40D	13.51	0.00	0.00	0.00	1.05	0.00	0.00	0.00
Q11A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q11B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q11C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q11D	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q12A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q12B	0.15	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Q12C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
Q13A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
Q13B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
Q13C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q14A	0.53	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Q14B	3.51	0.00	0.00	0.00	0.16	0.00	0.00	0.00
Q14C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q14D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q14E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q21A	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q21B	1.38	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Q22A	0.11	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Q22B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION	aCAUi AREA UNDER DRYLAND SUGAR CANE	aFCAi AREA UNDER AFFORESTATION	aFINi AREA OF INDIGENOUS FORESTS	oARDo REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	oCDo REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	oFRDo REDUCTION IN RUNOFF DUE TO AFFORESTATION	vLRLi RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
Q30A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q30B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q30C	0.08	0.00	0.00	0.00	0.00	0.00	0.00	5.00
Q30D	1.43	0.00	0.00	0.00	0.03	0.00	0.00	2.00
Q30E	7.97	0.00	0.00	0.00	0.16	0.00	0.00	3.00
Q41A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q41B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q41C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q41D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q42A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q42B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q43A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q43B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q44A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q44B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q44C	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q50A	3.48	0.00	0.00	0.00	0.08	0.00	0.00	6.00
Q50B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
Q50C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q60A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q60B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q60C	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	vLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
Q70A	0.79	0.00	0.00	0.00	0.03	0.00	0.00	4.00
Q70B	2.66	0.00	0.00	0.00	0.12	0.00	0.00	5.00
Q70C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
Q80A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q80B	0.37	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Q80C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q80D	0.88	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Q80E	0.32	0.00	0.00	0.00	0.01	0.00	0.00	4.00
Q80F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q80G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
Q91A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
Q91B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00
Q91C	6.55	0.00	0.00	0.00	0.26	0.00	0.00	6.00
Q92A	0.53	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Q92B	0.00	0.00	0.00	1.43	0.00	0.00	0.00	0.00
Q92C	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00
Q92D	0.71	0.00	3.06	2.17	0.06	0.00	0.10	0.00
Q92E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q92F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q92G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q93A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
Q93B	5.50	0.00	0.00	0.00	0.21	0.00	0.00	1.00

QUATERNARY CATCHMENT	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCDo	oFRDo	vLRLi
	AREA UNDER ALIEN VEGETATION	AREA UNDER DRYLAND SUGAR CANE	AREA UNDER AFFORESTATION	AREA OF INDIGENOUS FORESTS	REDUCTION IN RUNNOFF DUE TO ALIEN VEGETATION	REDUCTION IN RUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km²	km²	km²	km²	million m³/a	million m³/a	million m³/a	million m³/a
Q93C	1.52	0.00	0.00	0.00	0.06	0.00	0.00	7.00
Q93D	8.88	0.00	0.00	0.00	0.54	0.00	0.00	6.00
Q94A	9.42	0.00	3.56	5.38	1.20	0.00	0.16	0.00
Q94B	2.33	0.00	11.62	8.10	0.25	0.00	0.59	0.00
Q94C	5.82	0.00	30.03	5.43	0.70	0.00	1.39	0.00
Q94D	0.00	0.00	3.38	3.55	0.00	0.00	0.08	0.00
Q94E	4.21	0.00	24.73	9.09	0.34	0.00	0.55	0.00
Q94F	0.00	0.00	0.00		0.00	0.00	0.00	0.00
TOTALS	939.41	0.00	417.58	64.61	88.46	0.00	53.66	112.00

APPENDIX F.6
FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

EASTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2: NOTES ON PROCEEDINGS

Prepared for

THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY
Directorate: Water Resources Planning

By:

NINHAM SHAND
Environmental & Engineering Consultants

81 Church Street, Cape Town, 8001
P O Box 1347, Cape Town, 8000
Tel: (021) 424 5544
Fax: (021) 424 5588

Report No. 2948b/ 8331 April 2000

EASTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2: NOTES ON PROCEEDINGS

CONTENTS

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Eastern Cape Water Resources Situation Assessment has been commissioned by the Directorate: Water Resources Planning, of the Department of Water Affairs and Forestry (DWAF) as one of several studies required to provide data for the development of a national water resource strategy in compliance with the provisions of the National Water Act No. 36 of 1998. A requirement of the study was that rough, desktop (i.e. based on available information) estimates of the ecological flow requirements of rivers should be made for each quaternary catchment in the study area (Ninham Shand, 1999) by a procedure prescribed by the Department (Kleynhans *et al.*, 1998). During these workshops, the Ecological Importance and Sensitivity Class (EI&SC) was determined in order to derive the Default Ecological Management Class (DEMC).

Subsequently, a second phase of workshops was commissioned to build on work done in Phase 1. In the Phase 2 workshops, the EI&SC and DEMC were reviewed and then the Present Ecological Status Class (PESC) and Attainable Ecological Status Class (AESC) of rivers within quaternary catchments were determined. This second round of workshops was therefore primarily concerned with assessing the present ecological status of rivers, as well as their potential for rehabilitation with respect to flow, and obtaining an Attainable Ecological Status Class for the rivers. Phase 2 also comprises a rough, desktop estimate, and is based on the methodology prescribed by the Department (Kleynhans, 1999 - see Annexure A). These notes are in respect of the second phase of workshops held for this purpose.

1.2 PARTICIPANTS

It was decided that a two day workshop would be held and a number of experts representing various disciplines relating to rivers were invited to attend. This group of experts was selected by a group referral method. In order to contain costs and facilitate progress, the group was limited to six people. The workshop was held at the Institute for Water Research at Rhodes University in Grahamstown and was facilitated by Neels Kleynhans of the Department of Water Affairs and Forestry's Institute for Water Quality Studies, and Susie Tyson of Ninham Shand's Environmental Section. The delegates who took part in the workshop are as follows:

- Dr N Kleynhans of DWAF (IWQS)
- Dr A Bok of Anton Bok & Associates
- Prof J O'Keefe of the Institute for Water Research
- Mrs H James of the Albany Museum
- Dr J Cambray of the Albany Museum
- S Tyson of Ninham Shand

1.3 PURPOSE AND STRUCTURE OF THIS REPORT

The purpose of this report is to summarise the findings of the workshop. It contains information on the EI&SC, DEMC, PESC, and AESC of the main stem river in each quaternary catchment. In addition, during the workshop, issues and concerns were raised and these are summarised in order to convey these concerns to DWAF. Lastly, it was suggested at the workshop that participants should be given the opportunity to review the findings. Therefore, this draft report affords the participants the opportunity to review the findings by assessing the EI&SC, DEMC, PESC and AESC information contained in the figures and spreadsheet.

CHAPTER 2: METHODOLOGY

2.1 INTRODUCTION

The methodology utilised in the workshop is described in Kleynhans (1999 - see Annexure A). This methodology is summarised in Figure 2.1, which indicates the steps required in the determination of the AEMC.

The first step in the process is to determine the EI&SC. The EI&SC refers to the ecological importance and sensitivity of rivers, i.e., an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. Once the EI&SC has been determined, this index is used as an indicator of the DEMC. For the purposes of the National Water Act, a high EI&SC should justify the assignment of a very high DEMC, as the DEMC is defined in terms of the sensitivity of a system to disturbance and the risk of damaging the system and its capacity for self-recovery. These first two steps in assessing the AEMC were undertaken during the first phase workshop and were merely reviewed during this second phase workshop.

After the EI&SC and DEMC have been determined, the PESC needs to be assessed. This PESC is based on the present habitat integrity (i.e. ecological integrity, condition and naturalness) of the system. Using the EI&SC, DEMC and PESC, the AEMC is then determined. The AEMC is then used as an input into the hydrological model of Hughes and Munster, and is indicative of the most attainable ecological management class that can be achieved for each quaternary as a result of restoring the system from the PESC. In the context of the workshop, restoration is defined as the reestablishment of the structure and function of an ecosystem, including its natural diversity within a 5 year period as a result of changing flows only (Kleynhans, 1999).

Utilisation of this methodology was essential in order to ensure a consistent approach for each of the provinces. An updated version of the previous EcoInfo programme was used to process all the data obtained about the quaternary catchments during the workshop. The programme allowed the classes to be derived immediately as the data was entered.

2.2 GROUPING OF QUATERNARY CATCHMENTS

Due to the vast number of quaternary catchments in the Eastern Cape, it was decided that "like" quaternary catchments would be grouped together. Those catchments which displayed similar characteristics were therefore dealt with as one catchment, and thus only one quaternary catchment for each group was entered into the EcoInfo database. Where knowledge about riverine systems was low, the systems were compared to more well known rivers and low confidence scorings were given.

The quaternary catchment groupings are listed below. Those catchments in bold and underlined contain information in the database that is relevant for all quaternary catchments within that grouping. It was decided during the second round of workshops to subdivide certain groups so as to facilitate assessment thereof. These groups are indicated in the following list.

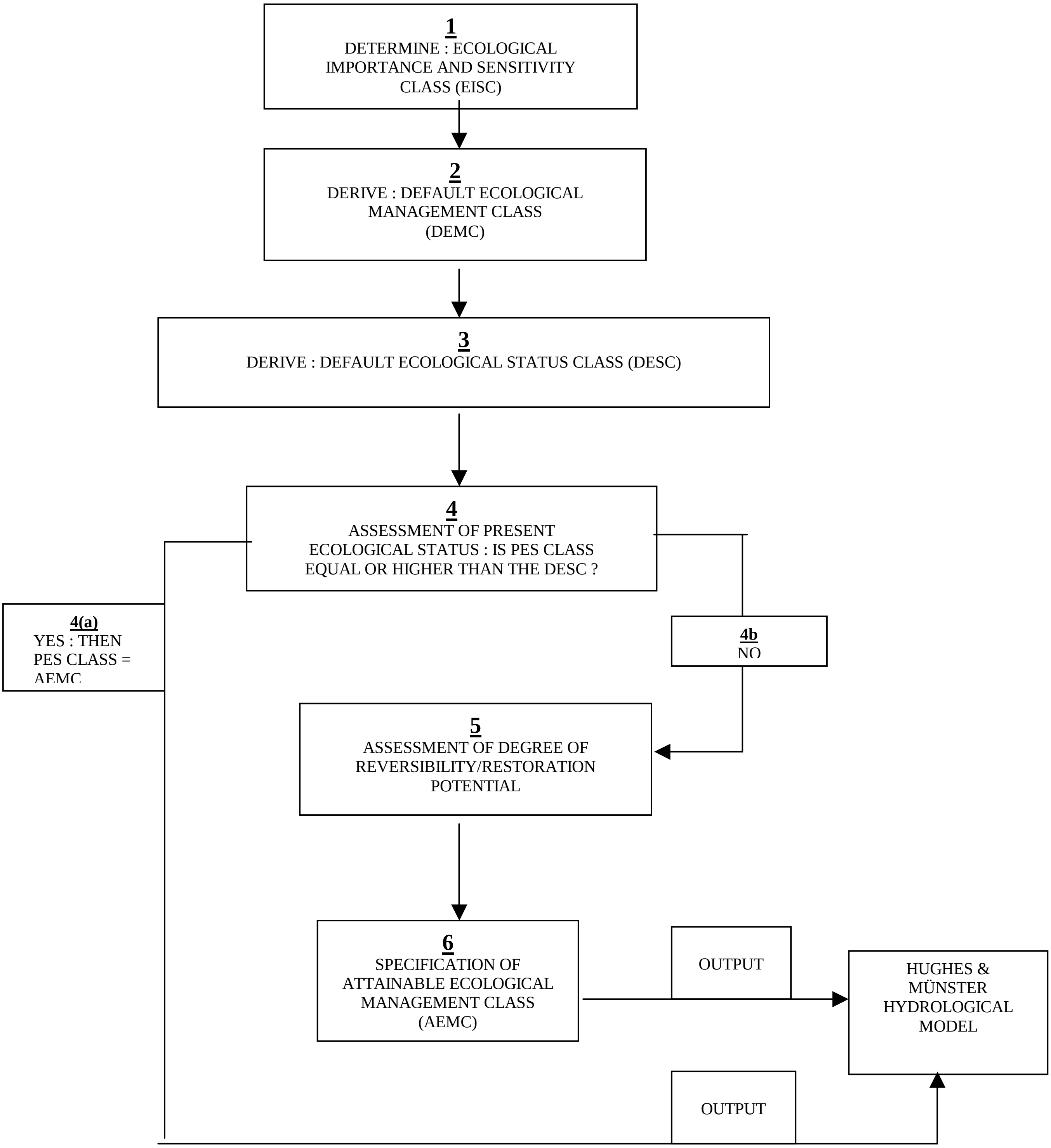


Figure 2.1 : Flow diagram indicating the sequence of steps proposed for the determination of the Attainable Ecological Management Class (From Kleynhans, 1999)

- **K70B**, K80A, K80B, K80C, K80D
- **K80E**, K80F
- **K90A**
- **K90B**, K90C, K90D, K90E
- **K90F**
- **K90G**

- **L11A**, L11B, L11C, L11D, L11E, L11F
- **L12A**, L12B, L12C, L12D
- **L21A**, L21B, L21C, L21D, L21E, L21F, L22A, L22B, L22C, L22D, L23A, L23B, L23C, L23D
- **L40A**, L40B, L60A, L60B, L30A, L30B, L30C, L30D, L50B
- **L70A**, L70B, L70C, L70D, L70E, L70F, L70G
- **L81A**, L81B
- **L81C**, L81D
- **L82A**, L82B, L82C, L82D, L82E, L82F, L82G
- **L82H**, L82J
- **L90A**, L90B, L90C

- **M10A**
- **M10B**
- **M10C**, M10D
- **M20A**
- **M20B**
- **M30A**
- **M30B**
- **N11A**, N11B, N12A, N12B, N12C
- **N13A**, N13B
- **N13C**, 14D, N21A, N21D
- **N14A**, N14B, N14C, N24A
- **N21B,** N21C, N30A
- **N22A**, N22D
- **N23A**
- **N23B**
- **N24B**, N24C, N24D, N22B, N22C, N22E
- **N30B**, N30C
- **N40D**

- **N 40A**
- **N40B**, N40C N40E
- **N40F**

- **P10A**, P10B, P10C, P10D, P30A, P40A
- **P10E**, P10F, P10G, P20A, P20B
- **P30B**, P40B, P40C, P40D

- **Q12C,** Q13A, Q13B, Q13C, Q22B, Q30B, Q30C, Q30D, Q30E
- **Q14A**, Q14D, Q14E, Q21A, Q21B, Q22A, Q30A
- **Q14B**, Q14C, Q11A, Q11B, Q11C, Q11D, Q12A, Q12B
- **Q43B**, Q42B, Q41A, Q41B, Q41C, Q41D Q44A, Q44B, Q44C
- **Q50A**, Q50B, Q50C, Q70A, Q70B, Q70C, Q91A, Q91B, Q91C
- **Q60A**, Q60B, Q60C, Q92B, Q92C, Q92D, Q92E, Q92F, Q92G
- **Q80A**
- **Q80B**, Q80C, Q80D, Q80E
- **Q80F**
- **Q80G**
- **Q92A**, Q94A, Q94B, Q94C, Q94D, Q94E, Q94F
- **Q93A**, Q93B, Q93C, Q93D

- **R10C**, R10D, R10E, R10G, R10H
- **R10J**, R10K, R10L, R10M
- **R20A**, R10A, R10B, R10F
- **R20B**, R20C, R20D, R20E, R20F, R20G
- **R30A**, R30B, R30C, R30D, R30E, R30F
- **R50A**, R50B, R40A, R40B, R40C

- **S10E**, S10G, S10H, S10J, S20C, S20D
- **S31A**, S31B, S10A, S10B, S10C, S10D, S10F, S20A, S20B
- **S31D**, S31F, S32J, S32K, S32L, S32M, S40A, S40B, S40C
- **S32D**, S32A, S32B, S32C, S32E, S32F, S32G, S32H, S31C, S31E, S31G
- **S40D**, S40E, S40F, S70A, S70B, S70F
- **S50A**, S50B, S50C, S50D, S50E
- **S50F**, S50G, S50H, S50J
- S60A, **S60B**, S60C, S60D, S60E
- **S70C**, S70D, S70E
- **T11A**, T11B, T11C, T11D, T11E, T11F, T12A
- **T12B**, T12C, T12D, T12E, T12F, T12G, T13A, T13B, T13C, T11G, T11H

- **T13D**, T13E
- **T20A**, T20B
- **T20C, T20D, T20E, T20G**
- **T20F**
- **T32A, T32B, T32C, T32D, T32E**
- **T32G**
- **T33G**, T33H, T33J, T32F, T32H, T34H, T34J, T34K, T35K, T35L, T35M
- **T35A**, T35B, T35C, T35D, T35E, T35F, T35G, T35H, T34A, T34B, T34C, T34D, T34E, T34F, T34G, T33A, T33B, T33C, T33D, T33E, T33F, T31A, T31B, T31C, T31D, T31E, T31F, T31G, T31H, T31J
- **T36A**, T36B
- **T40A**, T40B, T40C, T40D, T40E
- **T60A**, T60B, T60C, T60D, T60E, T60F, T60G, T60H, T60J, T60K
- **T90A**, T90B, T90C, T90D, T90E, T90F, T90G, T80 (all), T70 (all), T40F, T40G

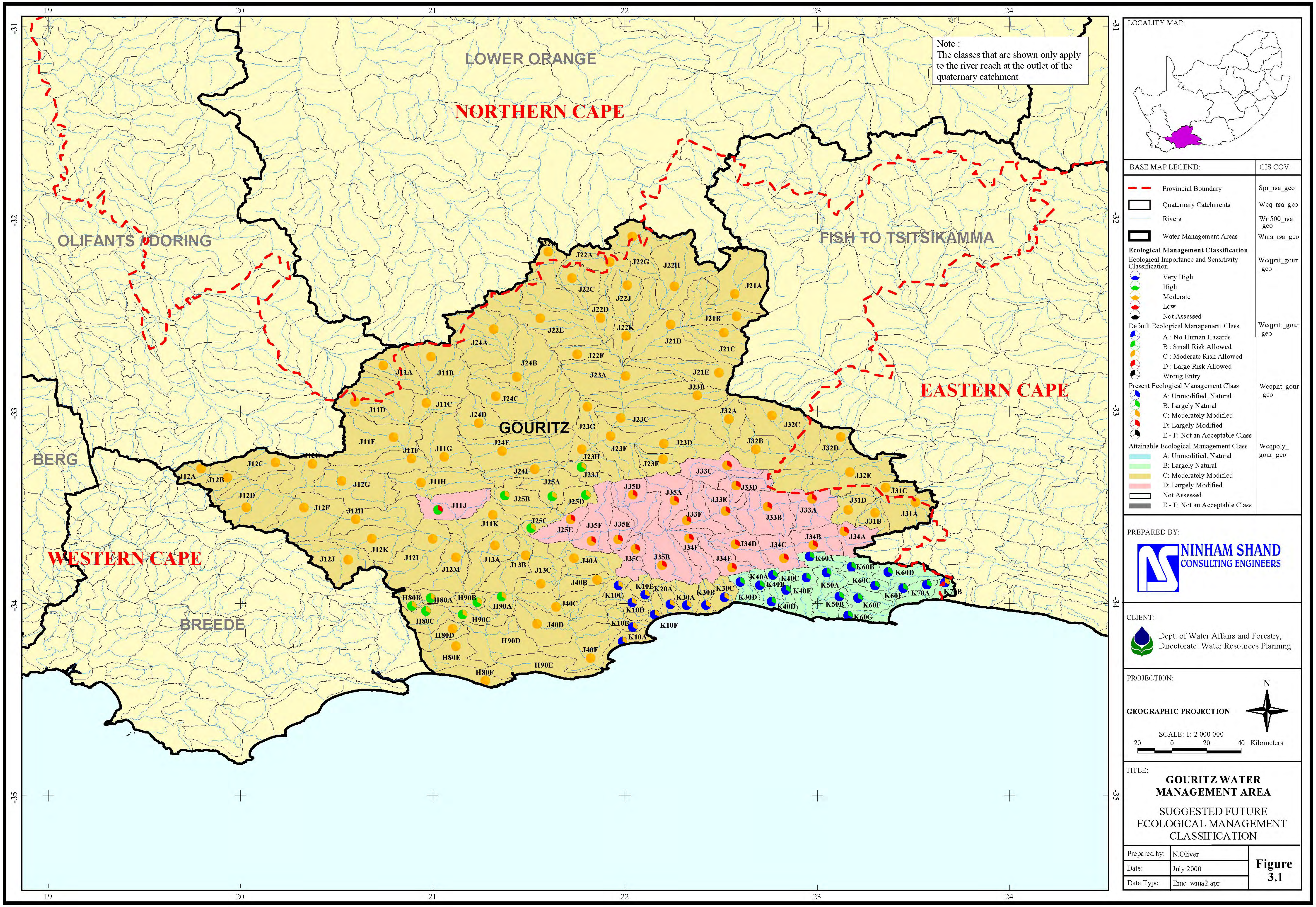
CHAPTER 3: RESULTS OF THE WORKSHOP

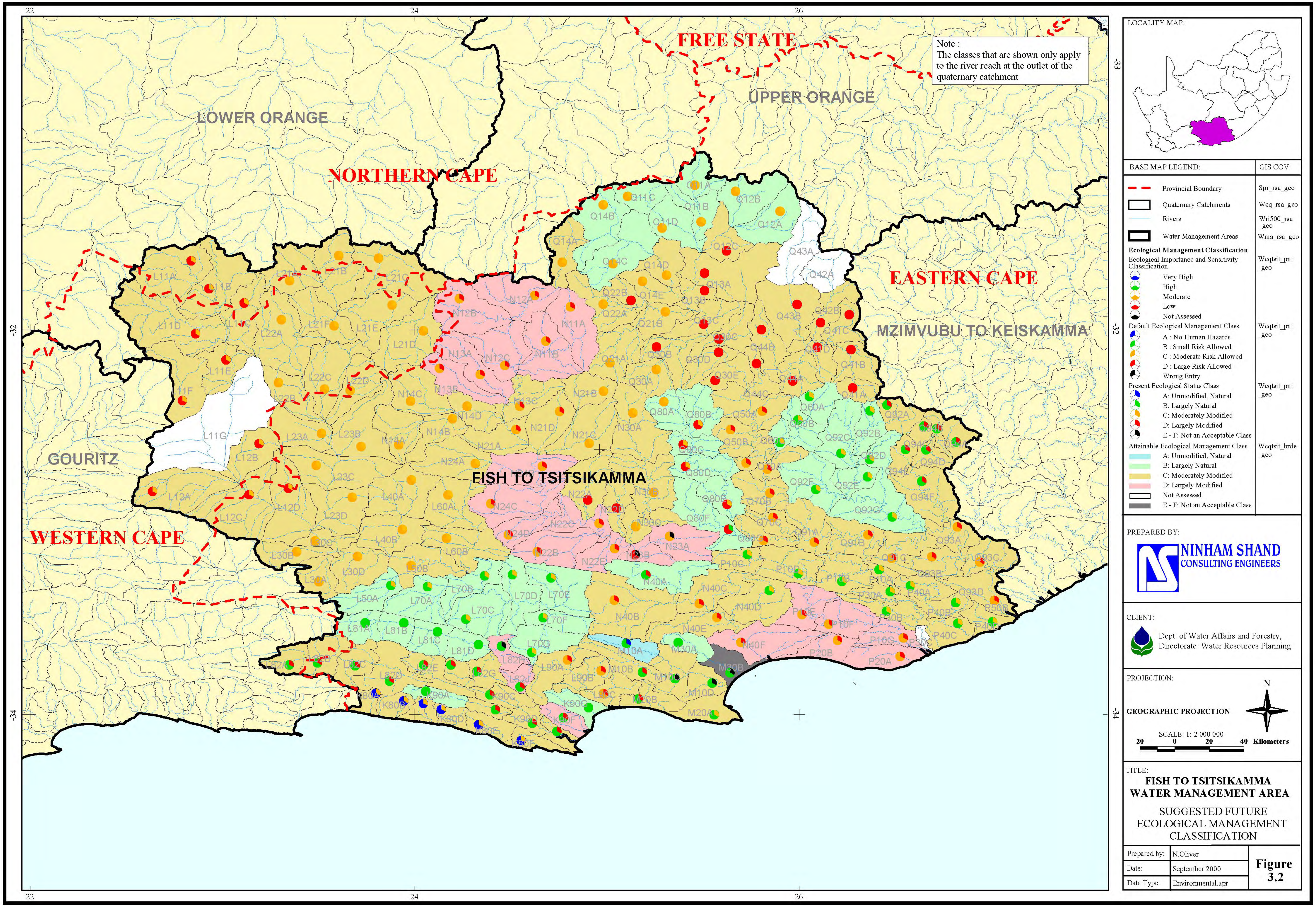
3.1 INTRODUCTION

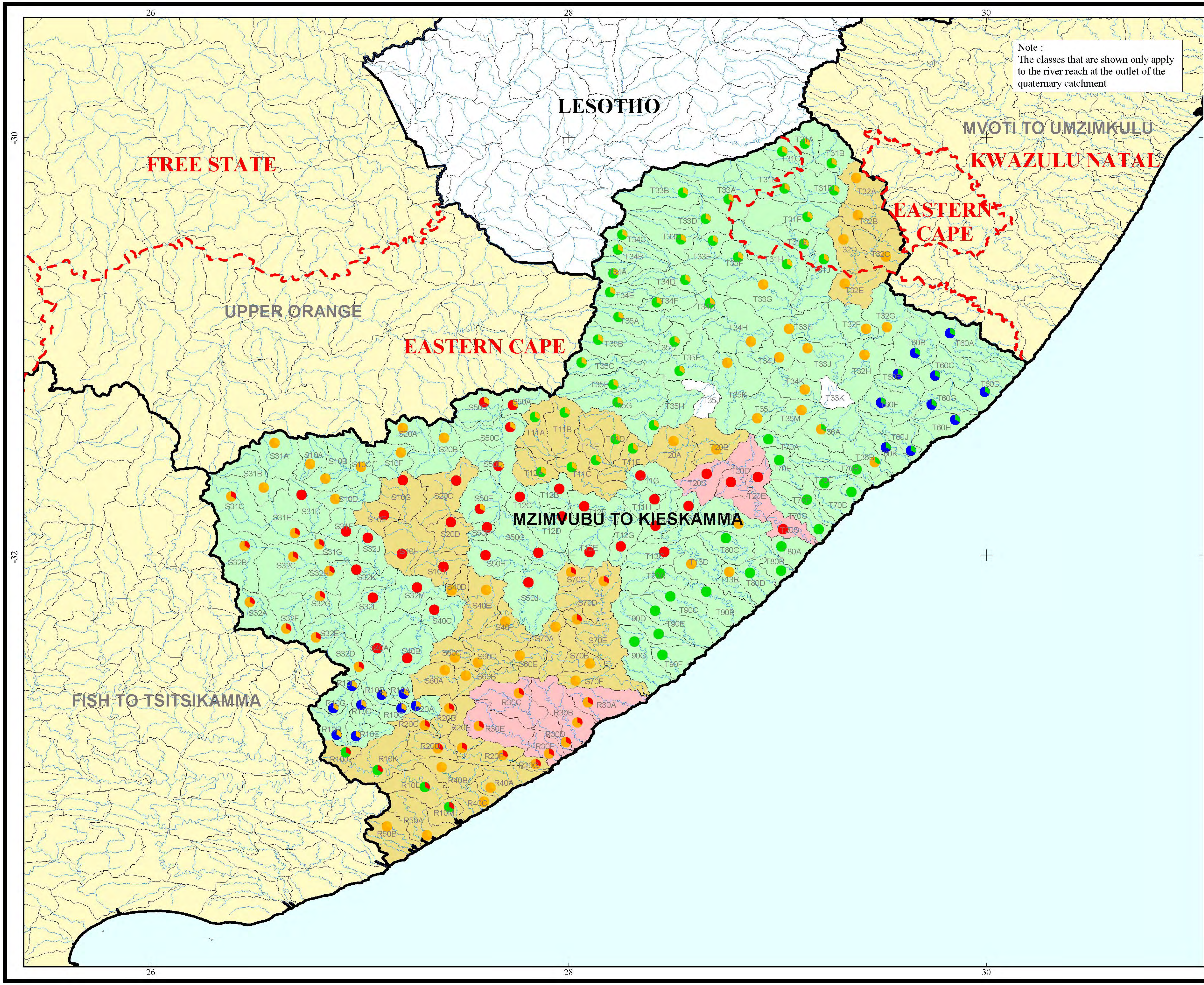
During the previous workshop, a number of participants requested that the results of the workshop be reviewed once they have been captured and made available by DWAF in a GIS format. The primary reason for this request can be attributed to the conservative EI&SC which the Ecoinfo programme derived from information put into the different categories. Participants felt that the DEMC were sometimes not reflective of the river, and also wanted to get an overall picture of the quaternary catchments for the Eastern Cape.

3.2 MANAGEMENT CLASSES

Since the abovementioned information was not available in GIS format prior to the Phase 2 workshops, this report contains a summary of the EI&SC and DEMC, as well as the PESC and AESC in both GIS format (see Figures 3.1 to 3.3) and the data entered in the Ecoinfo programme on CD Rom (see Annexure B).


LOWER ORANGE
NORTHERN CAPE
OLIFANTS / DORING
FISH TO TSITSIKAMMA
EASTERN CAPE
GOURITZ
BERG
WESTERN CAPE
BREEDE
Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Wcq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Wcqpnt_gour_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Wcqpnt _gour_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
Wcqpnt_gour_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Wcqpoly_gour_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 2 000 000
20 0 20 40 Kilometers
TITLE:
GOURITZ WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Eme_wma2.apr
Figure 3.1


Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
FREE STATE
UPPER ORANGE
LOWER ORANGE
NORTHERN CAPE
EASTERN CAPE
MZIMVUBU TO KEISKAMMA
GOURITZ
WESTERN CAPE
FISH TO TSITSIKAMMA
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Wcq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Wcqtsit_pnt_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Wcqtsit_pnt_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Status Class
Wcqtsit_pnt_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Wcqtsit_brde_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 2 000 000
20 0 20 40 Kilometers
TITLE:
FISH TO TSITSIKAMMA
WATER MANAGEMENT AREA
SUGGESTED FUTURE
ECOLOGICAL MANAGEMENT
CLASSIFICATION
Prepared by: N.Oliver
Date: September 2000
Data Type: Environmental.apr
Figure 3.2



LOCALITY MAP:

BASE MAP LEGEND:	GIS COV:
Provincial Boundary	Spr_rsa_geo
Quaternary Catchments	Wcq_rsa_geo
Rivers	Wri500_rsa_geo
Water Management Areas	Wma_rsa_geo
Ecological Management Classification	
Ecological Importance and Sensitivity Classification	Wcqkies_pnt_geo
Very High	
High	
Moderate	
Low	
Not Assessed	
Default Ecological Management Class	Wcqkies_pnt_geo
A : No Human Hazards	
B : Small Risk Allowed	
C : Moderate Risk Allowed	
D : Large Risk Allowed	
Wrong Entry	
Present Ecological Status Class	Wcqkies_pnt_geo
A: Unmodified, Natural	
B: Largely Natural	
C: Moderately Modified	
D: Largely Modified	
E - F: Not an Acceptable Class	
Attainable Ecological Management Class	Wcqkies_poly_geo
A: Unmodified, Natural	
B: Largely Natural	
C: Moderately Modified	
D: Largely Modified	
Not Assessed	
E - F: Not an Acceptable Class	

PREPARED BY:

NINHAM SHAND CONSULTING ENGINEERS

CLIENT:

Dept. of Water Affairs and Forestry, Directorate: Water Resources Planning

PROJECTION:

GEOGRAPHIC PROJECTION

N

SCALE: 1: 2 000 000

20 0 20 40 Kilometers

TITLE:

MZIMVUBU TO KIESKAMMA WATER MANAGEMENT AREA

SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION

Prepared by:	N.Oliver	**Figure 3.3**
Date:	September 2000	
Data Type:	Environmental.apr	

CHAPTER 4: DISCUSSION

4.1 COMMENTS AND OBSERVATIONS BY PARTICIPANTS

The participants made the following comments with regard to the methodology and the updated EcoInfo computer programme in particular. At the end of the workshop the participants were encouraged to provide feedback on the strengths and weaknesses of the process. These are:

- The computer programme tended to crash and over-writing of previous data caused problems. As a result, there was a lack of confidence in the computer programme.

- There were problems with the data from the previous workshop, as data had not been converted to the requested GIS format. Furthermore, data seemed to be missing from the DWAF report on the Eastern Cape rivers.

- The workshop highlights rivers which need more baseline studies (use surveys as well as SASS in the more detailed studies).

- All the participants felt more confident with Phase 2 than with Phase 1, however, the process could still be improved with the use of up to date GIS land usage maps with the EI&SC on them.

- Having Neels Kleynhans present at the workshop to interpret the method and to ensure consistency improved the process greatly.

- Inclusion of an amphibian and vegetation expert would aid the process and validity of the Eastern Cape data.

- Findings should be treated with extreme caution and only used as a desktop estimate as some of the confidence levels are very low.

- There is a need for a follow-up survey to validify the data.

- WR90 quaternary areas are still a problem as they are non-ecological (should be an eco-region approach)

- There is a need to note that present status of rivers can vary within groupings due to localised degradation of sections of rivers.

- In order to aid the process, more readily available information in the form of maps (e.g. land-use coverages, vegetation zones, etc) should have been made available.

- Even where very little or no direct knowledge of a river was available, it proved possible to provide quite a good assessment by using regional expertise to extrapolate and using 1:250 000 maps to examine contours (for gradient, gorges, etc), roads (for indicators of access or isolation), towns and villages (as indications of population density) and landuses (e.g. plantations).

- Confidence scores should be extrapolated to ensure that where riverine systems are not well known this can be indicated.

- Need for GIS database overlay to review data.

- Models based only on flow and water quality therefore improvements to the riverine system by means of changing landuse practices was not taken into account.

- The overall workshop is still a lengthy process.

CHAPTER 5: CONCLUSIONS

5.1 CONCLUSIONS

This report has described the methodology used during the workshop and also presented the observations made by participants regarding the process and the methodology. Comments on the process, as well as recommendations, can be viewed in Chapter 4. This draft report will be finalised once the results of the study have been reviewed by the workshop participants.

It should be reiterated (from Kleynhans, 1999) that the estimates originating from the application of this procedure only be used for broad, very general planning purposes. In addition, the confidence levels assigned to the various classes are highly variable, depending on the level of knowledge of participants, and this, as well as the comments given regarding each quaternary, should be borne in mind when utilising the data. In all cases where information requirements go beyond the general planning level, the procedures being developed for the determination of the preliminary, intermediate, or full reserve should be applied.

REFERENCES

Kleynhans, C.J. 1999. *A procedure for the determination of the ecological reserve for the purpose of the National Water Balance Model for South African rivers*. Department of Water Affairs and Forestry.

Ninham Shand, 1999. *Eastern Cape water resources situation assessment: Workshop on ecological flow requirements: notes on proceedings.* Prepared for the Department of Water Affairs and Forestry. Report No. 2949/ 7970

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX F.7

ASSUMED RURAL DOMESTIC PER CAPITA WATER REQUIREMENTS PER QUATERNARY

Areas	Rural domestic l/c/d
K80A	37
K80B	38
K80C	37
K80D	114
K80E	45
K80F	47
K90A	140
K90B	62
K90C	148
K90D	133
K90E	47
K90F	39
K90G	49
L11A	116
L11B	93
L11C	43
L11D	50
L11E	39
L11F	52
L11G	73
L12A	70
L12B	71
L12C	81
L12D	155
L21A	90
L21B	71
L21C	76
L21D	67
L21E	69
L21F	62
L22A	70
L22B	154
L22C	155
L22D	159
L23A	164
L23B	155
L23C	158
L23D	146
L30A	70
L30B	157
L30C	77
L30D	133
L40A	158
L40B	135
L50A	133
L50B	137
L60A	67

Areas	Rural domestic l/c/d
L60B	59
L70A	140
L70B	61
L70C	141
L70D	137
L70E	136
L70F	145
L70G	128
L81A	127
L81B	47
L81C	46
L81D	124
L82A	34
L82B	114
L82C	35
L82D	36
L82E	140
L82F	143
L82G	141
L82H	119
L82J	141
L90A	36
L90B	36
L90C	36
M10A	152
M10B	136
M10C	37
M10D	46
M20A	38
M20B	36
M30A	127
M30B	50
N11A	152
N11B	147
N12A	74
N12B	147
N12C	143
N13A	139
N13B	136
N13C	58
N14A	140
N14B	64
N14C	134
N14D	138
N21A	139
N21B	159
N21C	145
N21D	178
N22A	129
N22B	129
N22C	126
N22D	129
N22E	125
N23A	139

Areas	Rural domestic l/c/d
N23B	128
N24A	150
N24B	152
N24C	134
N24D	49
N30A	55
N30B	131
N30C	130
N40A	123
N40B	50
N40C	37
N40D	44
N40E	38
N40F	49
P10A	127
P10B	47
P10C	129
P10D	46
P10E	47
P10F	120
P10G	41
P20A	39
P20B	124
P30A	118
P30B	116
P30C	119
P40A	38
P40B	42
P40C	43
P40D	43
Q11A	137
Q11B	130
Q11C	131
Q11D	128
Q12A	141
Q12B	62
Q12C	130
Q13A	51
Q13B	131
Q13C	130
Q14A	143
Q14B	44
Q14C	133
Q14D	129
Q14E	133
Q21A	216
Q21B	132
Q22A	142
Q22B	135
Q30A	149
Q30B	141
Q30C	135
Q30D	125
Q30E	49

Areas	Rural domestic l/c/d
Q41A	130
Q41B	130
Q41C	58
Q41D	148
Q42A	139
Q42B	139
Q43A	131
Q43B	140
Q44A	159
Q44B	153
Q44C	124
Q50A	123
Q50B	121
Q50C	122
Q60A	129
Q60B	130
Q60C	133
Q70A	46
Q70B	41
Q70C	129
Q80A	135
Q80B	141
Q80C	125
Q80D	43
Q80E	124
Q80F	133
Q80G	123
Q91A	133
Q91B	127
Q91C	44
Q92A	44
Q92B	130
Q92C	133
Q92D	131
Q92E	55
Q92F	59
Q92G	125
Q93A	57
Q93B	37
Q93C	34
Q93D	37
Q94A	35
Q94B	34
Q94C	34
Q94D	35
Q94E	38
Q94F	36

APPENDIX G

WATER RESOURCES

APPENDIX G.1	**Hydrological data per quaternary catchment.**
APPENDIX G.2	**Potential vulnerability of surface water and groundwater to microbial contamination.**
APPENDIX G.3	**Sedimentation data.**
APPENDIX G.4	**Groundwater.**
APPENDIX G.5	**Water quality information.**

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX G.1

HYDROLOGICAL DATA PER QUATERNARY CATCHMENT

1	2	6	4	3	5
Areas	aMTCi	eMRTo	oMAEi	oMAPi	oMARi
	Catchment area	Natural mean annual runoff (accumulative)	Mean annual evaporation	Mean annual precipitation	Natural mean annual runoff (incremental)
	km²	million m³/a	mm/a	mm/a	million m³/a
K80A	146	72.33	1400	1030	72.33
K80B	208	101.4	1400	1031	101.40
K80C	189	81.01	1400	1017	81.01
K80D	176	67.34	1400	936	67.34
K80E	266	53.75	1400	895	53.75
K80F	221	34.04	1400	769	34.04
K90A	214	30.42	1400	716	30.42
K90B	150	55.95	1400	774	25.53
K90C	267	13.59	1450	596	13.59
K90D	215	86.6	1400	693	17.06
K90E	176	98.62	1400	676	12.02
K90F	250	18.78	1400	699	18.78
K90G	286	17.14	1460	654	17.14
L11A	930	5.39	2150	218	5.39
L11B	875	11.8	2155	235	6.41
L11C	568	16.3	2180	241	4.50
L11D	1286	8.11	2185	224	8.11
L11E	456	27.29	2250	227	2.88
L11F	745	4.27	2280	220	4.27
L11G	2024	37.64	2300	195	6.08
L12A	906	2.42	2310	159	2.42
L12B	519	40.17	2300	192	2.53
L12C	1068	45.06	2255	152	2.47
L12D	952	48.27	2220	170	3.21
L21A	609	5.24	2135	244	5.24
L21B	756	12.25	2105	250	7.01
L21C	1033	11.05	2040	300	11.05
L21D	865	17.18	2000	367	17.18
L21E	712	35.01	2050	289	6.78

1	2	6	4	3	5
Areas	**aMTCi**	**eMRTo**	**oMAEi**	**oMAPi**	**oMARi**
	Catchment area	**Natural mean annual runoff (accumulative)**	**Mean annual evaporation**	**Mean annual precipitation**	**Natural mean annual runoff (incremental)**
	km²	**million m³/a**	**mm/a**	**mm/a**	**million m³/a**
L21F	576	52.66	2115	251	5.40
L22A	1072	61.01	2160	227	8.35
L22B	475	63.31	2185	210	2.30
L22C	760	5.3	2100	235	5.30
L22D	530	74.75	2050	276	6.14
L23A	516	77.23	2200	179	2.48
L23B	818	85.97	2080	235	8.74
L23C	891	90.55	2130	183	4.58
L23D	665	94.2	2110	187	3.65
L30A	361	3.01	1980	284	3.01
L30B	378	5.87	2125	221	2.86
L30C	237	144.9	2100	245	2.47
L30D	552	153.8	1975	249	2.95
L40A	763	3.5	1985	216	3.50
L40B	594	7.4	1975	241	3.90
L50A	466	4.42	1860	295	4.42
L50B	557	169.4	1885	268	3.83
L60A	677	4.04	1920	234	4.04
L60B	671	7.21	1860	218	3.17
L70A	582	3.11	1790	249	3.11
L70B	441	181	1760	217	1.31
L70C	662	183.7	1740	236	2.64
L70D	536	186.4	1735	253	2.72
L70E	702	191.6	1720	283	5.20
L70F	306	194.9	1670	316	3.27
L70G	470	209.4	1640	504	14.50
L81A	332	17.69	1740	527	17.69
L81B	261	26.1	1715	428	8.41
L81C	332	37.53	1670	437	11.43
L81D	308	45.78	1640	393	8.25
L82A	269	14.92	1620	595	14.92
L82B	405	46.38	1630	678	31.46
L82C	362	74.92	1570	674	28.54
L82D	591	106.5	1550	598	31.55

1	2	6	4	3	5
Areas	**aMTCi**	**eMRTo**	**oMAEi**	**oMAPi**	**oMARi**
	Catchment area	**Natural mean annual runoff (accumulative)**	**Mean annual evaporation**	**Mean annual precipitation**	**Natural mean annual runoff (incremental)**
	km²	**million m³/a**	**mm/a**	**mm/a**	**million m³/a**
L82E	365	125	1530	585	18.55
L82F	169	130.7	1540	512	5.68
L82G	265	137.8	1550	472	7.14
L82H	230	188.9	1620	451	5.29
L82J	164	4.96	1530	491	4.96
L90A	516	423.2	1580	542	19.93
L90B	366	459.1	1550	597	35.91
L90C	319	490.9	1530	607	31.78
M10A	265	15.99	1600	533	15.99
M10B	393	24.48	1600	557	24.48
M10C	430	70.97	1550	565	30.50
M10D	307	76.58	1550	471	5.61
M20A	362	20.36	1500	660	20.36
M20B	308	39.66	1500	725	39.66
M30A	258	5.06	1600	451	5.06
M30B	307	10.38	1550	434	5.32
N11A	701	9.28	1850	362	9.28
N11B	775	17.25	1900	333	7.97
N12A	739	9.54	1900	363	9.54
N12B	801	9.11	1950	348	9.11
N12C	657	43.76	1900	354	7.86
N13A	555	8.58	1950	381	8.58
N13B	483	15.87	1950	378	7.29
N13C	492	63.5	1900	307	3.87
N14A	506	4.83	2000	261	4.83
N14B	389	8.75	1950	266	3.92
N14C	657	19.51	2000	390	19.51
N14D	367	33.02	1950	290	4.76
N21A	458	100.3	1900	273	3.81
N21B	388	10.97	1850	411	10.97
N21C	752	20.72	1850	316	9.75
N21D	560	126.5	1850	288	5.48
N22A	607	7.5	1800	277	7.50
N22B	643	3.75	1800	217	3.75

1	**2**	**6**	**4**	**3**	**5**
Areas	**aMTCi**	**eMRTo**	**oMAEi**	**oMAPi**	**oMARi**
	Catchment area	**Natural mean annual runoff (accumulative)**	**Mean annual evaporation**	**Mean annual precipitation**	**Natural mean annual runoff (incremental)**
	km²	**million m³/a**	**mm/a**	**mm/a**	**million m³/a**
N22C	399	162.8	1800	254	3.79
N22D	344	5.56	1800	303	5.56
N22E	343	171.1	1750	240	2.74
N23A	537	8.82	1700	318	8.82
N23B	245	217.7	1700	277	2.64
N24A	667	5.78	1950	246	5.78
N24B	667	138.2	1850	247	5.85
N24C	798	145.6	1850	252	7.44
N24D	384	147.8	1850	214	2.18
N30A	850	20.66	1800	387	20.66
N30B	737	30.49	1800	316	9.83
N30C	347	35.08	1750	315	4.59
N40A	668	224.1	1700	353	6.46
N40B	1211	232.3	1650	319	8.20
N40C	580	245.8	1650	504	13.46
N40D	669	13.61	1600	474	13.61
N40E	510	263.4	1600	364	3.97
N40F	762	280	1550	482	16.61
P10A	126	4.51	1550	600	4.51
P10B	508	16.76	1550	531	12.25
P10C	281	2.38	1650	386	2.38
P10D	564	26.15	1600	432	7.01
P10E	466	34.86	1550	493	8.71
P10F	469	48.53	1550	557	13.67
P10G	343	58.29	1500	550	9.76
P20A	422	30.27	1500	715	30.27
P20B	332	15.43	1550	635	15.43
P30A	176	6.95	1550	623	6.95
P30B	403	18.62	1500	559	11.67
P30C	68	20.31	1500	536	1.69
P40A	312	13.58	1500	635	13.58
P40B	264	21.75	1500	570	8.17
P40C	342	35.93	1450	616	14.18
P40D	246	13.36	1450	666	13.36

1	2	6	4	3	5
Areas	**aMTCi**	**eMRTo**	**oMAEi**	**oMAPi**	**oMARi**
	Catchment area	**Natural mean annual runoff (accumulative)**	**Mean annual evaporation**	**Mean annual precipitation**	**Natural mean annual runoff (incremental)**
	km²	**million m³/a**	**mm/a**	**mm/a**	**million m³/a**
Q11A	382	7.48	1800	396	7.48
Q11B	376	12.67	1800	352	5.19
Q11C	362	4.82	1800	348	4.82
Q11D	481	22.28	1800	316	4.79
Q12A	627	10.22	1750	384	10.22
Q12B	637	12.42	1750	407	12.42
Q12C	428	27.56	1800	343	4.92
Q13A	1031	60.52	1800	327	10.68
Q13B	240	113.2	1800	289	1.71
Q13C	455	117	1800	305	3.81
Q14A	487	6.63	1850	348	6.63
Q14B	726	16.26	1850	345	9.63
Q14C	836	25.12	1850	320	8.86
Q14D	409	28.34	1800	290	3.22
Q14E	343	31.55	1850	307	3.21
Q21A	601	7.76	1850	354	7.76
Q21B	381	19.45	1850	303	3.08
Q22A	518	6.35	1850	348	6.35
Q22B	220	8.61	1850	328	2.26
Q30A	395	7	1850	390	7.00
Q30B	482	11.84	1850	339	4.84
Q30C	421	132.7	1800	328	3.84
Q30D	311	136	1800	344	3.27
Q30E	326	139.5	1800	347	3.52
Q41A	230	7.66	1700	537	7.66
Q41B	434	16.03	1700	449	8.37
Q41C	333	21.78	1700	433	5.75
Q41D	295	57.56	1750	360	2.88
Q42A	446	9.58	1750	454	9.58
Q42B	376	16.08	1750	423	6.50
Q43A	706	9.61	1750	391	9.61
Q43B	803	16.82	1750	341	7.21
Q44A	426	62.24	1750	353	4.68
Q44B	449	65.88	1800	319	3.64

1	2	6	4	3	5
Areas	**aMTCi**	**eMRTo**	**oMAEi**	**oMAPi**	**oMARi**
	Catchment area	**Natural mean annual runoff (accumulative)**	**Mean annual evaporation**	**Mean annual precipitation**	**Natural mean annual runoff (incremental)**
	km²	**million m³/a**	**mm/a**	**mm/a**	**million m³/a**
Q44C	254	68.42	1750	342	2.54
Q50A	640	215.6	1750	373	7.63
Q50B	403	222	1750	410	6.42
Q50C	198	225.2	1700	412	3.22
Q60A	316	8.04	1700	499	8.04
Q60B	370	17.87	1700	506	9.83
Q60C	132	20.28	1700	449	2.41
Q70A	251	250.1	1700	427	4.65
Q70B	458	255.8	1700	375	5.65
Q70C	250	258.6	1650	363	2.80
Q80A	357	7.01	1800	421	7.01
Q80B	450	15.04	1800	407	8.03
Q80C	281	20.34	1800	415	5.30
Q80D	418	33.23	1750	493	12.89
Q80E	365	38.9	1700	376	5.67
Q80F	701	9.07	1700	355	9.07
Q80G	266	51.54	1650	358	3.57
Q91A	478	317.5	1600	397	7.37
Q91B	515	329.2	1600	451	11.69
Q91C	485	337.3	1550	491	8.12
Q92A	324	21.73	1650	662	21.73
Q92B	324	33.34	1650	586	11.61
Q92C	601	51.72	1650	559	18.38
Q92D	249	9.48	1600	594	9.48
Q92E	287	63.9	1600	464	2.70
Q92F	665	4.02	1650	415	4.02
Q92G	884	76.39	1600	466	8.47
Q93A	337	488	1500	445	4.33
Q93B	392	494.2	1500	470	6.18
Q93C	413	501.1	1450	476	6.89
Q93D	491	518.5	1450	561	17.42
Q94A	259	23.57	1550	804	23.57
Q94B	147	33.78	1600	706	10.21
Q94C	135	45.11	1600	768	11.33
Q94D	212	52.56	1550	607	7.45
Q94E	228	9.28	1600	641	9.28

1	**2**	**6**	**4**	**3**	**5**
Areas	**aMTCi**	**eMRTo**	**oMAEi**	**oMAPi**	**oMARi**
	Catchment area	**Natural mean annual runoff (accumulative)**	**Mean annual evaporation**	**Mean annual precipitation**	**Natural mean annual runoff (incremental)**
	km²	**million m³/a**	**mm/a**	**mm/a**	**million m³/a**
Q94F	734	70.03	1550	482	8.19
TOTALS	**97023**	**2154.35**	**---**	**---**	**2154.35**

APPENDIX G.2

WATER RESOURCES SITUATION ASSESSMENTS

DEPARTMENT: WATER AFFAIRS & FORESTRY
DIRECTORATE: WATER RESOURCE PLANNING

POTENTIAL VULNERABILITY OF SURFACE WATER & GROUNDWATER TO MICROBIAL CONTAMINATION

AUGUST 2001

Parsons & Associates

P O Box 2606
SOMERSET WEST
7129

IWQS

Private Bag X313
PRETORIA
0001

Ninham Shand

P O Box 1348
CAPE TOWN
8000

SUMMARY

This report forms part of the Water Resources Situation Assessments undertaken for the Department of Water Affairs and Forestry. Information is provided on the potential microbial contamination of surface water and groundwater resources in South Africa.

For surface water, initial mapping information was taken from the National Microbiological Monitoring Program where priority contaminated areas were identified and mapped. As part of this project, it was necessary to produce a surface contamination map for the whole country. A national surface faecal contamination map was produced using population density and sanitation type available from DWAF databases. A three category rating system was used (low, medium and high) to describe the surface faecal contamination. This information was delineated on a quaternary catchment basis for the whole country.

For groundwater, the first step involved the development of a groundwater vulnerability map using the depth to groundwater, soil media and impact of the vadose zone media. A three category rating system was used (least, moderate, most) to describe the ease with which groundwater could be contaminated from a source on the surface. The second step involved using the surface contamination and aquifer vulnerability maps to derive a groundwater contamination map. The derived map shows the degree of faecal contamination that could be expected of the groundwater for all areas in South Africa.

Conclusions and recommendations

- Maps were produced that provide an overall assessment of potential microbial contamination of the surface water and groundwater resources of South Africa.

- Spatial resolution of the maps is based on a quaternary catchment scale. It is recommended that these maps are not used to derive more detailed spatial information.

- Once sufficient microbial data are available, it is recommended that the numerical methods, and their associated assumptions, be checked, and the maps replotted where necessary.

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ACKNOWLEDGEMENT

The support of Mr Julian Conrad of Environmentek, CSIR for providing the GIS DRASTIC coverages. His help is fully acknowledged and appreciated.

GLOSSARY

Aquifer	Strata, or a group of interconnected strata, comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes
Contamination	Introduction into the environment of an anthropogenic substance
DRASTIC	Numerical method that describes groundwater characteristics, using: water depth, recharge, aquifer media, soil media, topography, impact on vadose zone, and conductivity
Faecal	Material that contains bodily waste matter derived from ingested food and secretions from the intestines, of all warm-blooded animals including humans
Fitness for use	Assessment of the quality of water based on the chemical, physical and biological requirements of users
Groundwater	Subsurface water occupying voids within a geological stratum
Microbial	Microscopic organism that is disease causing
Ratio	Mathematical relationship defined by dividing one number by another number
Rating	Classification according to order, or grade
Vadose zone	Part of the geological stratum above the saturated zone where voids contain both air and water
Vulnerability	In the context of this report, it is the capability of surface water or groundwater resources to become contaminated

1. INTRODUCTION

The purpose of the Water Resources Situation Assessments is to prepare an overview of the water resources in South Africa. This will take account of the availability and requirements for water, as well as deal with issues such as water quality. The country has been divided into nineteen water management areas. Eight separate studies are being carried out within catchment boundaries that roughly approximate provincial borders. Once these studies have been completed, all information will also be synthesized into a single report for the whole country.

This report describes the method used to prepare a series of maps that show the microbial rating of surface water and groundwater resources in South Africa. Maps are produced at a quaternary catchment scale. It is intended that the appropriate portions of the maps be incorporated into each of the Water Management Area reports.

The microbial information provided in this report is intended for planning purposes, and is not suitable for detailed water quality assessment. The maps provide a comparative rating of the faecal contamination status of the surface water and groundwater resources in South Africa.

This report contains five sections:

- Section One: Introduction
- Section Two: Mapping of surface contamination
- Section Three: Mapping Groundwater Resources
- Section Four: Conclusions and recommendations.
- Section Five: References

2. MAPPING SURFACE WATER RESOURCES

2.1 Background

The water resources of South Africa have come under increasing influence from faecal contamination as a result of increased urban development and lack of appropriate sanitation. Due to increased use of contaminated water for domestic consumption, people are at serious risk of contracting water-borne disease (e.g. gastroenteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis). The Department of Water Affairs and Forestry (DWAF) is the custodian of the national water resources and should ensure *fitness for use* of the water resources. Thus, the Department has developed a monitoring system to provide the necessary management information to assess and control the health hazard in selected areas. This project is called the National Microbiological Monitoring Programme (NMMP).

As part of the NMMP, a screening exercise was carried out to determine the number of catchments that experience faecal contamination. A short-list of tertiary catchment areas was compiled. Data from the database of the Directorate: Water Services Planning of DWAF was used to prioritize catchments to assess the overall health hazard (see Figure 1).

Ratings for land use activity were assigned using the method developed by Goodmin & Wright (1991), IWQS (1996), and Murray (1999). Ratings for land and water use were combined to establish an overall rating. Water use was considered to have a higher effect than the land use so that a 60:40 weighting was used (see Equation 1).

$$OR = 0.4\ TLU + 0.6\ TWU \qquad \text{........ (1)}$$

Where OR = Area Rating (no units)
TLU = Total land use rating for area (no units)
TWU = Total water use rating for area (no units)

Each area was assigned a rating to indicate low (1), medium (2) or high (3) potential risk to users in the catchment area. The following values were used to designate each class:

Low	OR = 0 to 1000
Medium	OR = 1001 to100 000
High	OR > 100 000 ....(2)

Figure 1 shows the surface faecal contamination map for priority rated catchments in South Africa.

Rating of Surface Faecal Contamination

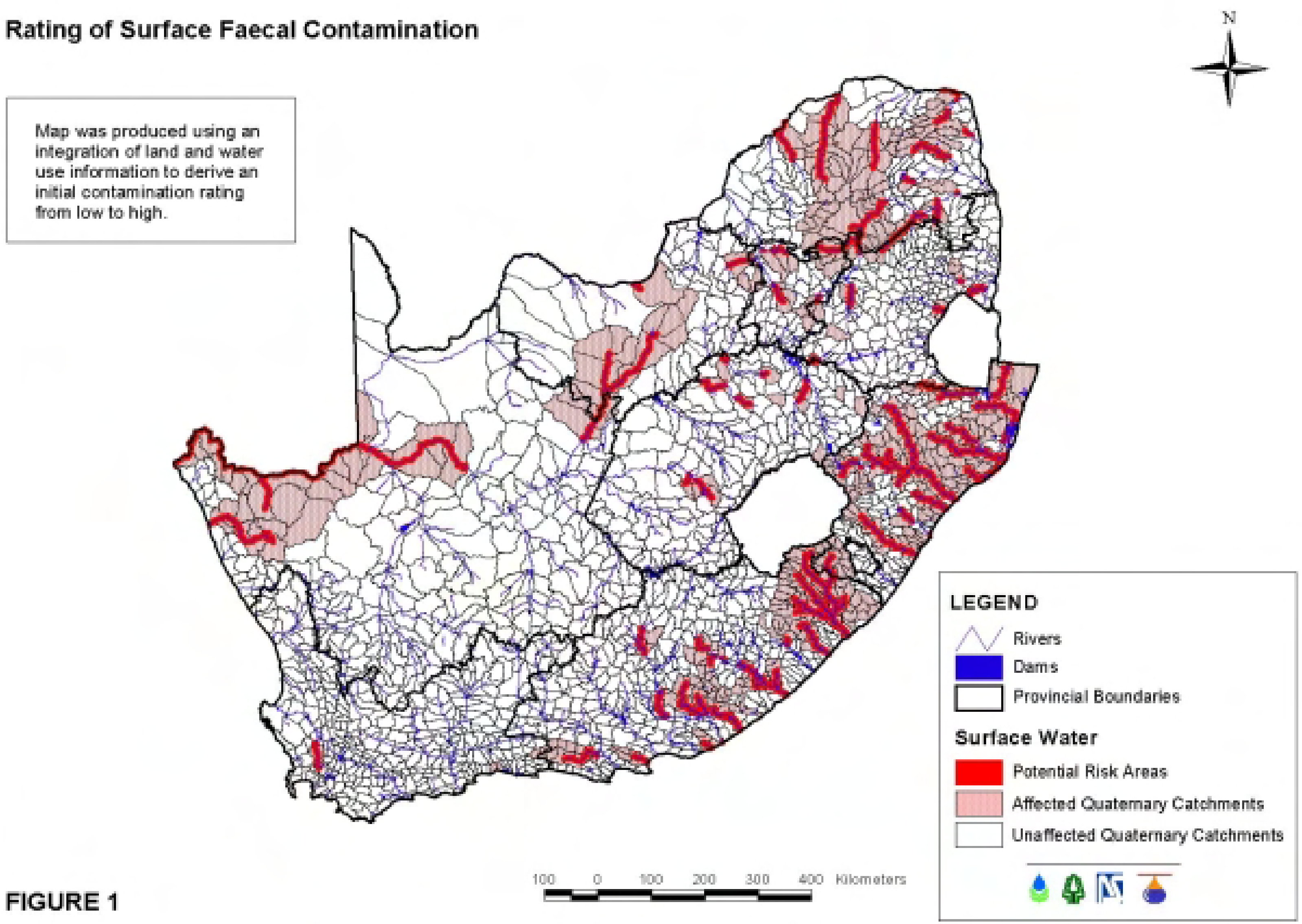


FIGURE 1

2.2 Surface faecal contamination

Figure 2 shows the potential surface faecal contamination map, developed using average population density (for a quaternary) and degree of sanitation (Venter, 1998). The land use rating is given by:

$$LU = SA + PD \qquad \text{........ (3)}$$

Where LU = Land use rating per settlement (no units)
SA = No/poor sanitation rating (no units)
PD = Population Density rating (no units)

Land use rankings for quaternary catchments were determined by calculating the total ratings of all settlements within a particular quaternary catchment, given by:

$$TLU = (LU_n) \qquad \text{........ (4)}$$

Where TLU = Total land use rating per quaternary catchment
LU_n = Land use rating for n settlements, per quaternary

Each quaternary catchment was allocated a low (1), medium (2) and high (3) priority rating used to map the information using GIS. Classes were designated by the following values:

Low	=	$TLU < 1000$
Medium	=	$1000 < TLU < 3000$
High	=	$TLU > 3000$ .... (5)

2.3 Results: GIS Surface Water Mapping

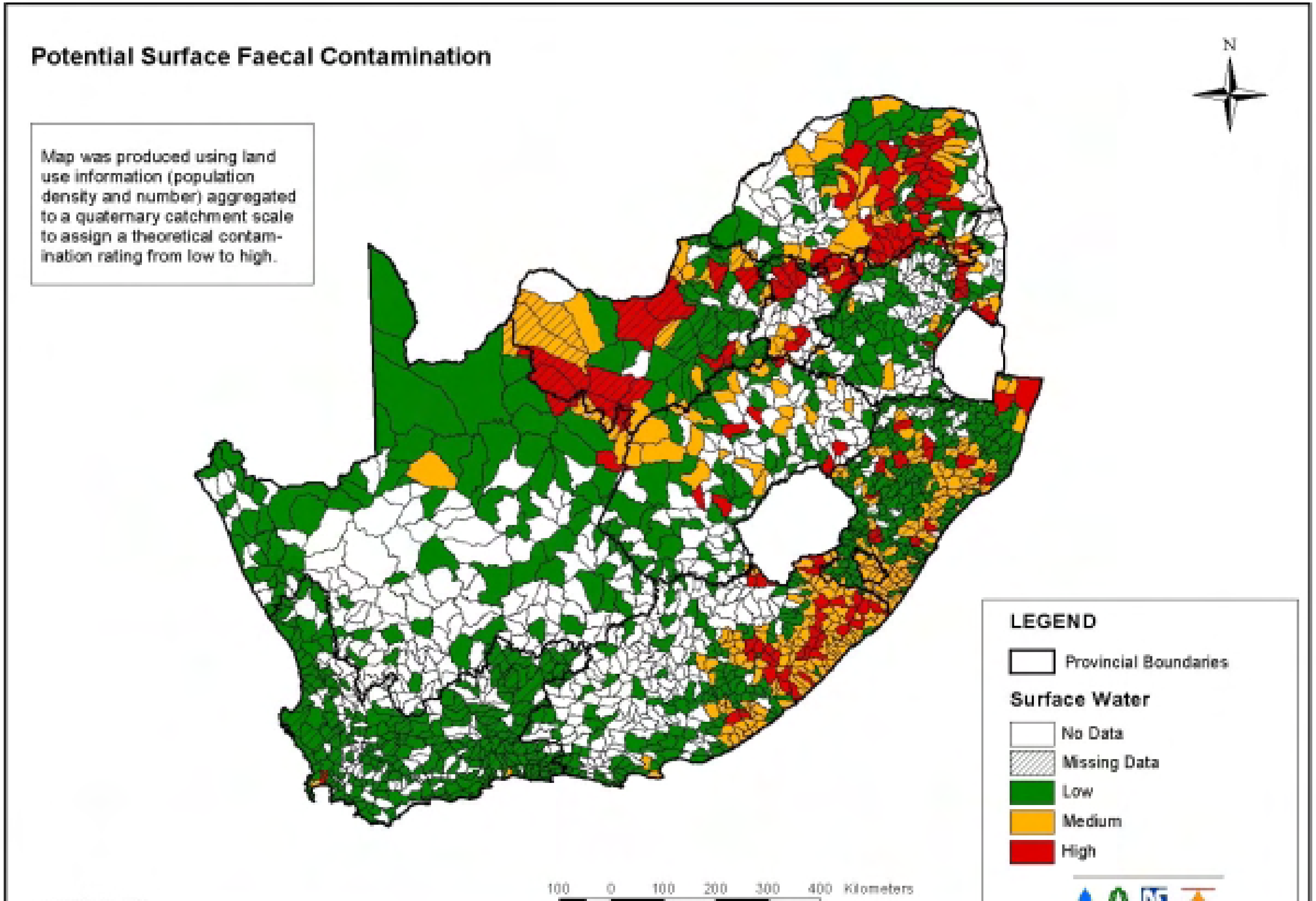
Figure 1 was plotted on GIS by firstly assembling the national coverages for the quaternary catchments, rivers and dams. The data described above were processed using the following method:

The quaternary catchments were shaded according to whether they were considered potential risk areas or not (refer to Equations 1 & 2).

Within the quaternaries at risk, the rivers were buffered and shaded red to indicate the risk to potential surface water users.

Figure 2, the potential surface faecal contamination map, was produced as follows:

The ratings (TLU) were distributed into intervals (refer to Equations 5 and 6).



Potential Surface Faecal Contamination
N
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
100 0 100 200 300 400 Kilometers

FIGURE 2

The quaternary catchments were then shaded according to these rating intervals indicating areas of Low, Medium or High Risk, see below.

Low	Green	TLU < 1000	
Medium	Yellow	1000 < TLU < 3000	
High	Red	TLU > 3000	.... (6)

Quaternary catchments with no data were unshaded.

Quaternary catchments containing missing data were hatched.

3. MAPPING GROUNDWATER RESOURCES

3.1 Background

Groundwater is an important national water resource that plays an important role in meeting water requirements in remote areas. This is particularly true in areas where rainfall is low and surface water resources are scarce.

Microbial contamination of groundwater increases in high population density areas and areas with inadequate sanitation. Approximately three quarters of the population of South Africa do not have access to adequate sanitation.

Considerable work has already been carried out to map the groundwater resources in South Africa. Examples include: the national Groundwater Resources of the Republic of South Africa map produced by Vegter (1995) for the Water Research Commission (WRC), regional 1: 500 000 scale hydrogeological maps produced by DWAF, the national groundwater vulnerability map prepared by Reynders & Lynch (1993) and the aquifer classification map of Parsons & Conrad (1998). Figure 3 shows the vulnerability map used by Parsons & Conrad (1998). The existing work, particularly the vulnerability map (Figure 3), has therefore been used as a basis for assessing the potential of microbial contamination of groundwater systems.

3.2 Method

It is recognised that certain aquifers are more vulnerable to contamination than others. The DRASTIC method (Aller *et al.*, 1985) is a well-known and studied method of assessing aquifer vulnerability to contamination. Reynders & Lynch (1993) and Lynch *et al*. (1994, 1997) prepared a national scale aquifer vulnerability map using DRASTIC that was revised by Parsons & Conrad (1998) using additional data (see Figure 3).

DRASTIC is a weighting, and rating, technique that considers seven factors when estimating the groundwater vulnerability. Factors are geologically and geohydrologically based. Controls relating to the magnitude or severity of the pollution source are not considered. DRASTIC factors are shown in Table 1.

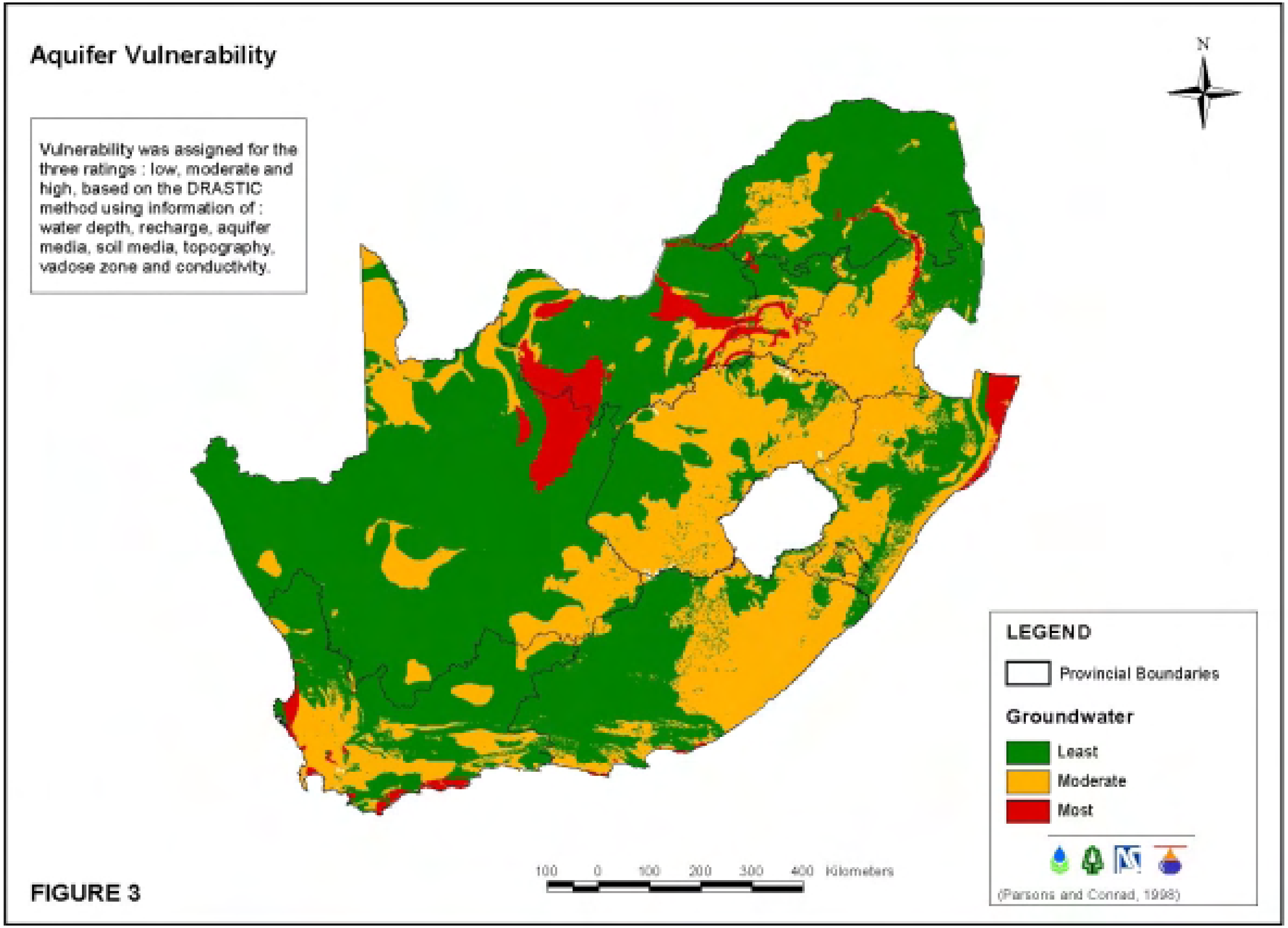

Aquifer Vulnerability
Vulnerability was assigned for the three ratings : low, moderate and high, based on the DRASTIC method using information of : water depth, recharge, aquifer media, soil media, topography, vadose zone and conductivity.
N
100 0 100 200 300 400 Kilometers
LEGEND
Provincial Boundaries
Groundwater
Least
Moderate
Most
(Parsons and Conrad, 1998)

FIGURE 3

TABLE 1: FACTORS USED BY DRASTIC

D	Depth to water
R	(net) Recharge
A	Aquifer media
S	Soil media
T	Topography (slope)
I	Impact of the vadose zone media
C	Conductivity (hydraulic) of the aquifer

Each factor was weighted according to its relative importance (Aller *et al.*, 1985). Using a set of tables, a rating is assigned based on prevailing conditions. A relative DRASTIC index (I) is derived using the following formula, with higher index values showing greater groundwater vulnerability:

$$I = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad .....(7)$$

where: I = index rating
$_R$ is the rating for each factor, and
$_W$ is the weighting for each factor.

DRASTIC was also developed to assess the vulnerability to pesticide contamination (Aller *et al.*, 1985). In this case, those factors that play an important role in defining vulnerability to pesticide contamination are assigned higher weights.

In the case of microbial contamination, other factors are more important in terms of aquifer vulnerability to microbial contamination. Travel time in the vadose zone is recognised as an important control in this regard (Xu & Braune, 1995; Wright, 1995; DWAF, 1997). It was hence decided to assess aquifer vulnerability to microbial contamination in terms of D, S and I (i.e. all factors that relate to the vadose zone). [1]

The weighting and rating technique used by DRASTIC was followed in the current study, adopting the weights used by the pesticide DRASTIC. Using the following formula, the highest possible index value is 140 and the lowest value is 14,

$$\text{Index} = 5\ D_R + 5\ S_R + 4\ I_R \qquad .... (8)$$

It must be noted that (1) the value of the index is relative, (2) the factors used in the index were considered by the team to have the greatest influence in assessing the potential for microbial contamination at the surface entering underlying aquifers.

[1] A similar approach was used by Xu & Braune (1995) where they used the factors D, A and S, and used the weightings assigned by DRASTIC and not Pesticide DRASTIC.

3.3 Aquifer vulnerability map

Three DRASTIC groundwater coverages were used to produce an indication of vulnerability of groundwater contamination, namely, depth to groundwater, soil media and vadose.

Each grid element on the DRASTIC coverages was allocated a rating, that was multiplied by a weighting factor (Depth = 5, Soil = 5, Vadose = 4) to produce a score. These three coverages were intersected and their scores added to produce a relative index for each point on the resulting coverage. An additional assumption was applied that assigned a low vulnerability to all areas with a Depth score of less than or equal to 2. This was used to account for deep infiltration of groundwater (over 35 metres) where long residence time and filtration will reduce the degree of contamination.

The relative index (RI) obtained for each grid allowed for grouping into high, medium and low categories. However, setting the intervals for the three categories proved difficult because of sensitivity to the interval chosen. A large percentage of indices fell in the interval of 60 to 80. It was thus decided to use the interval of 70 to 85 to allow for equal distribution between high, medium and low vulnerability areas (see Figure 4), namely:

Low	Green	$RI < 70$	
Medium	Yellow	$70 < RI < 85$	
High	Red	$RI > 85$	.... (9)

To illustrate the sensitivity to the interval chosen the map was replotted using two further intervals of 60-90 and 65-90 (see Figure 5).

Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider D, S and I. Comparison of Figures 3 and 4 shows remarkable similarity and confirms that the vulnerability *per se* is largely controlled by the three factors (D, S and I), which promotes confidence in the resultant microbial contamination vulnerability map.

A limitation of the study is the inability to validate results obtained. Little information is available regarding groundwater microbial contamination. Monitoring data, from selected areas, should be collected to assess the validity of the vulnerability assessment presented in this report.

3.4 Groundwater faecal contamination

Figure 2 (*Potential Surface Faecal Contamination)* and Figure 4 (*Aquifer vulnerability to Faecal Contamination)* maps were intersected to produce a combined *Risk of Faecal Contamination of Aquifers* map on a quaternary basis, see Figure 6.

A total rating score was calculated for each quaternary (e.g. two medium risk areas and one high risk area gives 2 + 2 + 3). This total was then divided by the total number of different risk areas present in each quaternary to produce an average risk value. Each quaternary catchment was shaded according to this average risk value.

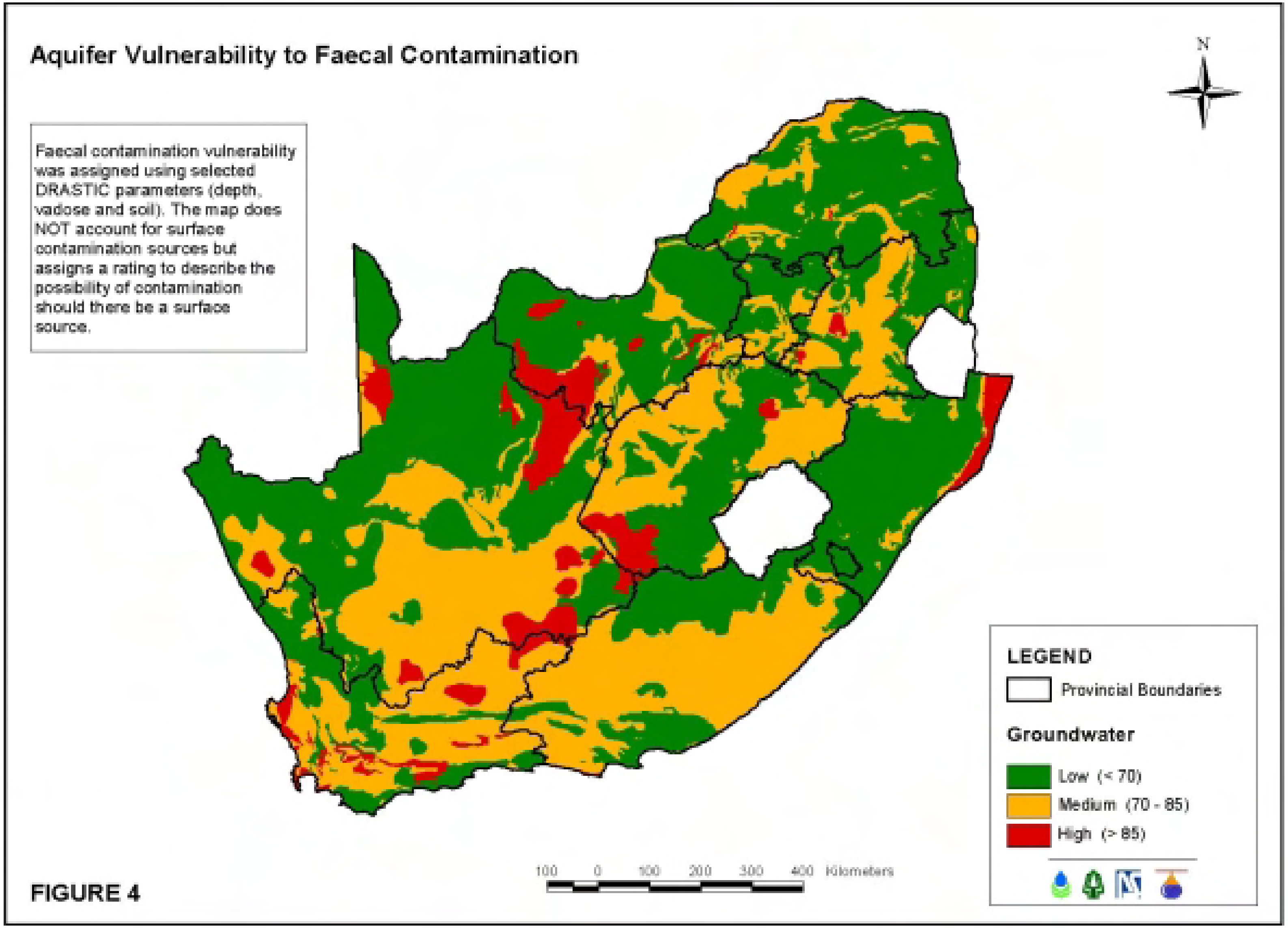
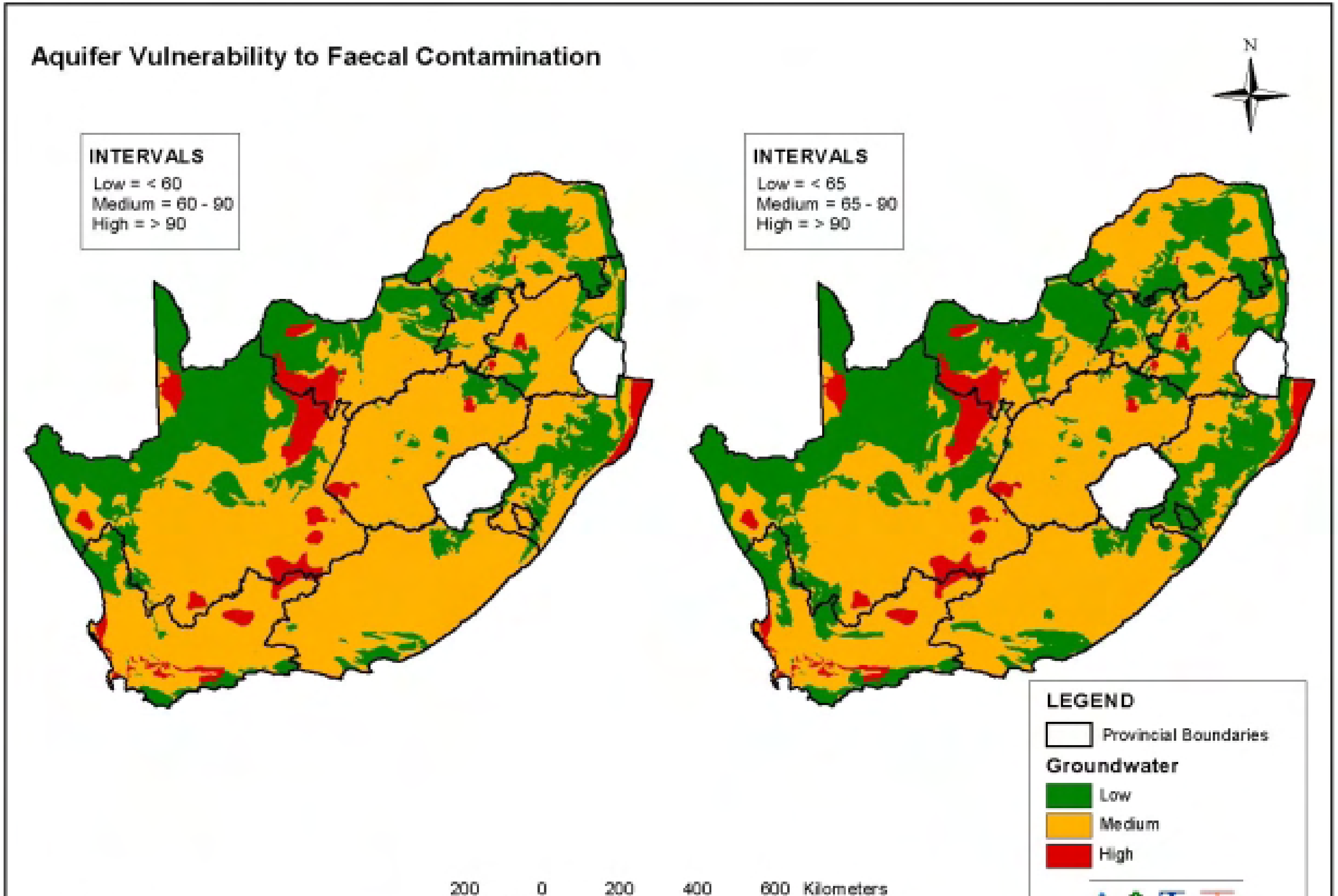
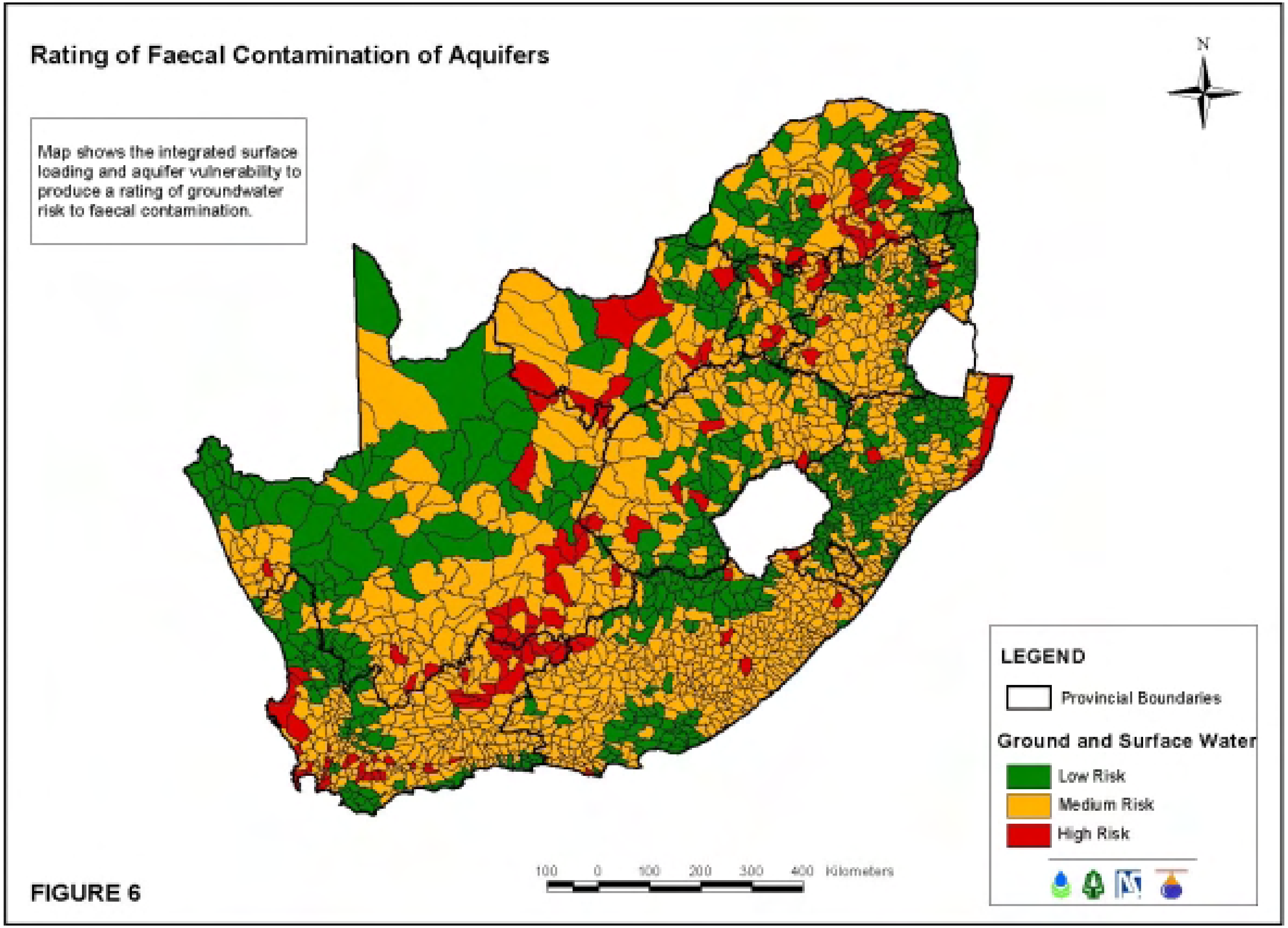

Aquifer Vulnerability to Faecal Contamination
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
N
LEGEND
Provincial Boundaries
Groundwater
Low (< 70)
Medium (70 - 85)
High (> 85)
100 0 100 200 300 400 Kilometers

FIGURE 4


Aquifer Vulnerability to Faecal Contamination
N
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
LEGEND
Provincial Boundaries
Groundwater
Low
Medium
High
200 0 200 400 600 Kilometers
FIGURE 5


Rating of Faecal Contamination of Aquifers
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
N
LEGEND
Provincial Boundaries
Ground and Surface Water
Low Risk
Medium Risk
High Risk
100 0 100 200 300 400 Kilometers
FIGURE 6

4. CONCLUSIONS & RECOMMENDATIONS

- A series of maps (and their associated GIS coverages) have been produced to show the potential microbial contamination of surface water and groundwater resources in South Africa.

- Maps are produced on a quaternary catchment scale. Where more detailed spatial information is required, alternative methods should be used.

- Once sufficient microbial data are available, it is recommended that the numerical methods are calibrated, and the maps replotted.

- The surface water and groundwater maps should be used in the assessments of water quality for each water management area.

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FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX G.3

SEDIMENTATION DATA PER QUATERNARY CATCHMENT

QUAT	Catchment Area km^2	Sediment yield_t/a	25yr sediment volume m^3
K80A	146	2981.015	81679.811
K80B	208	4359.96	119462.9
K80C	189	4526.164	124016.89
K80D	176	3358.176	92014.022
K80E	266	2139.861	58632.191
K80F	221	26000	712400
K90A	214	1719.016	47101.038
K90B	150	1204.25	32996.45
K90C	267	3540.401	97006.987
K90D	215	5306.83	145407.14
K90E	176	4415.081	120973.22
K90F	250	5933.049	162565.54
K90G	286	7745.924	212238.32
L11A	930	75000	2055000
L11B	875	71000	1945400
L11C	568	46000	1260400
L11D	1 286	104000	2849600
L11E	456	37000	1013800
L11F	745	60000	1644000
L11G	2 024	163366.826	4476251
L12A	906	42000	1150800
L12B	519	41855.297	1146835.1
L12C	1 068	52130.617	1428378.9
L12D	952	58396.682	1600069.1
L21A	609	49000	1342600
L21B	756	61000	1671400
L21C	1 033	83404.284	2285277.4
L21D	865	69770.148	1911702.1
L21E	712	57000	1561800
L21F	576	46000	1260400
L22A	1 072	87000	2383800
L22B	475	38299.122	1049395.9
L22C	760	61301.818	1679669.8
L22D	530	42803.651	1172820
L23A	516	41643.597	1141034.6
L23B	818	66001.807	1808449.5
L23C	891	69723.705	1910429.5
L23D	665	39452.756	1081005.5
L30A	361	12626.254	345959.36
L30B	378	13229.268	362481.94
L30C	237	8303.313	227510.78
L30D	552	19309.18	529071.53
L40A	763	141089.784	3865860.1
L40B	594	109852.637	3009962.3
L50A	466	15883.13	435197.76

QUAT	Catchment Area km^2	Sediment yield_t/a	25yr sediment volume m^3
L50B	557	19489.934	534024.19
L60A	677	125276.09	3432564.9
L60B	671	124139.408	3401419.8
L70A	582	19644.765	538266.56
L70B	441	15419.682	422499.29
L70C	662	21968.187	601928.32
L70D	536	18747.534	513682.43
L70E	702	22175.177	607599.85
L70F	306	9819.119	269043.86
L70G	470	6191.413	169644.72
L81A	332	8575.191	234960.23
L81B	261	7743.728	212178.15
L81C	332	9088.359	249021.04
L81D	308	9290.705	254565.32
L82A	269	3000	82200
L82B	405	3257.77	89262.898
L82C	362	2914.634	79860.972
L82D	591	4806.325	131693.31
L82E	365	3257.191	89247.033
L82F	169	2023.262	55437.379
L82G	265	3553.894	97376.696
L82H	230	2116.002	57978.455
L82J	164	1319.983	36167.534
L90A	516	9973.321	273269
L90B	366	10668.293	292311.23
L90C	319	10117.133	277209.44
M10A	265	2158.968	59155.723
M10B	393	7230.655	198119.95
M10C	430	7860.287	215371.86
M10D	307	10498.078	287647.34
M20A	362	8311.482	227734.61
M20B	308	7756.203	212519.96
M30A	258	8094.202	221781.13
M30B	307	10711.924	293506.72
N11A	701	129472.416	3547544.2
N11B	775	143202.422	3923746.4
N12A	739	136455.763	3738887.9
N12B	801	147937.389	4053484.5
N12C	657	121432.094	3327239.4
N13A	555	102448.768	2807096.2
N13B	483	89187.61	2443740.5
N13C	492	90886.146	2490280.4
N14A	506	93436.904	2560171.2
N14B	389	71907.24	1970258.4
N14C	657	121221.154	3321459.6
N14D	367	67790.037	1857447
N21A	458	84613.45	2318408.5
N21B	388	71733.398	1965495.1
N21C	752	138951.668	3807275.7
N21D	560	103550.697	2837289.1
N22A	607	112244.16	3075490
N22B	643	118869.985	3257037.6
N22C	399	73767.948	2021241.8

QUAT	Catchment Area km^2	Sediment yield_t/a	25yr sediment volume m^3
N22D	344	63647.868	1743951.6
N22E	343	63318.639	1734930.7
N23A	537	99357.314	2722390.4
N23B	245	45384.335	1243530.8
N24A	667	123166.355	3374758.1
N24B	667	123156.572	3374490.1
N24C	798	147512.969	4041855.4
N24D	384	71029.74	1946214.9
N30A	850	157044.503	4303019.4
N30B	737	136268.763	3733764.1
N30C	347	64062.719	1755318.5
N40A	668	12676.889	347346.76
N40B	1 211	40546.388	1110971
N40C	580	12048.156	330119.47
N40D	669	18225.445	499377.19
N40E	510	17703.506	485076.06
N40F	762	26673.164	730844.69
P10A	126	23216.543	636133.28
P10B	508	94037.37	2576623.9
P10C	281	51921.242	1422642
P10D	564	104321.296	2858403.5
P10E	466	86271.322	2363834.2
P10F	469	86790.194	2378051.3
P10G	343	63494.617	1739752.5
P20A	422	11053.901	302876.89
P20B	332	8268.172	226547.91
P30A	176	32514.334	890892.75
P30B	403	74497.892	2041242.2
P30C	68	12503.192	342587.46
P40A	312	57647.461	1579540.4
P40B	264	48897.577	1339793.6
P40C	342	63286.742	1734056.7
P40D	246	45446.969	1245247
Q11A	382	70707.272	1937379.3
Q11B	376	69458.602	1903165.7
Q11C	362	66887.472	1832716.7
Q11D	481	89014.451	2438996
Q12A	627	115967.968	3177522.3
Q12B	637	117870.457	3229650.5
Q12C	428	79198.278	2170032.8
Q13A	1 031	190740.098	5226278.7
Q13B	240	44407.079	1216754
Q13C	455	84049.951	2302968.7
Q14A	487	89905.039	2463398.1
Q14B	726	134180.746	3676552.4
Q14C	836	154444.369	4231775.7
Q14D	409	75537.59	2069730
Q14E	343	63421.501	1737749.1
Q21A	601	111042.087	3042553.2
Q21B	381	70371.845	1928188.6
Q22A	518	95833.48	2625837.4
Q22B	220	40643.404	1113629.3
Q30A	395	72969.258	1999357.7

QUAT	Catchment Area km^2	Sediment yield_t/a	25yr sediment volume m^3
Q30B	482	89148.798	2442677.1
Q30C	421	77773.222	2130986.3
Q30D	311	57511.769	1575822.5
Q30E	326	60269.268	1651377.9
Q41A	230	42472.266	1163740.1
Q41B	434	80269.163	2199375.1
Q41C	333	61619.019	1688361.1
Q41D	295	54618.487	1496546.5
Q42A	446	82420.686	2258326.8
Q42B	376	69492.977	1904107.6
Q43A	706	130520.903	3576272.7
Q43B	803	148482.212	4068412.6
Q44A	426	78705.135	2156520.7
Q44B	449	83041.755	2275344.1
Q44C	254	47021.693	1288394.4
Q50A	640	118317.6	3241902.2
Q50B	403	74537.56	2042329.1
Q50C	198	36606.603	1003020.9
Q60A	316	58377.305	1599538.2
Q60B	370	68343.333	1872607.3
Q60C	132	24324.017	666478.07
Q70A	251	46473.73	1273380.2
Q70B	458	84669.711	2319950.1
Q70C	250	46159.998	1264783.9
Q80A	357	65957.31	1807230.3
Q80B	450	83170.894	2278882.5
Q80C	281	52019.593	1425336.8
Q80D	418	77294.883	2117879.8
Q80E	365	67414.944	1847169.5
Q80F	701	129672.29	3553020.7
Q80G	266	49260.919	1349749.2
Q91A	478	88343.026	2420598.9
Q91B	515	95202.091	2608537.3
Q91C	485	89719.403	2458311.6
Q92A	324	59947.485	1642561.1
Q92B	324	60023.381	1644640.6
Q92C	601	111115.629	3044568.2
Q92D	249	46000.926	1260425.4
Q92E	287	53094.198	1454781
Q92F	665	123075.132	3372258.6
Q92G	884	163618.231	4483139.5
Q93A	337	62276.739	1706382.6
Q93B	392	72555.028	1988007.8
Q93C	413	76493.888	2095932.5
Q93D	491	90799.483	2487905.8
Q94A	259	47897.46	1312390.4
Q94B	147	27272.933	747278.36
Q94C	135	25009.666	685264.85
Q94D	212	39223.78	1074731.6
Q94E	228	42126.647	1154270.1
Q94F	734	135817.268	3721393.1
Totals	97 023		334039025.0

APPENDIX G.4

GROUNDWATER RESOURCES OF SOUTH AFRICA

1. BACKGROUND

The Department of Water Affairs and Forestry (DWAF) has decided to conduct a Water Situation Assessment Study for South Africa to give a broad overview of national water requirements and water resources. These studies will enable the DWAF to utilize the Water Situation Assessment Model (WSAM), to assist in the decision making process when doing long term water resources planning.

WSM (Pty) Ltd was appointed to undertake the Situation Assessment Study of the Ground Water Resources of South Africa. This study took the form of a desk study evaluating all relevant existing data and reports at a reconnaissance level. The study area consists of all the quaternary sub-catchments of South Africa and the adjoining sub-catchments of the neighbouring states.

This report gives the findings of the study.

2. STUDY OBJECTIVES

The objective of the study is mainly to provide quantitative information on the Ground Water Resources on a quaternary catchment basis for the whole of South Africa for input into the WSAM. The information provided will consist of the following, viz :-

- ground water resource potential or harvest potential
- ground water resources available to be exploited or exploitation potential
- interaction between ground water and surface water ie the portion of ground water that contributes to stream flow (base flow)
- present ground water use
- a ground water balance identifying quaternary catchments where over exploitation occurs as well as catchments having a potential for increased ground water development
- ground water quality evaluation, determining the portion of ground water which is potable

3. METHODOLOGY

This study is a reconnaissance study making use of existing available information.

The quantification of the ground water resources is probably one of the most difficult aspects of ground water to access. Information on recharge to the ground water systems, storage capacity of the ground water systems, the hydraulic conductivity and thickness of these ground water systems, the interaction with surface water and water quality is required. Once the ground water resources are quantified a ground water balance is set up, comparing the resource with the existing use, to determine areas of over exploitation and identify areas which have a potential for further ground water exploitation. These parameters have been evaluated and the methodology is given below.

3.1 Harvest Potential

The evaluation of the mean annual recharge and storage on a national scale has been done by Vegter, 1995. This information together with a rainfall reliability factor (20^{th} percentile precipitation divided by the median precipitation), which gives an indication of the possible drought length, has been utilized by Seward and Seymour, 1996, to produce the Harvest Potential of South Africa.

The Harvest Potential is defined as the maximum volume of ground water that may be abstracted per area without depleting the aquifers. The Harvest Potential as determined by Seward and Seymour, 1996 has been used as the starting point for the determination of the Ground Water Resources of South Africa.

3.2 Exploitation Potential

It is however not possible to abstract all the ground water available. This is mainly due to economic and/or environmental considerations. The main contributing factor is the hydraulic conductivity or transmissivity of the aquifer systems. As no regional information is available, a qualitative evaluation has been done using available borehole yield information, as there is a good relationship between borehole yield and transmissivity.

The average borehole yield was determined for each quaternary catchment using information available from the National Ground Water Database and the borehole database of the Chief Directorate Water Services. Where no information was available, the average of the tertiary catchment was used. The average yields were then divided into 5 groups and an exploitation factor allocated to each group as follows, viz:-

AVERAGE BOREHOLE YIELD	EXPLOITATION FACTOR
>3.0 ℓ/s	0.7
1.5 - 3.0 ℓ/s	0.6
0.7 - 1.5 ℓ/s	0.5
0.3 - 0.7 ℓ/s	0.4
<0.3 ℓ/s	0.3

This factor was then multiplied by the Harvest Potential of each quaternary catchment to obtain the exploitation potential. The exploitation potential is considered to be a conservative estimate of the groundwater resources available for exploitation.

3.3 Ground Water, Surface Water Interaction

In order to avoid double counting the water resources, the interaction between Surface and Ground Water needs to be quantified. At a workshop held at the DWAF where ground and surface water specialists were represented, it was agreed that the baseflow, be regarded as the portion of water common to both ground and surface water for the purposes of this study.

- ***Baseflow***

  The baseflow has been considered as that portion of ground water which contributes to the low flow of streams. Baseflow can therefore be regarded as that portion of the total water resource that can either be abstracted as ground water or surface water. The baseflow in this study is defined as the annual equivalent of the average low flow that is equaled or exceeded 75% of the time during the 4 driest months of the year. The baseflow has been calculated by Schultz and Barnes, 2001.

- ***Baseflow factor***

  The baseflow factor gives an indication of the portion of ground water which contributes to base flow and has been calculated by dividing the baseflow by the Harvest Potential.

If baseflow = 0, then ground water does not contribute to baseflow and the baseflow factor is therefore also = 0.

If baseflow ≥ harvest potential then all ground water can be abstracted as surface water and the baseflow factor is therefore ≥ 1. As the contribution of the Harvest Potential to baseflow cannot be greater than the Harvest Potential, the baseflow factor has therefore been corrected to equal 1 where it was > 1.

- ***Impact of Ground Water Abstraction on Surface Water Resources***

  The impact that ground water abstraction will have on surface water resources has been evaluated qualitatively by using the corrected baseflow factor ie,

  - negligible where corrected baseflow factor is = 0
  - low where the corrected baseflow factors is ≤ 0.3
  - moderate where the corrected baseflow factor is ≤ 0.8
  - high where the corrected baseflow factor is > 0.8

- ***Contribution of Ground Water to the Total Utilization Water Resource***

  This assessment of the interaction of groundwater and the base flow component of the surface water can however, not be used directly to determine the additional contribution of groundwater abstraction to the total utilizable water resource without also taking account of the effect of surface water storage capacity and the reduction in surface water runoff that is caused by the increase of groundwater recharge (induced recharge) that results from groundwater abstraction. For the purpose of this water resources assessment the proportion of the utilizable groundwater not contributing to the base flow of the surface water that can be added to the utilizable surface water to estimate the total utilizable resources has therefore been ignored.

3.4 Existing Ground Water Use

Data on existing ground water use was not readily accessible especially the main use sectors, viz agriculture and mining. Available borehole information was thus utilized to give a first estimate.

This was done by adding all the estimated yields or blow yields of all the boreholes for an 8 hr/day pumping period, 365 days per year.

Ground Water use was also evaluated from work done by Jane Baron (Baron and Seward, 2000). The use was evaluated for the following sectors, ie

- Municipal Use

  This data was obtained from a study done by DWAF in 1990 with additional information obtained from DWAF hydrogeologists and town clerk /engineers.

- Rural Use

  Rural use was estimated from the DWAF, Water Services Database linking water source to population and allowing for 25 ℓ/capita/day.

- Livestock use

  The number of equivalent large livestock units per quaternary catchment was taken from the WSAM and multiplied by 45 ℓ/day and then multiplied by the % reliance on ground water obtained from the Glen College Food Survey (1990).

- Irrigation Use

  The total irrigation use per quaternary catchment was taken from the WSAM. This use was then multiplied by the % reliance on ground water obtained from the Glen College Food Survey (1990).

The total use was determined by summation of the municipal, rural, livestock and irrigation use. It must be noted that information on mining and industrial use was not available and has not been included in the total use.

Workshops held in each of the Water Management Area's by the Water Resources Situation Assessment teams, provided local input to the water use numbers. These numbers were then adjusted by applying a factor to the Baron & Seward (2000) number to give the final ground water use figures.

3.5 Ground Water Balance

The Ground Water Balance was calculated for each quaternary catchment to determine the extent to which the ground water resources have been developed. This was done by means of comparing the values of Harvest Potential and Exploitation Potential with adjusted ground water use (as determined by Baron and Seward, 2000).

The following scenarios were mapped, viz :-

- If the total use was greater than the Harvest Potential then the catchment was considered to be over utilized.

- If the total use was greater than the Exploitation Potential but less than the Harvest Potential then the catchment was considered to be heavily utilized.

- If the total use was less than the Exploitation Potential but greater than 66% of the Exploitation Potential then the catchment was considered to be moderately utilized.

- If the total use was less than 66% of the Exploitation Potential the catchment was considered under utilized.

3.6 Water Quality

The ground water quality is one of the main factors affecting the development of available ground water resources. Although there are numerous problems associated with water quality, some of which are easily remediated, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality has been evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (M Simonic 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegters Maps (Vegter, 1995). The potability evaluation done by Simonic (M Simonic, 2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998).

The TDS is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements of other uses. The South African Water Quality Guidelines for the Department of Water Affairs and

Forestry (1996) for these two uses were combined into a single classification system as shown in Table 3.6.1

TABLE 3.6.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

Class	Colour Code	Description	TDS Range (mg/l)
0	Blue	Ideal water quality	<260
1	Green	Good water quality	260 – 600
2	Yellow	Marginal water quality	601 – 1800
3	Red	Poor water quality	1801 – 3400
4	Purple	Completely unacceptable water quality	>3400

The portion of the ground water resources considered potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) according to the Quality of Domestic Water Supplies, Volume I (DWAF, 1998). Water classified as poor and unacceptable has been considered **not** potable.

In catchments where no information was available estimates of the portion potable were made using Vegters maps (Vegter 1995).

4. DATA LIMITATIONS

It must be noted that this evaluation was done using existing available information. The evaluation is based on the harvest potential map which was derived from interpretations of limited existing information on recharge and a very broad qualitative assessment of storage capacity. The comparison of base flow with the harvest potential indicates that the harvest potential could be significantly underestimated in the wetter parts of the country. It is thought that this is due to an under estimation of the storage capacity.

Although yield data on some 91000 boreholes was used the accuracy of this data in some instances is questionable, as it was not known whether the yield was a blow yield estimated during drilling, or a yield recommended by a hydrogeologist from detailed pumping test results. In general, however, the yields do highlight areas of higher and lower yield potential such as the dolomite areas but in some areas such as catchment W70 appear to grossly underestimate the yield. Underestimation of the yield would negatively impact on the calculation of exploitation potential.

Information on ground water use was obtained mainly from indirect qualitative evaluations. Further, mining and industrial use was not available and was therefore not included in the total usage. This could have a significant effect on the ground water balance in specifically the gold mining areas.

Water quality data should also only be used to give regional trends. In many catchments data at only a few sample points were available. As a catchment could be underlain by numerous different lithologies, a large range in water quality can occur. The samples used in the analysis could thus be non representative of the catchment as a whole.

In general this study should be seen as a first quantitative estimate of the ground water resources of South Africa.

5. OVERVIEW OF THE GROUNDWATER RESOURCES OF SOUTH AFRICA

In over 90% of the surface area of South Africa, ground water occurs in secondary openings such as pores in weathered rock and faults, fractures, fissures and dissolution channels in so-called hard rock. These rocks consist of igneous, metamorphic and sedimentary rocks and range in age from Jurassic (± 140 x 10^6 yrs) to Swazian (3750 x 10^6 yrs).

In the remaining 10% of the surface area of South Africa ground water occurs in primary openings i.e., intergranular pores in mainly unconsolidated classic rocks. These rocks are generally recent in age (< 65 x 10^6 yrs) and consist of the Kalahari beds, the alluvial strip along some rivers and cenozoic deposits fringing the coast line, mainly in Northern Kwa Zulu Natal and the Southern and Western Cape.

The total Harvest Potential for South Africa has been calculated as 19100 x $10^6 m^3$/annum and varies from less than 0.5 mm/annum in quaternary catchment D82J to more than 352 mm/annum in quaternary catchment W12J.

Borehole yields vary considerably. The highest boreholes yields (up to 100 ℓ/s) have been found in the Malmani Dolomites. Other high borehole yielding (> 10 ℓ/s) lithostratigraphic units include the Table Mountain Quartsites of the Southern Cape, Basement Granites in the Pietersburg Dendron and Coetzerdam area, coastal deposits along Northern Natal, the eastern southern and western Cape, and alluvial deposits along certain sections of some of the major rivers such as the Limpopo River.

Moderate to good yields (> 5 ℓ/s) are found in the Letaba Basalt formation and where the Ecca has been intruded by dolerite dykes and sheets.

The total exploitation potential for South Africa has been calculated as 10100 x $10^6 m^3$/annum and varies from less than 0.2 mm/annum in quaternary catchment D82G to more than 211 mm/annum in quaternary catchment W12J.

The ground water use, excluding mines and industries, has been estimated to be some 1040 x $10^6 m^3$/annum and is concentrated in a few isolated areas.

The ground water balance shows that in general ground water is underutilized except for a few areas where over or heavy utilization occurs.

The extreme north western parts of South Africa show the poorest quality with TDS > 20000 mg/ℓ. The higher rainfall eastern parts have the best water quality, TDS < 100 mg/ℓ. The potability ranges between 0% in the extreme north-western parts of South Africa and 100% in the central and eastern areas. The main problems being brackish water and high nitrates and fluorides.

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

GROUNDWATER USE PER QUATERNARY CATCHMENT

QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	oGHPi HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	oGBYi AVERAGE YIELD BOREHOLES	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	oGEPo EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	oGWSo TOTAL USE	TOTAL USE
	(km^2)	($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	DATA	(l/s)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	(mm/a)
K80A	146	114626	114.6	16.74	1.00	0.33	0.5	57313	57.3	8.37	0	0.00	0.00	0	0.0000	0.0000	0.0000	0.0027	0.6850	0.0018	0.0
K80B	208	116303	116.3	24.19	2.00	0.67	0.6	69782	69.8	14.51	1	2.00	0.02	0	0.0000	0.0000	0.0000	0.0048	0.6850	0.0033	0.0
K80C	189	119643	119.6	22.61	2.25	0.75	0.6	71786	71.8	13.57	2	4.50	0.05	0	0.0000	0.0000	0.0001	0.0000	0.6850	0.0001	0.0
K80D	176	112271	112.3	19.76	1.00	0.33	0.5	56136	56.1	9.88	0	0.00	0.00	0	0.0000	0.0000	0.0010	0.0000	0.6850	0.0007	0.0
K80E	266	105424	105.4	28.04	0.90	0.30	0.5	52712	52.7	14.02	14	12.62	0.13	0	0.0000	0.0000	0.0016	0.0000	0.6850	0.0011	0.0
K80F	221	103853	103.9	22.95	1.43	0.48	0.5	51926	51.9	11.48	13	18.53	0.19	5	0.1000	0.0000	0.0013	0.0000	0.6850	0.0694	0.3
K90A	214	89610	89.6	19.18	1.95	0.65	0.6	53766	53.8	11.51	12	23.42	0.25	0	0.0000	0.0000	0.0008	0.0117	0.6850	0.0086	0.0
K90B	150	83785	83.8	12.57	1.73	0.58	0.6	50271	50.3	7.54	2	3.45	0.04	2	0.0500	0.0000	0.0009	0.0000	0.6850	0.0349	0.2
K90C	267	60304	60.3	16.10	0.87	0.29	0.5	30152	30.2	8.05	21	18.36	0.19	0	0.0000	0.0000	0.0016	0.0000	0.6850	0.0011	0.0
K90D	215	87900	87.9	18.90	2.32	0.77	0.6	52740	52.7	11.34	11	25.49	0.27	0	0.0000	0.0000	0.0013	0.0000	0.6850	0.0009	0.0
K90E	176	44929	44.9	7.91	1.48	0.49	0.5	22465	22.5	3.95	25	36.99	0.39	24	0.5500	0.0000	0.0010	0.0000	0.6850	0.3774	2.1
K90F	250	53766	53.8	13.44	1.14	0.38	0.5	26883	26.9	6.72	42	47.94	0.50	46	0.8030	0.0000	0.0015	0.0000	0.6850	0.5511	2.2
K90G	286	45961	46.0	13.14	4.75	1.58	0.7	32173	32.2	9.20	64	303.68	3.19	9	0.6500	0.0000	0.0017	0.0000	0.6850	0.4464	1.6
L11A	930	7465	7.5	6.94	0.05	0.02	0.3	2240	2.2	2.08	1	0.05	0.00	261	0.0000	0.0000	0.0477	1.3242	0.1000	0.1372	0.1
L11B	875	7688	7.7	6.73	0.83	0.28	0.5	3844	3.8	3.36	2	1.65	0.02	13	0.0000	0.0000	0.0446	1.1237	0.1000	0.1168	0.1
L11C	568	7840	7.8	4.45	8.16	2.72	0.7	5488	5.5	3.12	10	81.62	0.86	1	0.0000	0.0000	0.0308	0.6463	0.1000	0.0677	0.1
L11D	1286	7719	7.7	9.93	1.31	0.44	0.5	3859	3.9	4.96	43	56.38	0.59	0	0.0000	0.0000	0.0615	0.0000	0.1000	0.0062	0.0
L11E	456	7702	7.7	3.51	2.18	0.73	0.6	4621	4.6	2.11	58	126.51	1.33	10	0.0000	0.0000	0.0236	2.2038	0.1000	0.2227	0.5
L11F	745	7840	7.8	5.84	3.94	1.31	0.7	5488	5.5	4.09	330	1299.44	13.66	2	0.0000	0.0000	0.0384	0.7213	0.1000	0.0760	0.1
L11G	2024	6052	6.1	12.25	1.72	0.57	0.6	3631	3.6	7.35	80	137.43	1.44	6	0.0000	0.0000	0.1066	0.9703	0.1000	0.1077	0.1
L12A	906	3000	3.0	2.72	0.95	0.32	0.5	1500	1.5	1.36	2	1.89	0.02	0	0.0000	0.0000	0.0467	0.0000	0.1000	0.0047	0.0
L12B	519	6942	6.9	3.60	1.00	0.33	0.5	3471	3.5	1.80	0	0.00	0.00	21	0.0000	0.0000	0.0273	2.2180	0.1000	0.2245	0.4
L12C	1068	3605	3.6	3.85	4.59	1.53	0.7	2523	2.5	2.70	5	22.95	0.24	9	0.0000	0.0000	0.0706	4.1230	0.1000	0.4194	0.4
L12D	870	4831	4.8	4.20	1.33	0.44	0.5	2416	2.4	2.10	14	18.60	0.20	0	0.0000	0.0000	0.0613	0.0000	0.1000	0.0061	0.0
L21A	609	7834	7.8	4.77	1.00	0.33	0.5	3917	3.9	2.39	0	0.00	0.00	0	0.0000	0.0000	0.0397	0.0000	0.1000	0.0040	0.0
L21B	756	8181	8.2	6.18	2.27	0.76	0.6	4908	4.9	3.71	2	4.53	0.05	0	0.0000	0.0000	0.0574	0.0000	0.1000	0.0057	0.0
L21C	1033	10556	10.6	10.90	0.59	0.20	0.4	4222	4.2	4.36	2	1.17	0.01	33	0.0000	0.0000	0.0696	1.9355	0.1000	0.2005	0.2
L21D	865	11202	11.2	9.69	0.50	0.17	0.4	4481	4.5	3.88	0	0.00	0.00	11	0.0000	0.0000	0.0593	0.5240	0.1000	0.0583	0.1

QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	oGHPi HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	oGBYi AVERAGE YIELD BOREHOLES	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	oGEPo EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	oGWSo TOTAL USE	TOTAL USE
	(km^2)	(m^3/km^2/a)	(mm)	(x10^6 m^3/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		(m^3/km^2/a)	(mm)	(x10^6 m^3/a)	DATA	(l/s)	(x10^6 m^3/a)		(x10^6 m^3/a)	(x10^6 m^3/a)	(x10^6 m^3/a)	(x10^6 m^3/a)		(x10^6 m^3/a)	(mm/a)
L21E	712	9461	9.5	6.74	2.33	0.78	0.6	5676	5.7	4.04	2	4.66	0.05	1	0.1132	0.0000	0.0486	0.0000	0.1000	0.0162	0.0
L21F	576	7840	7.8	4.52	0.50	0.17	0.4	3136	3.1	1.81	0	0.00	0.00	1	0.0000	0.0000	0.0394	0.0000	0.1000	0.0039	0.0
L22A	1072	7747	7.7	8.30	0.50	0.17	0.4	3099	3.1	3.32	0	0.00	0.00	1	0.0000	0.0000	0.0720	0.0000	0.1000	0.0072	0.0
L22B	475	7384	7.4	3.51	0.50	0.17	0.4	2954	3.0	1.40	0	0.00	0.00	34	0.0000	0.0000	0.0321	1.7499	0.1000	0.1782	0.4
L22C	760	7632	7.6	5.80	0.50	0.17	0.4	3053	3.1	2.32	0	0.00	0.00	38	0.0000	0.0000	0.0535	1.9577	0.1000	0.2011	0.3
L22D	530	9257	9.3	4.91	1.26	0.42	0.5	4629	4.6	2.45	1	1.26	0.01	0	0.0000	0.0000	0.0397	0.0000	0.1000	0.0040	0.0
L23A	516	7745	7.7	4.00	1.00	0.33	0.5	3872	3.9	2.00	1	1.00	0.01	12	0.0000	0.0000	0.0405	1.2526	0.1000	0.1293	0.3
L23B	818	8336	8.3	6.82	0.50	0.17	0.4	3335	3.3	2.73	0	0.00	0.00	37	0.0000	0.0000	0.0641	1.8746	0.1000	0.1939	0.2
L23C	891	7721	7.7	6.88	4.00	1.33	0.7	5405	5.4	4.82	1	4.00	0.04	5	0.0000	0.0000	0.0697	2.0437	0.1000	0.2113	0.2
L23D	665	5867	5.9	3.90	0.16	0.05	0.3	1760	1.8	1.17	4	0.62	0.01	3	0.0000	0.0000	0.0496	0.0000	0.1000	0.0050	0.0
L30A	361	8097	8.1	2.92	2.17	0.72	0.6	4858	4.9	1.75	24	52.18	0.55	1	0.0000	0.0000	0.0265	0.2650	0.1000	0.0292	0.1
L30B	378	5450	5.5	2.06	0.91	0.30	0.5	2725	2.7	1.03	12	10.88	0.11	3	0.0000	0.0000	0.0278	0.2764	0.1000	0.0304	0.1
L30C	237	7345	7.3	1.74	3.51	1.17	0.7	5142	5.1	1.22	9	31.55	0.33	0	0.0000	0.0000	0.0174	0.1434	0.1000	0.0161	0.1
L30D	552	7996	8.0	4.41	3.40	1.13	0.7	5597	5.6	3.09	25	84.95	0.89	3	0.0000	0.0000	0.0403	1.1032	0.1000	0.1144	0.2
L40A	763	7130	7.1	5.44	1.07	0.36	0.5	3565	3.6	2.72	5	5.34	0.06	6	0.0000	0.0000	0.0605	0.6589	0.1000	0.0719	0.1
L40B	594	6746	6.7	4.01	0.78	0.26	0.5	3373	3.4	2.00	25	19.41	0.20	7	0.0000	0.0000	0.0431	0.5171	0.1000	0.0560	0.1
L50A	466	31808	31.8	14.82	2.88	0.96	0.6	19085	19.1	8.89	22	63.26	0.66	3	0.0000	0.0000	0.0306	0.9588	0.1000	0.0989	0.2
L50B	557	7845	7.8	4.37	0.88	0.29	0.5	3922	3.9	2.18	33	28.96	0.30	0	0.0000	0.0000	0.0070	0.0000	0.1000	0.0007	0.0
L60A	677	7571	7.6	5.13	1.11	0.37	0.5	3785	3.8	2.56	8	8.84	0.09	2	0.0400	0.0000	0.0479	0.1176	0.1000	0.0206	0.0
L60B	671	7129	7.1	4.78	1.55	0.52	0.6	4277	4.3	2.87	34	52.76	0.55	1	0.0048	0.0000	0.0331	0.0942	0.1000	0.0132	0.0
L70A	582	13447	13.4	7.83	1.06	0.35	0.5	6723	6.7	3.91	27	28.51	0.30	0	0.0000	0.0000	0.0079	0.0000	0.1000	0.0008	0.0
L70B	441	10884	10.9	4.80	1.66	0.55	0.6	6531	6.5	2.88	32	53.08	0.56	1	0.1000	0.0000	0.0000	0.0000	0.1000	0.0100	0.0
L70C	662	30049	30.0	19.89	2.55	0.85	0.6	18029	18.0	11.94	33	84.08	0.88	0	0.0070	0.0000	0.0000	0.0000	0.1000	0.0007	0.0
L70D	536	11886	11.9	6.37	1.07	0.36	0.5	5943	5.9	3.19	33	35.22	0.37	22	0.0000	0.0000	0.0014	2.5206	0.1000	0.2522	0.5
L70E	702	11715	11.7	8.22	1.14	0.38	0.5	5858	5.9	4.11	47	53.38	0.56	0	0.0000	0.0000	0.0165	0.0000	0.1000	0.0017	0.0
L70F	306	28274	28.3	8.65	2.16	0.72	0.6	16964	17.0	5.19	21	45.39	0.48	0	0.0000	0.0000	0.0095	0.0000	0.1000	0.0010	0.0
L70G	470	55253	55.3	25.97	0.91	0.30	0.5	27627	27.6	12.98	9	8.23	0.09	0	0.0000	0.0000	0.0023	0.0000	0.1000	0.0002	0.0
L81A	332	56892	56.9	18.89	2.44	0.81	0.6	34135	34.1	11.33	19	46.31	0.49	0	0.0000	0.0000	0.0134	0.0000	0.1000	0.0013	0.0
L81B	261	62043	62.0	16.19	3.10	1.03	0.7	43430	43.4	11.34	11	34.08	0.36	4	1.2000	0.0000	0.0120	0.0000	0.1000	0.1212	0.5
L81C	332	60616	60.6	20.12	11.30	3.77	0.7	42431	42.4	14.09	1	11.30	0.12	0	0.0000	0.0000	0.0108	0.0000	0.1000	0.0011	0.0
L81D	308	57500	57.5	17.71	2.00	0.67	0.6	34500	34.5	10.63	0	0.00	0.00	0	0.0000	0.0000	0.0077	0.0000	0.1000	0.0008	0.0
L82A	269	71143	71.1	19.14	3.63	1.21	0.7	49800	49.8	13.40	3	10.88	0.11	0	0.0000	0.0000	0.0000	0.0000	0.1000	0.0000	0.0

				oGHPi		oGBYi	fGECi			oGEPo				oGBNi						oGWSo	
QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	AVERAGE YIELD BOREHOLES	EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	TOTAL USE	TOTAL USE
	(km^2)	($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	DATA	(l/s)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	(mm/a)
L82B	405	71039	71.0	28.77	1.32	0.44	0.5	35519	35.5	14.39	12	15.83	0.17	0	0.0000	0.0000	0.0001	0.0362	0.1000	0.0036	0.0
L82C	362	76048	76.0	27.53	1.80	0.60	0.6	45629	45.6	16.52	1	1.80	0.02	0	0.0000	0.0000	0.0002	0.0216	0.1000	0.0022	0.0
L82D	591	75954	76.0	44.89	4.88	1.63	0.7	53168	53.2	31.42	16	78.11	0.82	0	0.0000	0.0000	0.0007	0.1619	0.1000	0.0163	0.0
L82E	365	67488	67.5	24.63	0.35	0.12	0.4	26995	27.0	9.85	7	2.43	0.03	0	0.0000	0.0000	0.0003	0.0000	0.1000	0.0000	0.0
L82F	169	61048	61.0	10.32	0.28	0.09	0.3	18314	18.3	3.10	1	0.28	0.00	0	0.0000	0.0000	0.0006	0.0000	0.1000	0.0001	0.0
L82G	265	66737	66.7	17.69	0.24	0.08	0.3	20021	20.0	5.31	7	1.70	0.02	0	0.0000	0.0000	0.0013	0.0000	0.1000	0.0001	0.0
L82H	230	62347	62.3	14.34	0.43	0.14	0.4	24939	24.9	5.74	1	0.43	0.00	0	0.0000	0.0000	0.0005	0.0000	0.1000	0.0001	0.0
L82J	164	67581	67.6	11.08	0.61	0.20	0.4	27033	27.0	4.43	2	1.21	0.01	0	0.0000	0.0000	0.0011	0.0000	0.1000	0.0001	0.0
L90A	516	43387	43.4	22.39	1.18	0.39	0.5	21693	21.7	11.19	15	17.67	0.19	49	0.0000	0.0000	0.0021	6.1170	0.1000	0.6119	1.2
L90B	366	26979	27.0	9.87	1.72	0.57	0.6	16187	16.2	5.92	26	44.69	0.47	24	0.0000	0.0000	0.0009	4.2636	0.1000	0.4265	1.2
L90C	319	37375	37.4	11.92	1.96	0.65	0.6	22425	22.4	7.15	32	62.79	0.66	27	0.0000	0.0000	0.0009	3.7791	0.1500	0.5670	1.8
M10A	265	58398	58.4	15.48	1.00	0.33	0.5	29199	29.2	7.74	0	0.00	0.00	2	0.0000	0.0000	0.0128	0.0000	1.6000	0.0205	0.1
M10B	393	49463	49.5	19.44	1.04	0.35	0.5	24731	24.7	9.72	14	14.55	0.15	65	0.0000	0.0000	0.0046	0.4420	1.6000	0.7146	1.8
M10C	430	40789	40.8	17.54	1.77	0.59	0.6	24474	24.5	10.52	138	244.77	2.57	213	1.8000	0.0000	0.0088	0.6745	1.6000	3.9733	9.2
M10D	307	26578	26.6	8.16	2.10	0.70	0.6	15947	15.9	4.90	11	23.05	0.24	13	0.0000	0.0000	0.0101	0.1654	1.6000	0.2808	0.9
M20A	362	70842	70.8	25.64	0.76	0.25	0.5	35421	35.4	12.82	28	21.33	0.22	26	0.0570	0.0000	0.0172	0.0541	1.6000	0.2053	0.6
M20B	308	45949	45.9	14.15	1.23	0.41	0.5	22975	23.0	7.08	46	56.55	0.59	31	0.2000	0.0000	0.0070	0.0451	1.6000	0.4034	1.3
M30A	258	25765	25.8	6.65	1.03	0.34	0.5	12883	12.9	3.32	31	32.08	0.34	22	0.0000	0.0000	0.0149	0.1319	1.6000	0.2349	0.9
M30B	307	16477	16.5	5.06	0.60	0.20	0.4	6591	6.6	2.02	17	10.12	0.11	18	0.0000	0.0000	0.0133	0.0579	1.6000	0.1139	0.4
N11A	701	11200	11.2	7.85	1.43	0.48	0.5	5600	5.6	3.93	40	57.10	0.60	9	0.0000	0.0000	0.0008	0.6794	0.2000	0.1360	0.2
N11B	775	11200	11.2	8.68	3.13	1.04	0.7	7840	7.8	6.08	104	325.80	3.42	5	0.0000	0.0000	0.0000	0.8389	0.2000	0.1678	0.2
N12A	739	11517	11.5	8.51	2.00	0.67	0.6	6910	6.9	5.11	17	33.98	0.36	2	0.0000	0.0000	0.0007	0.1798	0.2000	0.0361	0.0
N12B	801	11414	11.4	9.14	1.77	0.59	0.6	6849	6.8	5.49	13	22.98	0.24	0	0.0000	0.0000	0.0198	0.0000	0.2000	0.0040	0.0
N12C	657	11200	11.2	7.36	2.79	0.93	0.6	6720	6.7	4.42	132	368.23	3.87	6	0.0000	0.0000	0.0000	0.8507	0.2000	0.1701	0.3
N13A	555	11200	11.2	6.22	3.08	1.03	0.7	7840	7.8	4.35	103	317.66	3.34	4	0.0000	0.0000	0.0021	0.7155	0.2000	0.1435	0.3
N13B	483	11200	11.2	5.41	4.79	1.60	0.7	7840	7.8	3.79	128	613.22	6.45	8	0.0000	0.0000	0.0079	2.1162	0.2000	0.4248	0.9
N13C	492	11200	11.2	5.51	4.46	1.49	0.7	7840	7.8	3.86	129	575.95	6.05	3	0.1660	0.0000	0.0000	0.5844	0.2000	0.1501	0.3
N14A	506	9090	9.1	4.60	0.44	0.15	0.4	3636	3.6	1.84	3	1.31	0.01	64	0.0000	0.0000	0.0400	1.4233	0.2000	0.2927	0.6
N14B	389	10288	10.3	4.00	9.64	3.21	0.7	7202	7.2	2.80	17	163.90	1.72	15	0.0023	0.0000	0.0308	7.6440	0.2000	1.5354	3.9
N14C	657	11200	11.2	7.36	7.64	2.55	0.7	7840	7.8	5.15	36	275.00	2.89	33	0.0000	0.0000	0.0501	13.2870	0.2000	2.6674	4.1
N14D	367	11200	11.2	4.11	6.08	2.03	0.7	7840	7.8	2.88	108	656.91	6.91	18	0.0000	0.0000	0.0260	5.7789	0.2000	1.1610	3.2
N21A	458	11200	11.2	5.13	2.00	0.67	0.6	6720	6.7	3.08	1	2.00	0.02	44	0.0000	0.0000	0.0240	4.6080	0.2000	0.9264	2.0

				oGHPi		oGBYi	fGECi			oGEPo				oGBNi						oGWSo	
QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	AVERAGE YIELD BOREHOLES	EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	TOTAL USE	TOTAL USE
	(km^2)	($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	DATA	(l/s)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	(mm/a)
N21B	388	11174	11.2	4.34	0.96	0.32	0.5	5587	5.6	2.17	3	2.87	0.03	4	0.0000	0.0000	0.0010	0.2157	0.2000	0.0433	0.1
N21C	752	8468	8.5	6.37	1.53	0.51	0.6	5081	5.1	3.82	18	27.62	0.29	22	0.0000	0.0000	0.0444	1.7173	0.2000	0.3523	0.5
N21D	560	10793	10.8	6.04	1.16	0.39	0.5	5397	5.4	3.02	20	23.16	0.24	0	0.0000	0.0000	0.0000	0.0029	0.2000	0.0006	0.0
N22A	607	7997	8.0	4.85	2.46	0.82	0.6	4798	4.8	2.91	2	4.91	0.05	14	0.0000	0.0000	0.0379	1.7802	0.2000	0.3636	0.6
N22B	643	8348	8.3	5.37	1.53	0.51	0.6	5009	5.0	3.22	20	30.64	0.32	3	0.0000	0.0000	0.0381	0.2231	0.2000	0.0522	0.1
N22C	399	7465	7.5	2.98	2.48	0.83	0.6	4479	4.5	1.79	6	14.90	0.16	0	0.0000	0.0000	0.0249	0.0000	0.2000	0.0050	0.0
N22D	344	8134	8.1	2.80	0.84	0.28	0.5	4067	4.1	1.40	16	13.50	0.14	0	0.0000	0.0000	0.0216	0.0000	0.2000	0.0043	0.0
N22E	343	7582	7.6	2.60	1.65	0.55	0.6	4549	4.5	1.56	18	29.65	0.31	20	0.0000	0.0000	0.0182	1.7265	0.2000	0.3489	1.0
N23A	537	7615	7.6	4.09	2.25	0.75	0.6	4569	4.6	2.45	24	54.03	0.57	0	0.0000	0.0000	0.0534	0.0000	0.2000	0.0107	0.0
N23B	245	9046	9.0	2.22	1.85	0.62	0.6	5428	5.4	1.33	19	35.23	0.37	26	0.0000	0.0000	0.0221	2.5176	0.2000	0.5079	2.1
N24A	667	8915	8.9	5.95	2.22	0.74	0.6	5349	5.3	3.57	8	17.73	0.19	9	0.0000	0.0000	0.0527	1.0297	0.2000	0.2165	0.3
N24B	667	8918	8.9	5.95	1.95	0.65	0.6	5351	5.4	3.57	3	5.85	0.06	47	0.0000	0.0000	0.0404	4.8092	0.2000	0.9699	1.5
N24C	798	6690	6.7	5.34	2.86	0.95	0.6	4014	4.0	3.20	12	34.35	0.36	30	0.0220	0.0000	0.0499	4.4126	0.2000	0.8969	1.1
N24D	384	7814	7.8	3.00	0.73	0.24	0.5	3907	3.9	1.50	11	8.01	0.08	39	0.1200	0.0000	0.0241	1.3355	0.2000	0.2959	0.8
N30A	850	8707	8.7	7.40	1.84	0.61	0.6	5224	5.2	4.44	82	151.26	1.59	43	0.0000	0.0000	0.0475	4.1238	0.2000	0.8343	1.0
N30B	737	7705	7.7	5.68	2.49	0.83	0.6	4623	4.6	3.41	41	101.95	1.07	16	0.0000	0.0000	0.0491	2.0715	0.2000	0.4241	0.6
N30C	347	6517	6.5	2.26	2.31	0.77	0.6	3910	3.9	1.36	30	69.43	0.73	6	0.0000	0.0000	0.0331	0.7063	0.2000	0.1479	0.4
N40A	668	11881	11.9	7.94	1.11	0.37	0.5	5940	5.9	3.97	11	12.22	0.13	3	0.0000	0.0000	0.0515	0.1387	0.2000	0.0380	0.1
N40B	1211	18243	18.2	22.09	1.43	0.48	0.5	9121	9.1	11.05	54	77.07	0.81	10	0.0000	0.0000	0.1285	0.6474	0.2000	0.1552	0.1
N40C	580	13152	13.2	7.63	2.85	0.95	0.6	7891	7.9	4.58	25	71.13	0.75	28	0.0000	0.0000	0.0295	4.1701	0.2000	0.8399	1.4
N40D	669	13500	13.5	9.03	1.55	0.52	0.6	8100	8.1	5.42	32	49.48	0.52	23	0.0000	0.0000	0.0117	1.8556	0.2000	0.3735	0.6
N40E	510	18371	18.4	9.37	0.60	0.20	0.4	7348	7.3	3.75	31	18.69	0.20	93	0.0000	0.0000	0.0272	2.9206	0.2000	0.5896	1.2
N40F	762	25132	25.1	19.15	0.92	0.31	0.5	12566	12.6	9.58	88	81.07	0.85	25	0.0000	0.0000	0.0119	1.1840	0.2000	0.2392	0.3
P10A	126	12700	12.7	1.60	0.76	0.25	0.5	6350	6.4	0.80	10	7.61	0.08	2	0.0000	0.0000	0.0204	0.0000	0.6560	0.0134	0.1
P10B	508	12675	12.7	6.44	1.55	0.52	0.6	7605	7.6	3.86	29	44.99	0.47	3	0.0000	0.0000	0.0828	0.0000	0.6560	0.0543	0.1
P10C	281	9521	9.5	2.68	1.45	0.48	0.5	4761	4.8	1.34	25	36.27	0.38	1	0.0000	0.0000	0.0280	0.0000	0.6560	0.0184	0.1
P10D	564	11274	11.3	6.36	1.90	0.63	0.6	6764	6.8	3.82	71	134.95	1.42	2	0.0000	0.0000	0.0737	0.0000	0.6560	0.0483	0.1
P10E	466	13209	13.2	6.16	0.81	0.27	0.5	6604	6.6	3.08	56	45.54	0.48	4	0.0000	0.0000	0.0508	0.0000	0.6560	0.0333	0.1
P10F	469	13473	13.5	6.32	0.77	0.26	0.5	6737	6.7	3.16	99	76.55	0.80	6	0.0000	0.0000	0.0734	0.0000	0.6560	0.0482	0.1
P10G	343	15116	15.1	5.18	1.40	0.47	0.5	7558	7.6	2.59	56	78.15	0.82	6	0.0800	0.0000	0.0453	0.0000	0.6560	0.0822	0.2
P20A	452	35206	35.2	15.91	1.17	0.39	0.5	17603	17.6	7.96	73	85.51	0.90	40	0.7550	0.0000	0.0002	0.0000	0.6560	0.4954	1.1
P20B	332	71148	71.1	23.62	0.70	0.23	0.4	28459	28.5	9.45	68	47.33	0.50	0	0.0000	0.0000	0.0000	0.0000	0.6560	0.0000	0.0

QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	oGHPi HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	oGBYi AVERAGE YIELD BOREHOLES	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	oGEPo EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	oGWSo TOTAL USE	TOTAL USE
	(km^2)	($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	DATA	(l/s)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	(mm/a)
P30A	176	12700	12.7	2.24	0.87	0.29	0.5	6350	6.4	1.12	25	21.81	0.23	2	0.0000	0.0000	0.0292	0.0000	0.6560	0.0192	0.1
P30B	403	12700	12.7	5.12	0.88	0.29	0.5	6350	6.4	2.56	57	50.10	0.53	6	0.0000	0.0000	0.0811	0.0000	0.6560	0.0532	0.1
P30C	68	29229	29.2	1.99	1.02	0.34	0.5	14614	14.6	0.99	21	21.51	0.23	2	0.0000	0.0000	0.0248	0.0000	0.6560	0.0163	0.2
P40A	312	12700	12.7	3.96	0.59	0.20	0.4	5080	5.1	1.58	29	16.99	0.18	7	0.0000	0.0000	0.0619	0.0000	0.6560	0.0406	0.1
P40B	264	12700	12.7	3.35	0.90	0.30	0.5	6350	6.4	1.68	68	61.21	0.64	7	0.0000	0.0000	0.0950	0.0000	0.6560	0.0623	0.2
P40C	342	38324	38.3	13.11	0.69	0.23	0.4	15329	15.3	5.24	133	91.64	0.96	57	0.5008	0.0000	0.1269	0.0000	0.6560	0.4118	1.2
P40D	246	12779	12.8	3.14	1.76	0.59	0.6	7667	7.7	1.89	81	142.41	1.50	11	0.2200	0.0000	0.0906	0.0000	0.6560	0.2038	0.8
Q11A	382	11200	11.2	4.28	4.08	1.36	0.7	7840	7.8	2.99	12	49.01	0.52	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q11B	376	11200	11.2	4.21	3.49	1.16	0.7	7840	7.8	2.95	6	20.91	0.22	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q11C	362	11200	11.2	4.05	2.06	0.69	0.6	6720	6.7	2.43	10	20.58	0.22	1	0.0000	0.0000	0.0112	0.0000	1.0000	0.0112	0.0
Q11D	481	11200	11.2	5.39	2.38	0.79	0.6	6720	6.7	3.23	7	16.63	0.17	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q12A	627	11229	11.2	7.04	12.39	4.13	0.7	7860	7.9	4.93	1	12.39	0.13	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q12B	637	11200	11.2	7.13	1.00	0.33	0.5	5600	5.6	3.57	0	0.00	0.00	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q12C	428	11200	11.2	4.79	1.37	0.46	0.5	5600	5.6	2.40	6	8.23	0.09	19	0.0000	0.0000	0.0082	27.6084	0.0100	0.2762	0.6
Q13A	1031	11200	11.2	11.55	3.58	1.19	0.7	7840	7.8	8.08	9	32.18	0.34	1	0.1172	0.0000	0.0742	4.8027	0.0100	0.0499	0.0
Q13B	240	11200	11.2	2.69	1.67	0.56	0.6	6720	6.7	1.61	14	23.38	0.25	6	0.0000	0.0000	0.0279	11.1934	0.0100	0.1122	0.5
Q13C	455	11200	11.2	5.10	2.22	0.74	0.6	6720	6.7	3.06	48	106.45	1.12	13	0.0000	0.0000	0.0939	30.2077	0.0100	0.3030	0.7
Q14A	487	12616	12.6	6.14	2.19	0.73	0.6	7569	7.6	3.69	5	10.96	0.12	4	0.0000	0.0000	0.0192	9.5015	0.0100	0.0952	0.2
Q14B	726	11379	11.4	8.26	1.83	0.61	0.6	6827	6.8	4.96	54	98.71	1.04	5	1.1710	0.0000	0.0269	8.6250	0.0100	0.0982	0.1
Q14C	836	11200	11.2	9.36	2.53	0.84	0.6	6720	6.7	5.62	33	83.36	0.88	2	0.0000	0.0000	0.0217	4.6463	0.0100	0.0467	0.1
Q14D	409	11200	11.2	4.58	0.79	0.26	0.5	5600	5.6	2.29	6	4.72	0.05	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q14E	343	11200	11.2	3.84	2.26	0.75	0.6	6720	6.7	2.30	33	74.44	0.78	1	0.0000	0.0000	0.0026	2.7971	0.0100	0.0280	0.1
Q21A	601	11200	11.2	6.73	1.28	0.43	0.5	5600	5.6	3.37	12	15.40	0.16	20	0.0000	0.0000	0.1155	0.1485	1.0000	0.2640	0.4
Q21B	381	11200	11.2	4.27	0.46	0.15	0.4	4480	4.5	1.71	9	4.13	0.04	23	0.0000	0.0000	0.0799	11.1120	0.0100	0.1119	0.3
Q22A	518	11200	11.2	5.80	1.47	0.49	0.5	5600	5.6	2.90	31	45.44	0.48	1	0.0000	0.0000	0.0281	2.1802	0.0100	0.0221	0.0
Q22B	220	11200	11.2	2.46	1.59	0.53	0.6	6720	6.7	1.48	35	55.56	0.58	1	0.0000	0.0000	0.0089	2.4042	0.0100	0.0241	0.1
Q30A	395	11150	11.1	4.40	1.66	0.55	0.6	6690	6.7	2.64	31	51.37	0.54	5	0.0000	0.0000	0.0830	0.0000	1.0000	0.0830	0.2
Q30B	482	11200	11.2	5.40	1.25	0.42	0.5	5600	5.6	2.70	64	80.18	0.84	3	0.0000	0.0000	0.1027	3.2007	0.0100	0.0330	0.1
Q30C	421	11200	11.2	4.72	1.12	0.37	0.5	5600	5.6	2.36	24	26.94	0.28	10	0.0000	0.0000	0.0889	11.2304	0.0100	0.1132	0.3
Q30D	311	11200	11.2	3.48	2.05	0.68	0.6	6720	6.7	2.09	36	73.97	0.78	3	0.0000	0.0000	0.0662	5.4680	0.0100	0.0553	0.2
Q30E	326	11200	11.2	3.65	1.72	0.57	0.6	6720	6.7	2.19	21	36.16	0.38	17	0.0000	0.0000	0.0695	31.4270	0.0100	0.3150	1.0
Q41A	230	17008	17.0	3.91	1.10	0.37	0.5	8504	8.5	1.96	8	8.82	0.09	11	0.0000	0.0000	0.0000	0.1287	1.0000	0.1287	0.6

QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	oGHPi HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	oGBYi AVERAGE YIELD BOREHOLES	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	oGEPo EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD DATA	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	oGWSo TOTAL USE	TOTAL USE
	(km^2)	($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)		(l/s)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)	($x10^6$ m^3/a)		($x10^6$ m^3/a)	(mm/a)
Q41B	434	15522	15.5	6.74	1.26	0.42	0.5	7761	7.8	3.37	30	37.86	0.40	21	0.0000	0.0000	0.0122	2.8277	0.1000	0.2840	0.7
Q41C	333	11209	11.2	3.73	2.64	0.88	0.6	6726	6.7	2.24	53	139.84	1.47	13	0.0000	0.0000	0.0221	0.3287	1.0000	0.3508	1.1
Q41D	295	11804	11.8	3.48	1.98	0.66	0.6	7082	7.1	2.09	56	110.88	1.17	2	0.0000	0.0000	0.0485	0.4481	0.1000	0.0497	0.2
Q42A	446	11316	11.3	5.05	0.67	0.22	0.4	4526	4.5	2.02	11	7.32	0.08	3	0.0000	0.0000	0.0176	0.2239	0.1000	0.0242	0.1
Q42B	376	11200	11.2	4.21	12.63	4.21	0.7	7840	7.8	2.95	2	25.25	0.27	0	0.0000	0.0000	0.0322	0.1792	0.1000	0.0211	0.1
Q43A	706	11448	11.4	8.08	1.89	0.63	0.6	6869	6.9	4.85	27	51.10	0.54	1	0.0000	0.0000	0.0108	2.7140	0.0100	0.0272	0.0
Q43B	803	11200	11.2	8.99	1.12	0.37	0.5	5600	5.6	4.50	5	5.59	0.06	18	0.0000	0.0000	0.1345	1.9438	0.1000	0.2078	0.3
Q44A	426	11200	11.2	4.77	1.02	0.34	0.5	5600	5.6	2.39	84	85.71	0.90	2	0.0000	0.0000	0.0607	2.4173	0.0100	0.0248	0.1
Q44B	449	11200	11.2	5.03	3.21	1.07	0.7	7840	7.8	3.52	37	118.67	1.25	15	0.0000	0.0000	0.0925	4.8831	0.1000	0.4976	1.1
Q44C	254	11200	11.2	2.84	1.41	0.47	0.5	5600	5.6	1.42	28	39.60	0.42	10	0.0000	0.0000	0.0537	14.2150	0.0100	0.1427	0.6
Q50A	640	10083	10.1	6.45	1.47	0.49	0.5	5042	5.0	3.23	97	142.91	1.50	24	0.0000	0.0000	0.1330	37.5907	0.0100	0.3772	0.6
Q50B	403	8400	8.4	3.39	1.82	0.61	0.6	5040	5.0	2.03	82	149.07	1.57	8	0.0000	0.0000	0.0451	14.9997	0.0100	0.1504	0.4
Q50C	198	8400	8.4	1.66	1.24	0.41	0.5	4200	4.2	0.83	48	59.34	0.62	2	0.0000	0.0000	0.0255	0.0000	1.0000	0.0255	0.1
Q60A	316	11200	11.2	3.54	1.71	0.57	0.6	6720	6.7	2.12	22	37.72	0.40	4	0.0000	0.0000	0.0450	0.0233	1.0000	0.0683	0.2
Q60B	370	10304	10.3	3.81	1.59	0.53	0.6	6182	6.2	2.29	53	84.38	0.89	4	0.0000	0.0000	0.0592	0.0000	1.0000	0.0592	0.2
Q60C	132	8409	8.4	1.11	1.95	0.65	0.6	5046	5.0	0.67	29	56.68	0.60	24	0.0000	0.0000	0.0233	0.4654	1.0000	0.4887	3.7
Q70A	251	8400	8.4	2.11	2.43	0.81	0.6	5040	5.0	1.27	29	70.48	0.74	1	0.0000	0.0000	0.0369	0.0000	1.0000	0.0369	0.1
Q70B	458	8400	8.4	3.85	1.53	0.51	0.6	5040	5.0	2.31	96	146.46	1.54	4	0.0000	0.0000	0.0578	0.0000	1.0000	0.0578	0.1
Q70C	250	8400	8.4	2.10	0.83	0.28	0.5	4200	4.2	1.05	28	23.12	0.24	4	0.0000	0.0000	0.0324	0.0000	1.0000	0.0324	0.1
Q80A	357	8566	8.6	3.06	1.78	0.59	0.6	5139	5.1	1.83	24	42.66	0.45	6	0.0000	0.0000	0.0310	1.1423	0.1000	0.1173	0.3
Q80B	450	9181	9.2	4.13	1.28	0.43	0.5	4591	4.6	2.07	62	79.47	0.84	2	0.0000	0.0000	0.0655	2.9723	0.0100	0.0304	0.1
Q80C	281	8400	8.4	2.36	3.30	1.10	0.7	5880	5.9	1.65	33	108.96	1.15	3	0.0000	0.0000	0.0249	1.1797	0.1000	0.1205	0.4
Q80D	418	8400	8.4	3.51	2.02	0.67	0.6	5040	5.0	2.11	34	68.71	0.72	17	0.3120	0.0000	0.0402	0.0000	1.0000	0.3522	0.8
Q80E	365	8400	8.4	3.07	1.34	0.45	0.5	4200	4.2	1.53	27	36.28	0.38	3	0.0000	0.0000	0.0362	0.0000	1.0000	0.0362	0.1
Q80F	701	8546	8.5	5.99	1.31	0.44	0.5	4273	4.3	3.00	33	43.31	0.46	4	0.0000	0.0000	0.0693	5.1870	0.0100	0.0526	0.1
Q80G	266	8569	8.6	2.28	2.04	0.68	0.6	5141	5.1	1.37	17	34.73	0.37	1	0.0000	0.0000	0.0266	0.0000	1.0000	0.0266	0.1
Q91A	478	8750	8.7	4.18	0.88	0.29	0.5	4375	4.4	2.09	12	10.54	0.11	5	0.0000	0.0000	0.0498	0.0000	1.0000	0.0498	0.1
Q91B	515	8881	8.9	4.57	1.13	0.38	0.5	4441	4.4	2.29	20	22.65	0.24	2	0.0000	0.0000	0.0199	0.0000	1.0000	0.0199	0.0
Q91C	485	10335	10.3	5.01	0.62	0.21	0.4	4134	4.1	2.00	28	17.49	0.18	5	0.0000	0.0000	0.0299	0.0000	1.0000	0.0299	0.1
Q92A	324	17700	17.7	5.73	0.83	0.28	0.5	8850	8.9	2.87	24	19.97	0.21	0	0.0000	0.0000	0.0019	0.0000	1.0000	0.0019	0.0
Q92B	324	16680	16.7	5.40	1.78	0.59	0.6	10008	10.0	3.24	22	39.10	0.41	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q92C	601	9682	9.7	5.82	1.52	0.51	0.6	5809	5.8	3.49	37	56.29	0.59	1	0.0000	0.0000	0.0203	0.0000	1.0000	0.0203	0.0

QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	oGHPi HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	oGBYi AVERAGE YIELD BOREHOLES	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL	EXPLOITATION POTENTIAL	oGEPo EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE	RURAL USE	LIVESTOCK USE	IRRIGATION USE	TOTAL USE FACTOR	oGWSo TOTAL USE	TOTAL USE
	(km²)	(m³/km²/a)	(mm)	(x10⁶ m³/a)	(l/s, 8hrs/d)	(l/s, 24hrs/d)		(m³/km²/a)	(mm)	(x10⁶ m³/a)	DATA	(l/s)	(x10⁶ m³/a)		(x10⁶ m³/a)	(x10⁶ m³/a)	(x10⁶ m³/a)	(x10⁶ m³/a)		(x10⁶ m³/a)	(mm/a)
Q92D	249	17665	17.7	4.40	0.71	0.24	0.5	8833	8.8	2.20	12	8.49	0.09	0	0.0000	0.0000	0.0004	0.0000	1.0000	0.0004	0.0
Q92E	287	11442	11.4	3.28	2.37	0.79	0.6	6865	6.9	1.97	25	59.33	0.62	1	0.0125	0.0000	0.0127	0.0000	1.0000	0.0252	0.1
Q92F	665	8400	8.4	5.59	3.83	1.28	0.7	5880	5.9	3.91	143	547.16	5.75	3	0.0000	0.0000	0.1069	0.0000	1.0000	0.1069	0.2
Q92G	884	12830	12.8	11.34	1.17	0.39	0.5	6415	6.4	5.67	42	48.96	0.51	5	0.0000	0.0000	0.0556	0.0000	1.0000	0.0556	0.1
Q93A	337	15190	15.2	5.12	0.25	0.08	0.3	4557	4.6	1.54	1	0.25	0.00	2	0.0000	0.0000	0.0061	0.0000	1.0000	0.0061	0.0
Q93B	392	9405	9.4	3.69	1.20	0.40	0.5	4703	4.7	1.84	19	22.71	0.24	1	0.0000	0.0000	0.0148	0.0000	1.0000	0.0148	0.0
Q93C	413	12064	12.1	4.98	0.83	0.28	0.5	6032	6.0	2.49	45	37.45	0.39	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q93D	491	11842	11.8	5.81	1.09	0.36	0.5	5921	5.9	2.91	86	93.50	0.98	7	0.0000	0.0000	0.0825	0.0000	1.0000	0.0825	0.2
Q94A	259	17700	17.7	4.58	0.40	0.13	0.4	7080	7.1	1.83	3	1.19	0.01	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q94B	147	17700	17.7	2.60	1.45	0.48	0.5	8850	8.9	1.30	2	2.90	0.03	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q94C	135	17700	17.7	2.39	1.51	0.50	0.6	10620	10.6	1.43	39	58.95	0.62	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
Q94D	212	17700	17.7	3.75	1.37	0.46	0.5	8850	8.9	1.88	35	47.95	0.50	0	0.0000	0.0000	0.0001	0.0000	1.0000	0.0001	0.0
Q94E	228	17700	17.7	4.04	1.69	0.56	0.6	10620	10.6	2.42	42	70.95	0.75	0	0.0000	0.0000	0.0008	0.0000	1.0000	0.0008	0.0
Q94F	734	17631	17.6	12.94	1.90	0.63	0.6	10578	10.6	7.76	95	180.20	1.89	2	0.0000	0.0000	0.0405	0.0000	1.0000	0.0405	0.1

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

GROUNDWATER CONTRIBUTION TO BASEFLOW PER QUATERNARY CATCHMENT

QUATERNARY	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
	MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	BASE FLOW SCHULTZ	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER
	(x 10^6 m^3/a)		(mm/a)	(mm/a)	(x 10^6 m^3/a)						(x 10^6 m^3/a)
K80A	72.33	152.34	103.50	282.56	22.24	1.33	1.00	UNDER-UTILISED	HIGH	0.85	7.11
K80B	101.45	143.83	103.70	264.61	29.92	1.24	1.00	UNDER-UTILISED	HIGH	0.85	12.34
K80C	81.01	121.64	101.40	239.00	22.99	1.02	1.00	UNDER-UTILISED	HIGH	0.85	11.53
K80D	67.34	99.75	86.30	211.02	17.56	0.89	0.89	UNDER-UTILISED	HIGH	0.70	6.92
K80E	53.75	27.95	29.10	87.18	7.43	0.27	0.27	UNDER-UTILISED	LOW	0.96	13.41
K80F	34.04	22.41	23.40	66.71	4.95	0.22	0.22	UNDER-UTILISED	LOW	0.70	8.03
K90A	30.42	17.53	19.70	57.87	3.75	0.20	0.20	UNDER-UTILISED	LOW	0.70	8.05
K90B	25.53	21.60	23.60	69.97	3.24	0.26	0.26	UNDER-UTILISED	LOW	1.00	7.54
K90C	13.59	5.51	8.50	21.41	1.47	0.09	0.09	UNDER-UTILISED	LOW	1.00	8.05
K90D	17.06	8.38	12.30	32.94	1.80	0.10	0.10	UNDER-UTILISED	LOW	0.50	5.67
K90E	12.02	9.20	11.60	30.08	1.62	0.20	0.20	UNDER-UTILISED	LOW	0.50	1.98
K90F	18.78	10.21	12.60	32.62	2.55	0.19	0.19	UNDER-UTILISED	LOW	0.63	4.24
K90G	17.14	7.96	10.70	26.01	2.28	0.17	0.17	UNDER-UTILISED	LOW	0.92	8.43
L11A	5.39	0.00	0.00	0.33	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.65	1.36
L11B	6.41	0.00	0.00	0.49	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.90	3.02
L11C	4.50	0.00	0.00	0.41	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.94	2.92
L11D	8.11	0.00	0.00	0.48	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.90	4.47
L11E	2.88	0.00	0.00	0.14	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.52	1.10
L11F	4.27	0.00	0.00	0.23	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.70	2.87
L11G	6.08	0.00	0.00	0.04	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	1.46
L12A	2.42	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.68	0.92
L12B	2.53	0.00	0.00	0.00	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.20	0.36
L12C	2.47	0.00	0.00	0.00	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.50	1.35
L12D	3.21	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.15	0.32
L21A	5.24	0.00	0.00	0.44	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.92	2.18
L21B	7.01	0.00	0.00	0.59	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.88	3.27
L21C	11.05	0.03	0.00	1.51	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.89	3.87
L21D	17.18	0.10	0.00	3.29	0.09	0.01	0.01	UNDER-UTILISED	LOW	0.70	2.71
L21E	6.78	0.04	0.00	1.14	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.87	3.51
L21F	5.40	0.00	0.00	0.50	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.88	1.60
L22A	8.35	0.00	0.00	0.52	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.89	2.94

QUATERNARY	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
	MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	BASE FLOW SCHULTZ	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER
	(x 10^6 m^3/a)		(mm/a)	(mm/a)	(x 10^6 m^3/a)						(x 10^6 m^3/a)
L22B	2.30	0.00	0.00	0.00	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.40	0.56
L22C	5.30	0.00	0.00	0.09	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.40	0.93
L22D	6.14	0.00	0.00	0.34	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.50	1.23
L23A	2.48	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	0.80
L23B	8.74	0.00	0.00	0.29	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.40	1.09
L23C	4.58	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	1.93
L23D	3.65	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	0.23
L30A	3.01	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.29	0.50
L30B	2.86	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	0.21
L30C	2.47	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	0.24
L30D	2.95	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.43	1.32
L40A	3.50	0.00	0.00	0.01	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	1.09
L40B	3.90	0.00	0.00	0.09	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	0.40
L50A	4.42	0.00	0.00	0.22	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.29	2.54
L50B	3.83	0.00	0.00	0.04	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.43	0.94
L60A	4.04	0.00	0.00	0.08	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	0.51
L60B	3.17	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.76	2.18
L70A	3.11	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.30	1.17
L70B	1.31	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.25	0.72
L70C	2.64	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.19	2.24
L70D	2.72	0.00	0.00	0.00	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.73	2.33
L70E	5.20	0.00	0.00	0.26	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.50	2.06
L70F	3.27	0.00	0.00	0.18	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	1.04
L70G	14.50	3.70	6.00	13.07	1.74	0.07	0.07	UNDER-UTILISED	LOW	0.70	9.09
L81A	17.69	1.90	6.60	17.16	0.63	0.03	0.03	UNDER-UTILISED	LOW	0.85	9.63
L81B	8.41	1.15	4.50	10.46	0.30	0.02	0.02	UNDER-UTILISED	LOW	0.85	9.63
L81C	11.43	1.35	4.70	11.16	0.45	0.02	0.02	UNDER-UTILISED	LOW	0.85	11.97
L81D	8.25	1.17	3.80	8.79	0.36	0.02	0.02	UNDER-UTILISED	LOW	0.70	7.44
L82A	14.92	3.46	8.40	19.96	0.93	0.05	0.05	UNDER-UTILISED	LOW	0.85	11.39
L82B	31.46	4.73	11.70	27.71	1.92	0.07	0.07	UNDER-UTILISED	LOW	0.85	12.23
L82C	28.54	5.06	11.90	28.39	1.83	0.07	0.07	UNDER-UTILISED	LOW	0.85	14.04
L82D	31.55	4.12	7.90	20.00	2.43	0.05	0.05	UNDER-UTILISED	LOW	1.00	31.42
L82E	18.55	4.03	8.10	19.21	1.47	0.06	0.06	UNDER-UTILISED	LOW	0.85	8.38
L82F	5.68	3.38	6.20	13.56	0.57	0.06	0.06	UNDER-UTILISED	LOW	0.70	2.17

QUATERNARY	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
	MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	BASE FLOW SCHULTZ	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER
	($x\ 10^6\ m^3/a$)		(mm/a)	(mm/a)	($x\ 10^6\ m^3/a$)						($x\ 10^6\ m^3/a$)
L82G	7.14	2.72	5.40	10.75	0.72	0.04	0.04	UNDER-UTILISED	LOW	1.00	5.31
L82H	5.29	2.22	5.00	9.11	0.51	0.04	0.04	UNDER-UTILISED	LOW	0.70	4.02
L82J	4.96	3.11	5.80	12.31	0.51	0.05	0.05	UNDER-UTILISED	LOW	0.70	3.10
L90A	19.93	4.65	6.90	16.38	2.40	0.11	0.11	UNDER-UTILISED	LOW	0.50	5.60
L90B	35.91	8.12	13.30	37.61	2.97	0.30	0.30	MODERATELY-UTILISED	MODERATE	0.76	4.53
L90C	31.78	8.46	13.90	39.50	2.70	0.23	0.23	UNDER-UTILISED	LOW	0.42	2.98
M10A	15.99	2.82	4.80	20.16	0.75	0.05	0.05	UNDER-UTILISED	LOW	0.70	5.42
M10B	24.48	2.90	5.60	22.59	1.14	0.06	0.06	UNDER-UTILISED	LOW	0.89	8.64
M10C	30.50	3.49	6.20	23.93	1.50	0.09	0.09	UNDER-UTILISED	LOW	0.50	5.26
M10D	5.61	0.00	0.00	0.12	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.16	0.78
M20A	20.36	0.25	0.00	8.06	0.09	0.00	0.00	UNDER-UTILISED	LOW	0.72	9.26
M20B	39.66	6.03	13.80	45.81	1.86	0.13	0.13	UNDER-UTILISED	LOW	0.65	4.61
M30A	5.06	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.24	0.80
M30B	5.32	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.62	1.25
N11A	9.28	0.09	0.00	2.31	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.50	1.96
N11B	7.97	0.08	0.00	1.76	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.76	4.62
N12A	9.54	0.08	0.00	2.40	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.70	3.57
N12B	9.11	0.08	0.00	2.11	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.70	3.84
N12C	7.86	0.09	0.00	2.08	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.87	3.84
N13A	8.58	0.16	0.00	2.77	0.09	0.01	0.01	UNDER-UTILISED	LOW	0.59	2.57
N13B	7.29	0.19	0.00	2.58	0.09	0.02	0.02	UNDER-UTILISED	LOW	0.82	3.12
N13C	3.87	0.06	0.00	1.19	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.54	2.08
N14A	4.83	0.06	0.00	1.16	0.03	0.01	0.01	MODERATELY-UTILISED	LOW	0.56	1.03
N14B	3.92	0.08	0.00	1.07	0.03	0.01	0.01	OVER-UTILISED	LOW	0.68	1.91
N14C	19.51	0.19	0.00	5.30	0.12	0.02	0.02	OVER-UTILISED	LOW	0.91	4.68
N14D	4.76	0.08	0.00	1.57	0.03	0.01	0.01	OVER-UTILISED	LOW	0.38	1.08
N21A	3.81	0.06	0.00	1.29	0.03	0.01	0.01	HEAVILY-UTILISED	LOW	0.40	1.23
N21B	10.97	0.31	0.00	5.84	0.12	0.03	0.03	UNDER-UTILISED	LOW	0.40	0.87
N21C	9.75	0.12	0.00	2.61	0.09	0.01	0.01	UNDER-UTILISED	LOW	0.40	1.53
N21D	5.48	0.05	0.00	1.69	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.40	1.21
N22A	7.50	0.05	0.00	1.77	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.40	1.16
N22B	3.75	0.00	0.00	0.59	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.20	0.64
N22C	3.79	0.00	0.00	0.96	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.30	0.54
N22D	5.56	0.00	0.00	1.93	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	0.56

QUATERNARY	vMARi MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	oGBFi BASE FLOW SCHULTZ	BASE FLOW FACTOR	fGBDo CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	fGPQi PORTION POTABLE	oGWMo MAX UTILISABLE GROUND WATER
	(x 10^6 m^3/a)		(mm/a)	(mm/a)	(x 10^6 m^3/a)						(x 10^6 m^3/a)
N22E	2.74	0.00	0.00	0.67	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.20	0.31
N23A	8.82	0.11	0.00	2.73	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.20	0.49
N23B	2.64	0.00	0.00	1.08	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.20	0.27
N24A	5.78	0.04	0.00	1.13	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.40	1.43
N24B	5.85	0.04	0.00	1.14	0.03	0.01	0.01	HEAVILY-UTILISED	LOW	0.40	1.43
N24C	7.44	0.04	0.00	1.27	0.03	0.01	0.01	HEAVILY-UTILISED	LOW	0.40	1.28
N24D	2.18	0.00	0.00	0.35	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.20	0.30
N30A	20.66	0.21	0.00	5.61	0.18	0.02	0.02	MODERATELY-UTILISED	LOW	0.40	1.78
N30B	9.83	0.12	0.00	2.70	0.09	0.02	0.02	UNDER-UTILISED	LOW	0.52	1.77
N30C	4.59	0.09	0.00	2.22	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.40	0.54
N40A	6.46	0.40	1.10	2.95	0.27	0.03	0.03	UNDER-UTILISED	LOW	0.30	1.19
N40B	8.20	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.30	3.31
N40C	13.46	1.19	2.00	7.54	0.69	0.09	0.09	MODERATELY-UTILISED	LOW	0.30	1.37
N40D	13.61	0.00	0.00	0.56	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.30	1.63
N40E	3.97	0.00	0.00	0.00	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.30	1.12
N40F	16.61	0.00	0.00	0.81	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.17	1.63
P10A	4.51	1.90	3.00	11.31	0.24	0.15	0.15	UNDER-UTILISED	LOW	0.30	0.24
P10B	12.25	1.42	2.10	8.07	0.72	0.11	0.11	UNDER-UTILISED	LOW	0.88	3.38
P10C	2.38	0.53	1.20	2.99	0.15	0.06	0.06	UNDER-UTILISED	LOW	0.20	0.27
P10D	7.01	0.85	1.30	4.48	0.48	0.08	0.08	UNDER-UTILISED	LOW	0.67	2.54
P10E	8.71	0.00	0.00	0.75	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.32	0.98
P10F	13.67	0.00	0.00	2.21	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.14	0.45
P10G	9.76	0.00	0.00	1.79	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.00	0.00
P20A	30.27	0.20	0.00	12.13	0.09	0.01	0.01	UNDER-UTILISED	LOW	0.39	3.13
P20B	15.43	0.08	0.00	5.14	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.17	1.63
P30A	6.95	2.05	3.10	12.72	0.36	0.16	0.16	UNDER-UTILISED	LOW	0.30	0.34
P30B	11.67	0.00	0.00	2.30	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.13	0.32
P30C	1.69	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.50	0.50
P40A	13.58	2.40	3.20	14.23	0.75	0.19	0.19	UNDER-UTILISED	LOW	0.30	0.48
P40B	8.17	0.00	0.00	2.03	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.70	1.17
P40C	14.18	0.09	0.00	4.20	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.39	2.04
P40D	13.36	0.11	0.00	6.24	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.33	0.63
Q11A	7.48	0.08	0.00	2.52	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.70	2.10
Q11B	5.19	0.00	0.00	1.51	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.70	2.06

QUATERNARY	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
	MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	BASE FLOW SCHULTZ	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER
	(x 10^6 m^3/a)		(mm/a)	(mm/a)	(x 10^6 m^3/a)						(x 10^6 m^3/a)
Q11C	4.82	0.00	0.00	1.39	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.70	1.70
Q11D	4.79	0.00	0.00	1.05	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.70	2.26
Q12A	10.22	0.05	0.00	2.52	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.70	3.45
Q12B	12.42	0.05	0.00	3.17	0.03	0.00	0.00	UNDER-UTILISED	LOW	1.00	3.57
Q12C	4.92	0.07	0.00	1.58	0.03	0.01	0.01	OVER-UTILISED	LOW	0.70	1.68
Q13A	10.68	0.03	0.00	1.71	0.03	0.00	0.00	UNDER-UTILISED	LOW	1.00	8.08
Q13B	1.71	0.00	0.00	0.44	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.70	1.13
Q13C	3.81	0.00	0.00	0.92	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.70	2.14
Q14A	6.63	0.00	0.00	1.49	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.94	3.45
Q14B	9.63	0.04	0.00	1.77	0.03	0.00	0.00	OVER-UTILISED	LOW	0.95	4.72
Q14C	8.86	0.03	0.00	1.37	0.03	0.00	0.00	MODERATELY-UTILISED	LOW	1.00	5.62
Q14D	3.22	0.00	0.00	0.61	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.50	1.15
Q14E	3.21	0.00	0.00	0.73	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.50	1.15
Q21A	7.76	0.05	0.00	1.84	0.03	0.00	0.00	UNDER-UTILISED	LOW	0.50	1.68
Q21B	3.08	0.00	0.00	0.74	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.50	0.85
Q22A	6.35	0.00	0.00	1.67	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGABLE	0.50	1.45
Q22B	2.26	0.00	0.00	0.79	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.50	0.74
Q30A	7.00	1.82	2.30	6.39	0.72	0.16	0.16	UNDER-UTILISED	LOW	0.50	1.32
Q30B	4.84	0.00	0.00	1.48	0.00	0.00	0.00	HEAVILY-UTILISED	NEGLIGABLE	0.50	1.35
Q30C	3.84	0.00	0.00	1.29	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.70	1.65
Q30D	3.27	0.00	0.00	1.23	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.50	1.04
Q30E	3.52	0.00	0.00	1.50	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.50	1.10
Q41A	7.66	0.52	0.00	6.96	0.12	0.03	0.03	UNDER-UTILISED	LOW	0.70	1.37
Q41B	8.37	0.28	0.00	4.08	0.12	0.02	0.02	MODERATELY-UTILISED	LOW	0.70	2.36
Q41C	5.75	0.27	0.00	3.26	0.09	0.02	0.02	UNDER-UTILISED	LOW	0.70	1.57
Q41D	2.88	0.10	0.00	1.62	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.70	1.46
Q42A	9.58	0.14	0.00	4.09	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.70	1.41
Q42B	6.50	0.16	0.00	2.92	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.70	2.06
Q43A	9.61	0.09	0.00	2.59	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.78	3.77
Q43B	7.21	0.08	0.00	1.53	0.06	0.01	0.01	UNDER-UTILISED	LOW	0.70	3.15
Q44A	4.68	0.07	0.00	1.75	0.03	0.01	0.01	HEAVILY-UTILISED	LOW	0.50	1.19
Q44B	3.64	0.07	0.00	1.23	0.03	0.01	0.01	HEAVILY-UTILISED	LOW	0.70	2.46
Q44C	2.54	0.00	0.00	1.18	0.00	0.00	0.00	OVER-UTILISED	NEGLIGABLE	0.70	1.00
Q50A	7.63	0.14	0.00	2.44	0.09	0.01	0.01	OVER-UTILISED	LOW	0.40	1.29

QUATERNARY	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
	MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	BASE FLOW SCHULTZ	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER
	(x 10^6 m^3/a)		(mm/a)	(mm/a)	(x 10^6 m^3/a)						(x 10^6 m^3/a)
Q50B	6.42	0.22	0.00	3.26	0.09	0.03	0.03	OVER-UTILISED	LOW	0.40	0.81
Q50C	3.22	0.15	0.00	2.71	0.03	0.02	0.02	UNDER-UTILISED	LOW	0.40	0.33
Q60A	8.04	0.47	0.00	5.88	0.15	0.04	0.04	UNDER-UTILISED	LOW	0.70	1.49
Q60B	9.83	0.57	0.00	6.22	0.21	0.05	0.05	UNDER-UTILISED	LOW	0.40	0.91
Q60C	2.41	0.22	0.00	3.32	0.03	0.03	0.03	MODERATELY-UTILISED	LOW	0.40	0.27
Q70A	4.65	0.12	0.00	3.20	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.40	0.51
Q70B	5.65	0.13	0.00	2.23	0.06	0.02	0.02	UNDER-UTILISED	LOW	0.25	0.58
Q70C	2.80	0.12	0.00	1.85	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.32	0.34
Q80A	7.01	2.01	2.50	7.33	0.72	0.24	0.24	UNDER-UTILISED	LOW	0.40	0.73
Q80B	8.03	1.93	2.40	6.61	0.87	0.21	0.21	HEAVILY-UTILISED	LOW	0.40	0.83
Q80C	5.30	2.03	2.50	7.08	0.57	0.24	0.24	MODERATELY-UTILISED	LOW	0.40	0.66
Q80D	12.89	2.52	3.00	10.80	1.05	0.30	0.30	UNDER-UTILISED	LOW	1.00	2.11
Q80E	5.67	0.08	0.00	2.62	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.40	0.61
Q80F	9.07	0.13	0.00	2.29	0.09	0.01	0.01	HEAVILY-UTILISED	LOW	0.40	1.20
Q80G	3.57	0.11	0.00	2.04	0.03	0.01	0.01	UNDER-UTILISED	LOW	0.30	0.41
Q91A	7.37	0.25	0.00	3.32	0.12	0.03	0.03	UNDER-UTILISED	LOW	0.40	0.84
Q91B	11.69	0.41	0.00	5.31	0.21	0.05	0.05	UNDER-UTILISED	LOW	0.30	0.69
Q91C	8.12	0.00	0.00	0.32	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.00	0.00
Q92A	21.73	8.89	13.90	28.57	2.88	0.50	0.50	UNDER-UTILISED	MODERATE	0.70	2.01
Q92B	11.61	2.87	5.30	12.60	0.93	0.17	0.17	UNDER-UTILISED	LOW	0.50	1.62
Q92C	18.38	2.64	5.00	11.07	1.59	0.27	0.27	UNDER-UTILISED	LOW	0.40	1.40
Q92D	9.48	3.26	5.30	13.54	0.81	0.18	0.18	UNDER-UTILISED	LOW	0.50	1.10
Q92E	2.70	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	0.79
Q92F	4.02	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	1.56
Q92G	8.47	0.00	0.00	0.23	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.00	0.00
Q93A	4.33	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.40	0.61
Q93B	6.18	0.00	0.00	0.10	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.08	0.15
Q93C	6.89	0.00	0.00	0.13	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.00	0.00
Q93D	17.42	0.00	0.00	2.68	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.47	1.36
Q94A	23.57	14.82	24.10	39.84	3.84	0.84	0.84	UNDER-UTILISED	HIGH	0.50	0.92
Q94B	10.21	10.81	16.20	30.31	1.59	0.61	0.61	UNDER-UTILISED	MODERATE	0.50	0.65
Q94C	11.33	12.44	20.00	37.86	1.68	0.70	0.70	UNDER-UTILISED	MODERATE	0.50	0.72
Q94D	7.45	3.54	5.50	13.09	0.75	0.20	0.20	UNDER-UTILISED	LOW	0.50	0.94
Q94E	9.28	3.82	5.80	14.89	0.87	0.22	0.22	UNDER-UTILISED	LOW	0.50	1.21

QUATERNARY	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
	MEAN ANNUAL RUNOFF	BASE FLOW SCHULTZ	BASE FLOW PITTMAN	BASE FLOW HUGHES	BASE FLOW SCHULTZ	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER
	(x 10^6 m^3/a)		(mm/a)	(mm/a)	(x 10^6 m^3/a)						(x 10^6 m^3/a)
Q94F	8.19	0.00	0.00	0.33	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGABLE	0.50	3.88

FISH TO TSITSIKAMMA WATER MANAGEMENT AREA

APPENDIX G.5

WATER QUALITY INFORMATION

Quaternary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
K80A	NO					
K80B	NO					
K80C	K8H002Q01	61.6	143	Blue	Blue	Blue
K80D	NO					
K80E	NO					
K80F	NO					
K90A	K9H002Q01	138.2	159	Blue	Blue	Blue
K90B	K9H002Q01	138.2	159	Blue	Blue	Blue
K90C	K9H003Q01	349.9	762	Green	Yellow	Yellow
K90D	K9H003Q01	349.9	762	Green	Yellow	Yellow
K90E	K9H003Q01	349.9	762	Green	Yellow	Yellow
K90F	NO					
K90G	NO					
L11A	NO					
L11B	NO					
L11C	NO					
L11D	NO					
L11E	NO					
L11F	NO					
L11G	NO					
L12A	NO					
L12B	NO					
L12C	NO					
L12D	NO					
L21A	NO					
L21B	NO					
L21C	NO					
L21D	NO					
L21E	NO					
L21F	NO					
L22A	NO					
L22B	NO					
L22C	NO					
L22D	NO					
L23A	NO					
L23B	NO					
L23C	NO					
L23D	NO					
L30A	NO					
L30B	NO					
L30C	L3R001Q01	681.0	1441	Yellow	Yellow	Yellow
L30D	NO					
L40A	NO					
L40B	NO					
L50A	NO					

Quaternary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
L50B	NO					
L60A	NO					
L60B	NO					
L70A	L7H007Q01	3740.9	9714	Purple	Purple	Purple
L70B	L7H007Q01	3740.9	9714	Purple	Purple	Purple
L70C	L7H007Q01	3740.9	9714	Purple	Purple	Purple
L70D	L7H007Q01	3740.9	9714	Purple	Purple	Purple
L70E	L7H007Q01	3740.9	9714	Purple	Purple	Purple
L70F	L7H006Q01	668.2	3299	Yellow	Red	Red
L70G	L7H006Q01	668.2	3299	Yellow	Red	Red
L81A	NO					
L81B	NO					
L81C	NO					
L81D	NO					
L82A	L8H002Q01	69.6	90	Blue	Blue	Blue
L82B	L8H005Q01	101.5	178	Blue	Blue	Blue
L82C	L8H005Q01	101.5	178	Blue	Blue	Blue
L82D	L8H001Q01	42.7	114	Blue	Blue	Blue
L82E	L8H005Q01	101.5	178	Blue	Blue	Blue
L82F	L8H004Q01	113.1	133	Blue	Blue	Blue
L82G	L8H004Q01	113.1	133	Blue	Blue	Blue
L82H	L8H004Q01	113.1	133	Blue	Blue	Blue
L82J	L8H004Q01	113.1	133	Blue	Blue	Blue
L90A	L9R001Q01	193.7	896	Blue	Yellow	Green
L90B	L9R001Q01	193.7	896	Blue	Yellow	Green
L90C	L9R001Q01	193.7	896	Blue	Yellow	Green
M10A						
M10B						
M10C	M1H012Q01	1593.5	3031	Yellow	Red	Red
M10D	M1H011Q01	1179.9	2073	Yellow	Red	Red
M20A	NO					
M20B	M2H003Q01	290.9	441	Green	Green	Green
M30A	NO					
M30B	NO					
N11A	N1R001Q01	719.3	2293	Yellow	Red	Red
N11B	N1R001Q01	719.3	2293	Yellow	Red	Red
N12A	N1R001Q01	719.3	2293	Yellow	Red	Red
N12B	N1R001Q01	719.3	2293	Yellow	Red	Red
N12C	N1R001Q01	719.3	2293	Yellow	Red	Red
N13A	NO					
N13B	NO					
N13C	NO					
N14A	NO					
N14B	NO					
N14C	NO					
N14D	NO					
N21A	NO					
N21B	NO					
N21C	NO					
N21D	NO					
N22A	NO					
N22B	NO					

Quaternary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
N22C	NO					
N22D	NO					
N22E	NO					
N23A	N2H009Q01	901.4	1551	Yellow	Yellow	Yellow
N23B	N2R001Q01	666.5	889	Yellow	Yellow	Yellow
N24A	NO					
N24B	NO					
N24C	NO					
N24D	NO					
N30A	N3H002Q01	1012.5	2217	Yellow	Red	Red
N30B	N3H002Q01	1012.5	2217	Yellow	Red	Red
N30C	N3H002Q01	1012.5	2217	Yellow	Red	Red
N40A	N4H006Q01	696.5	1401	Yellow	Yellow	Yellow
N40B	N4H003Q01	2594.7	3246	Red	Red	Red
N40C	N4H003Q01	2594.7	3246	Red	Red	Red
N40D	N4H005Q01	4370.1	6410	Purple	Purple	Purple
N40E	N4H003Q01	2594.7	3246	Red	Red	Red
N40F	N4H003Q01	2594.7	3246	Red	Red	Red
P10A	P1H003Q01	2335.6	3654	Red	Purple	Purple
P10B	P1H003Q01	2335.6	3654	Red	Purple	Purple
P10C	P1H003Q01	2335.6	3654	Red	Purple	Purple
P10D	P1H003Q01	2335.6	3654	Red	Purple	Purple
P10E	NO					
P10F	NO					
P10G	NO					
P20A	NO					
P20B	NO					
P30A	P3H001Q01	3048.3	4684	Red	Purple	Purple
P30B	P3H001Q01	3048.3	4684	Red	Purple	Purple
P30C	P3H001Q01	3048.3	4684	Red	Purple	Purple
P40A	P4H001Q01	1770.4	3186	Yellow	Red	Red
P40B	P4H001Q01	1770.4	3186	Yellow	Red	Red
P40C	P4H001Q01	1770.4	3186	Yellow	Red	Red
P40D	NO					
Q11A	NO					
Q11B	NO					
Q11C	NO					
Q11D	NO					
Q12A	Q1H012Q01	248.6	1279	Blue	Yellow	Green
Q12B	Q1H014Q01	137.2	169	Blue	Blue	Blue
Q12C	Q1H012Q01	248.6	1279	Blue	Yellow	Green
Q13A	Q1H022Q01	188.9	226	Blue	Blue	Blue
Q13B	Q1H017Q01	220.6	595	Blue	Green	Green
Q13C	Q1H017Q01	220.6	595	Blue	Green	Green
Q14A	NO					
Q14B	NO					
Q14C	NO					
Q14D	NO					
Q14E	NO					
Q21A	Q2H002Q01	1000.5	1093	Yellow	Yellow	Yellow
Q21B	Q2H002Q01	1000.5	1093	Yellow	Yellow	Yellow
Q22A	NO					

Quaternary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
Q22B	NO					
Q30A	Q3H004Q01	1471.3	1689	Yellow	Yellow	Yellow
Q30B	Q3H004Q01	1471.3	1689	Yellow	Yellow	Yellow
Q30C	Q3H005Q01	589.6	1936	Green	Red	Yellow
Q30D	Q3H005Q01	589.6	1936	Green	Red	Yellow
Q30E	NO					
Q41A	Q4R002Q01	356.1	552	Green	Green	Green
Q41B	Q4R002Q01	356.1	552	Green	Green	Green
Q41C	Q4R002Q01	356.1	552	Green	Green	Green
Q41D	Q4R002Q01	356.1	552	Green	Green	Green
Q42A	NO					
Q42B	NO					
Q43A	NO					
Q43B	NO					
Q44A	Q4R001Q01	505.6	1231	Green	Yellow	Yellow
Q44B	Q4R001Q01	505.6	1231	Green	Yellow	Yellow
Q44C	Q4H013Q01	2227.3	2580	Red	Red	Red
Q50A	Q5R001Q01	638.1	1818	Yellow	Red	Red
Q50B	Q5R001Q01	638.1	1818	Yellow	Red	Red
Q50C	Q5R001Q01	638.1	1818	Yellow	Red	Red
Q60A	NO					
Q60B	NO					
Q60C	NO					
Q70A	Q7H003Q01	1086.0	1878	Yellow	Red	Red
Q70B	Q7H005Q01	1432.0	2206	Yellow	Red	Red
Q70C	Q7H005Q01	1432.0	2206	Yellow	Red	Red
Q80A	Q8H008Q01	1305.9	1644	Yellow	Yellow	Yellow
Q80B	Q8H008Q01	1305.9	1644	Yellow	Yellow	Yellow
Q80C	Q8H008Q01	1305.9	1644	Yellow	Yellow	Yellow
Q80D	Q8H008Q01	1305.9	1644	Yellow	Yellow	Yellow
Q80E	Q8R001Q01	718.4	939	Yellow	Yellow	Yellow
Q80F	Q8H011Q01	1742.1	2279	Yellow	Red	Red
Q80G	Q8H011Q01	1742.1	2279	Yellow	Red	Red
Q91A	Q9H012Q01	1404.4	1820	Yellow	Red	Red
Q91B	Q9H012Q01	1404.4	1820	Yellow	Red	Red
Q91C	Q9H001Q01	1456.8	2021	Yellow	Red	Red
Q92A	Q9H030Q01	219.6	370	Blue	Green	Green
Q92B	NO					
Q92C	NO					
Q92D	NO					
Q92E	NO					
Q92F	NO					
Q92G	NO					
Q93A	Q9H018Q01	1271.6	1721	Yellow	Yellow	Yellow
Q93B	Q9H018Q01	1271.6	1721	Yellow	Yellow	Yellow
Q93C	Q9H018Q01	1271.6	1721	Yellow	Yellow	Yellow
Q93D	NO					
Q94A	Q9H026Q01	132.6	193	Blue	Blue	Blue
Q94B	NO					
Q94C	Q9H019Q01	138.9	281	Blue	Green	Green
Q94D	NO					
Q94E	Q9H017Q01	586.5	757	Green	Yellow	Yellow

Quaternary	Station No	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
Q94F	NO					

APPENDIX H

WATER RESOURCES

APPENDIX H.1	**Data sources.**
APPENDIX H.2	**Data default values used in WRSA report.**

APPENDIX H.1

DATA SOURCES

Data type	Responsible organisation
Afforestation	CSIR
Alien vegetation	CSIR
Industrial, urban and strategic water use	WRSA consultants
Groundwater	WSM Consulting Engineers
Dams	DWAF
Transfer schemes	WRSA consultants
Run-of-river yields	Arcus Gibb
Population	Markdata
Ecological Reserve	IWR, Prof Hughes
Irrigation - Areas and crop types - Efficiency and losses - Evapotranspiration and crop factors	 WRSA consultant WRSA consultant WRP
Storage-draft-frequency curves	WRP

APPENDIX H.2

DATA DEFAULT VALUES USED IN THE WRSA REPORT

PARAMETER	DESCRIPTION	DEFAULT VALUE
FBMLi	Mining losses (factor)	0,1
FBOLi	Other industrial losses (factor)	0,1
FBSLi	Strategic losses (factor)	0,05
FIHCi	Irrigation conveyance losses- High category irrigation (factor)	0,1
FIMCi	Irrigation conveyance losses- Medium category irrigation (factor)	0,1
FILCi	Irrigation conveyance losses- Low category irrigation (factor)	0,1
FIPLi	Irrigation efficiency Low category irrigation (factor)	0,75
FilPMi	Irrigation efficiency Medium category irrigation (factor)	0,75
FilPHi	Irrigation efficiency High category irrigation (factor)	0,75
ORTLi	Rural losses (factor)	0,2

THE DATA AT QUATERNARY CATCHMENT RESOLUTION

For the record – not part of appendix

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D11A	278	278	7	10	203	56434	0.0565	0.0426	255	71024	0.0712	0.0536
D11B	236	236	7	10	203	47908	0.0480	0.0589	255	60294	0.0604	0.0741
D11C	292	292	7	10	203	59276	0.0594	0.0549	255	74601	0.0748	0.0691
D11D	319	319	7	10	203	64757	0.0649	0.0774	255	81499	0.0817	0.0975
D11E	322	322	7	10	203	65366	0.0655	0.1018	255	82266	0.0824	0.1281
D11F	413	413	7	10	203	83839	0.0840	0.0749	255	105514	0.1057	0.0943
D11G	320	320	7	10	203	64960	0.0651	0.1368	255	81755	0.0819	0.1722
D11H	359	359	7	10	203	72877	0.0730	0.1420	255	91718	0.0919	0.1787
D11J	440	440	7	10	203	89320	0.0895	0.1485	255	112412	0.1126	0.1869
D11K	381	381	7	10	203	77343	0.0775	0.1565	255	97339	0.0975	0.1970
0	**3360**	**3360**				**682080**	**0.6834**	**0.0863**		**858423**	**0.8601**	**0.1087**
D12A	369	369	6	13	335	123615	0.1239	0.2878	422	155574	0.1559	0.3622
D12B	385	385	6	13	335	128975	0.1292	0.1969	422	162320	0.1626	0.2478
D12C	343	343	6	13	335	114905	0.1151	0.5597	422	144612	0.1449	0.7044
D12D	355	355	6	12	335	118925	0.1192	0.6649	422	149671	0.1500	0.8368
D12E	712	712	6	12	335	238520	0.2390	0.7200	422	300186	0.3008	0.9062
D12F	803	803	6	13	335	269005	0.2695	0.9797	422	338553	0.3392	1.2330
0	**2967**	**2967**				**993945**	**0.9959**	**0.4791**		**1250916**	**1.2534**	**0.6030**
D13A	475	475	6	13	335	159125	0.1594	0.2239	422	200265	0.2007	0.2817
D13B	533	533	6	13	335	178555	0.1789	0.2420	422	224718	0.2252	0.3046
D13C	517	517	6	13	335	173195	0.1735	0.3160	422	217972	0.2184	0.3977
D13D	635	635	6	13	335	212725	0.2132	0.3679	422	267722	0.2683	0.4630
D13E	1031	1031	6	13	335	345385	0.3461	0.2673	422	434680	0.4355	0.3364
D13F	970	970	6	13	335	324950	0.3256	0.3358	422	408961	0.4098	0.4226
D13G	1125	1125	6	13	335	376875	0.3776	0.7118	422	474311	0.4753	0.8958
D13H	1144	1144	6	13	335	383240	0.3840	1.2843	422	482322	0.4833	1.6163
D13J	1167	1167	6	13	335	390945	0.3917	1.1828	422	492019	0.4930	1.4886

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D13K	397	397	6	13	335	132995	0.1333	0.2641	422	167379	0.1677	0.3324
D13L	682	682	6	13	335	228470	0.2289	0.9037	422	287538	0.2881	1.1373
D13M	678	678	6	13	335	227130	0.2276	1.0546	422	285851	0.2864	1.3272
0	**9354**	**9354**				**3133590**	**3.1399**	**0.4499**		**3943737.7**	**3.9516**	**0.5662**
D14A	764	764	6	12	335	255940	0.2565	1.0205	422	322110	0.3228	1.2843
D14B	324	324	6	13	335	108540	0.1088	1.3492	422	136602	0.1369	1.6981
D14C	722	722	6	13	335	241870	0.2424	1.3106	422	304402	0.3050	1.6494
D14D	680	680	6	13	335	227800	0.2283	1.9450	422	286695	0.2873	2.4479
D14E	663	663	6	13	335	222105	0.2225	2.1580	422	279527	0.2801	2.7159
D14F	541	541	6	13	335	181235	0.1816	1.2767	422	228091	0.2285	1.6067
D14G	605	605	6	13	335	202675	0.2031	1.0383	422	255074	0.2556	1.3068
D14H	697	697	6	13	335	233495	0.2340	1.5790	422	293862	0.2944	1.9872
D14J	515	515	6	13	335	172525	0.1729	1.5681	422	217129	0.2176	1.9735
D14K	634	634	6	13	335	212390	0.2128	1.6937	422	267301	0.2678	2.1316
0	**6145**	**6145**				**2058575**	**2.0627**	**1.4136**		**2590792**	**2.5960**	**1.7790**
D15A	437	437	7	10	203	88711	0.0889	0.0749	255	111646	0.1119	0.0942
D15B	393	393	7	10	203	79779	0.0799	0.0773	255	100405	0.1006	0.0973
D15C	276	276	7	10	203	56028	0.0561	0.1036	255	70513	0.0707	0.1304
D15D	437	437	7	12	203	88711	0.0889	0.0842	255	111646	0.1119	0.1060
D15E	619	619	7	12	203	125657	0.1259	0.1097	255	158144	0.1585	0.1380
D15F	352	352	7	12	203	71456	0.0716	0.2366	255	89930	0.0901	0.2978
D15G	485	485	7	12	203	98455	0.0987	0.3474	255	123909	0.1242	0.4372
D15H	361	361	7	12	203	73283	0.0734	0.4943	255	92229	0.0924	0.6221
0	**3360**	**3360**				**682080**	**0.6834**	**0.1199**		**858422.63**	**0.8601**	**0.1509**
D16A	159	159	7	10	203	32277	0.0323	0.0762	255	40622	0.0407	0.0960
D16B	249	249	7	10	203	50547	0.0506	0.0925	255	63615	0.0637	0.1164
D16C	438	438	7	10	203	88914	0.0891	0.2732	255	111902	0.1121	0.3438
D16D	339	339	7	10	203	68817	0.0690	0.1114	255	86609	0.0868	0.1402
D16E	434	434	7	10	203	88102	0.0883	0.1763	255	110880	0.1111	0.2219
D16F	277	277	7	10	203	56231	0.0563	0.1105	255	70769	0.0709	0.1391
D16G	290	290	7	10	203	58870	0.0590	0.1269	255	74090	0.0742	0.1597
D16H	345	345	7	10	203	70035	0.0702	0.2191	255	88142	0.0883	0.2758

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D16J	374	374	7	10	203	75922	0.0761	0.1584	255	95551	0.0957	0.1993
D16K	329	329	7	10	203	66787	0.0669	0.1116	255	84054	0.0842	0.1404
D16L	533	533	7	10	203	108199	0.1084	0.1819	255	136172	0.1364	0.2290
D16M	753	753	7	10	203	152859	0.1532	0.1152	255	192379	0.1928	0.1450
0	**4520**	**4520**				**917560**	**0.9194**	**0.1369**		**1154782.8**	**1.1571**	**0.1722**
D17A	638	638	7	10	203	129514	0.1298	0.0629	255	162998	0.1633	0.0791
D17B	442	442	7	10	203	89726	0.0899	0.0710	255	112923	0.1131	0.0894
D17C	525	525	7	10	203	106575	0.1068	0.1379	255	134129	0.1344	0.1735
D17D	748	748	7	10	203	151844	0.1521	0.1356	255	191101	0.1915	0.1707
D17E	605	605	7	10	203	122815	0.1231	0.1276	255	154567	0.1549	0.1606
D17F	582	582	7	10	203	118146	0.1184	0.2451	255	148691	0.1490	0.3084
D17G	849	849	7	10	203	172347	0.1727	0.1584	255	216905	0.2173	0.1994
D17H	852	852	7	10	203	172956	0.1733	0.1701	255	217671	0.2181	0.2140
D17J	437	437	7	10	203	88711	0.0889	0.0890	255	111646	0.1119	0.1120
D17K	383	383	7	10	203	77749	0.0779	0.1533	255	97850	0.0980	0.1929
D17L	590	590	7	10	203	119770	0.1200	0.1611	255	150735	0.1510	0.2027
D17M	528	528	7	10	203	107184	0.1074	0.1475	255	134895	0.1352	0.1857
0	**7179**	**7179**				**1457337**	**1.4603**	**0.1241**		**1834111.9**	**1.8378**	**0.1562**
D18A	599	599	7	10	203	121597	0.1218	0.1259	255	153034	0.1533	0.1584
D18B	327	327	7	10	203	66381	0.0665	0.1668	255	83543	0.0837	0.2100
D18C	466	466	7	12	203	94598	0.0948	0.1972	255	119055	0.1193	0.2482
D18D	766	766	7	10	203	155498	0.1558	0.1393	255	195700	0.1961	0.1753
D18E	376	376	7	10	203	76328	0.0765	0.1376	255	96062	0.0963	0.1731
D18F	446	446	7	12	203	90538	0.0907	0.2071	255	113945	0.1142	0.2607
D18G	492	492	7	13	203	99876	0.1001	0.1160	255	125698	0.1259	0.1460
D18H	384	384	7	13	203	77952	0.0781	0.1551	255	98105	0.0983	0.1952
D18J	859	859	7	12	203	174377	0.1747	0.1561	255	219460	0.2199	0.1964
D18K	935	935	7	13	203	189805	0.1902	0.1290	255	238877	0.2394	0.1623
D18L	610	610	7	12	203	123830	0.1241	0.1919	255	155845	0.1562	0.2415
0	**6260**	**6260**				**1270780**	**1.2733**	**0.1486**		**1599323.1**	**1.6025**	**0.1871**
D21A	309	309	6	10	335	103515	0.1037	0.1688	422	130277	0.1305	0.2124
D21B	394	394	6	10	335	131990	0.1323	0.1495	422	166114	0.1664	0.1882

Quat. Number	**Gross area (km2)**	**Net area (km2)**	**Sediment region**	**Erodibility index**	**Sediment (t/km2/a)**	**Sediment yield (t/a)**	**Sediment vol(MCM)**	**Volume (%MAR)**	***Sediment (t/km2/a)***	***Sediment yield (t/a)***	***Sediment vol(MCM)***	***Volume (%MAR)***
D21C	212	212	6	9	335	71020	0.0712	0.2287	422	89381	0.0896	0.2878
D21D	252	252	6	9	335	84420	0.0846	0.2762	422	106246	0.1065	0.3476
D21E	268	268	6	9	335	89780	0.0900	0.3430	422	112991	0.1132	0.4317
D21F	480	480	6	9	335	160800	0.1611	0.4945	422	202373	0.2028	0.6223
D21G	278	278	6	9	335	93130	0.0933	0.4354	422	117208	0.1174	0.5480
D21H	381	381	6	9	335	127635	0.1279	0.3292	422	160633	0.1610	0.4143
D21J	359	359	6	10	335	120265	0.1205	0.1620	422	151358	0.1517	0.2039
D21K	326	326	6	10	335	109210	0.1094	0.1772	422	137445	0.1377	0.2230
D21L	304	304	6	9	335	101840	0.1020	0.2519	422	128169	0.1284	0.3170
0	**3563**	**3563**				**1193605**	**1.1960**	**0.2357**		**1502195.6**	**1.5052**	**0.2967**
D22A	636	636	6	9	335	213060	0.2135	0.5977	422	268144	0.2687	0.7522
D22B	457	457	6	9	335	153095	0.1534	0.4794	422	192676	0.1931	0.6033
D22C	486	486	6	9	335	162810	0.1631	0.3321	422	204902	0.2053	0.4180
D22D	628	628	6	9	335	210380	0.2108	0.5729	422	264771	0.2653	0.7211
D22E	498	498	6	10	335	166830	0.1672	0.3266	422	209962	0.2104	0.4111
D22F	633	633	6	9	335	212055	0.2125	0.4105	422	266879	0.2674	0.5166
D22G	969	969	6	9	335	324615	0.3253	0.6144	422	408540	0.4094	0.7733
D22H	541	541	6	9	335	181235	0.1816	0.5043	422	228091	0.2285	0.6347
D22J	652	652	6	10	335	218420	0.2189	0.3533	422	274890	0.2754	0.4447
D22K	324	324	6	10	335	108540	0.1088	0.3859	422	136602	0.1369	0.4857
D22L	376	376	6	11	335	125960	0.1262	0.5836	422	158525	0.1588	0.7345
0	**6200**	**6200**				**2077000**	**2.0812**	**0.4551**		**2613980.5**	**2.6192**	**0.5728**
D23A	608	608	6	12	335	203680	0.2041	0.5334	422	256339	0.2569	0.6713
D23B	597	597	6	12	335	199995	0.2004	0.4911	422	251701	0.2522	0.6181
D23C	861	861	3	12	82	70602	0.0707	0.1730	103	88855	0.0890	0.2177
D23D	565	565	6	12	335	189275	0.1897	0.8614	422	238210	0.2387	1.0841
D23E	702	702	6	12	335	235170	0.2356	0.8219	422	295970	0.2966	1.0343
D23F	352	352	6	12	335	117920	0.1182	0.6037	422	148407	0.1487	0.7598
D23G	512	512	6	12	335	171520	0.1719	0.6553	422	215864	0.2163	0.8248
D23H	776	776	6	12	335	259960	0.2605	1.3243	422	327169	0.3278	1.6667
D23J	534	534	6	12	335	178890	0.1792	1.1169	422	225140	0.2256	1.4057

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
0	**5507**	**5507**				**1627012**	**1.6303**	**0.6465**		**2047654.1**	**2.0517**	**0.8136**
D24A	310	310	6	12	335	103850	0.1041	0.5452	422	130699	0.1310	0.6862
D24B	470	470	6	12	335	157450	0.1578	0.6896	422	198157	0.1986	0.8679
D24C	398	398	6	12	335	133330	0.1336	0.9886	422	167801	0.1681	1.2442
D24D	598	598	6	12	335	200330	0.2007	1.3334	422	252123	0.2526	1.6781
D24E	489	489	6	12	335	163815	0.1641	1.3315	422	206167	0.2066	1.6757
D24F	567	567	6	12	335	189945	0.1903	1.0849	422	239053	0.2395	1.3653
D24G	626	626	6	13	335	209710	0.2101	0.9379	422	263928	0.2645	1.1804
D24H	736	736	6	12	335	246560	0.2471	1.3026	422	310305	0.3109	1.6394
D24J	1032	1032	6	12	335	345720	0.3464	1.6795	422	435101	0.4360	2.1137
D24K	877	877	6	12	335	293795	0.2944	1.7489	422	369752	0.3705	2.2011
D24L	511	511	6	12	335	171185	0.1715	1.8793	422	215443	0.2159	2.3651
0	**6614**	**6614**				**2215690**	**2.2201**	**1.1787**		**2788526.9**	**2.7941**	**1.4834**
D31A	1160	1160	5	12	30	34800	0.0349	0.2128	38	43797	0.0439	0.2678
D31B	996	757	5	13	30	22710	0.0228	0.5438	38	28581	0.0286	0.6844
D31C	677	677	5	12	30	20310	0.0204	0.4541	38	25561	0.0256	0.5715
D31D	1108	833	5	12	30	24990	0.0250	0.2575	38	31451	0.0315	0.3241
D31E	969	969	5	12	30	29070	0.0291	0.3395	38	36586	0.0367	0.4273
0	**4910**	**4396**				**131880**	**0.1321**	**0.3048**		**165975.8**	**0.1663**	**0.3836**
D32A	716	716	5	12	30	21480	0.0215	0.5253	38	27033	0.0271	0.6611
D32B	582	582	5	13	30	17460	0.0175	0.3693	38	21974	0.0220	0.4648
D32C	850	850	5	12	30	25500	0.0256	0.5117	38	32093	0.0322	0.6440
D32D	851	851	5	12	30	25530	0.0256	0.5400	38	32130	0.0322	0.6796
D32E	1157	1157	5	13	30	34710	0.0348	0.9054	38	43684	0.0438	1.1395
D32F	1443	1443	5	13	30	43290	0.0434	0.5841	38	54482	0.0546	0.7351
D32G	1045	1045	5	12	30	31350	0.0314	0.4304	38	39455	0.0395	0.5417
D32H	572	572	5	12	30	17160	0.0172	0.4476	38	21596	0.0216	0.5634
D32J	1114	1041	5	12	30	31230	0.0313	0.5128	38	39304	0.0394	0.6454
D32K	824	824	5	12	30	24720	0.0248	0.4606	38	31111	0.0312	0.5797
0	**9154**	**9081**				**272430**	**0.2730**	**0.5204**		**342863.12**	**0.3435**	**0.6550**
D33A	593	472	5	12	30	14160	0.0142	0.9903	38	17821	0.0179	1.2463
D33B	1018	323	5	12	30	9690	0.0097	1.1770	38	12195	0.0122	1.4813

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D33C	805	520	5	12	30	15600	0.0156	0.9679	38	19633	0.0197	1.2182
D33D	952	311	5	12	30	9330	0.0093	1.4309	38	11742	0.0118	1.8008
D33E	1554	343	5	12	30	10290	0.0103	1.3347	38	12950	0.0130	1.6797
D33F	863	77	5	12	30	2310	0.0023	1.7295	38	2907	0.0029	2.1766
D33G	1406	400	5	12	30	12000	0.0120	1.7610	38	15102	0.0151	2.2163
D33H	1054	468	5	7	80.7	37767.6	0.0378	4.0585	102	47532	0.0476	5.1077
D33J	865	200	5	12	30	6000	0.0060	2.1668	38	7551	0.0076	2.7270
D33K	488	290	5	12	30	8700	0.0087	1.6299	38	10949	0.0110	2.0513
0	**9598**	**3404**				**125847.6**	**0.1261**	**1.6044**		**158383.81**	**0.1587**	**2.0191**
D34A	794	794	5	12	30	23820	0.0239	0.2193	38	29978	0.0300	0.2760
D34B	706	706	5	12	30	21180	0.0212	0.2960	38	26656	0.0267	0.3725
D34C	760	760	5	12	30	22800	0.0228	0.3641	38	28695	0.0288	0.4583
D34D	599	599	5	12	30	17970	0.0180	0.3348	38	22616	0.0227	0.4214
D34E	519	519	5	12	30	15570	0.0156	0.2834	38	19595	0.0196	0.3566
D34F	692	692	5	12	30	20760	0.0208	0.3868	38	26127	0.0262	0.4868
D34G	950	950	5	12	30	28500	0.0286	0.2593	38	35868	0.0359	0.3264
0	**5020**	**5020**				**150600**	**0.1509**	**0.2924**		**189535.61**	**0.1899**	**0.3680**
D35A	254	254	6	12	335	85090	0.0853	1.9440	422	107089	0.1073	2.4465
D35B	260	260	6	13	335	87100	0.0873	2.1655	422	109619	0.1098	2.7253
D35C	943	943	6	13	335	315905	0.3165	2.9344	422	397578	0.3984	3.6931
D35D	586	586	6	13	335	196310	0.1967	3.5307	422	247063	0.2476	4.4435
D35E	312	312	6	13	335	104520	0.1047	2.6773	422	131542	0.1318	3.3695
D35F	557	557	6	12	335	186595	0.1870	2.1607	422	234837	0.2353	2.7193
D35G	552	552	6	13	335	184920	0.1853	3.7217	422	232729	0.2332	4.6839
D35H	498	498	6	12	335	166830	0.1672	2.7651	422	209962	0.2104	3.4800
D35J	1002	1002	5	12	30	30060	0.0301	0.3909	38	37832	0.0379	0.4920
D35K	674	674	5	12	30	20220	0.0203	0.2947	38	25448	0.0255	0.3709
0	**5638**	**5638**				**1377550**	**1.3803**	**2.1929**		**1733697.1**	**1.7372**	**2.7599**
0	0	0										
TOTALS	**99349**	**92568**				**20367562**	**20.4083**	**0.3027**		**25633321**	**25.6846**	**0.3810**

LIST OF FIGURES


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UPPER ORANGE WMA
Eastern Cape
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Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Steynsburg
Middelburg
Hofmeyr
Murraysburg
Graaf-Reinett
Tarkastad
Cradock
Aberdeen
Pearston
Somerset East
Bedford
Adelaide
Seymour
Fort Beaufort
Cookhouse
Uitkeer
Jansenville
Rietbron
Klipplaat
Riebeeck-Oos
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Willowmore
Kleinpoort
Enon
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WMA Boundaries
Provincial Boundaries
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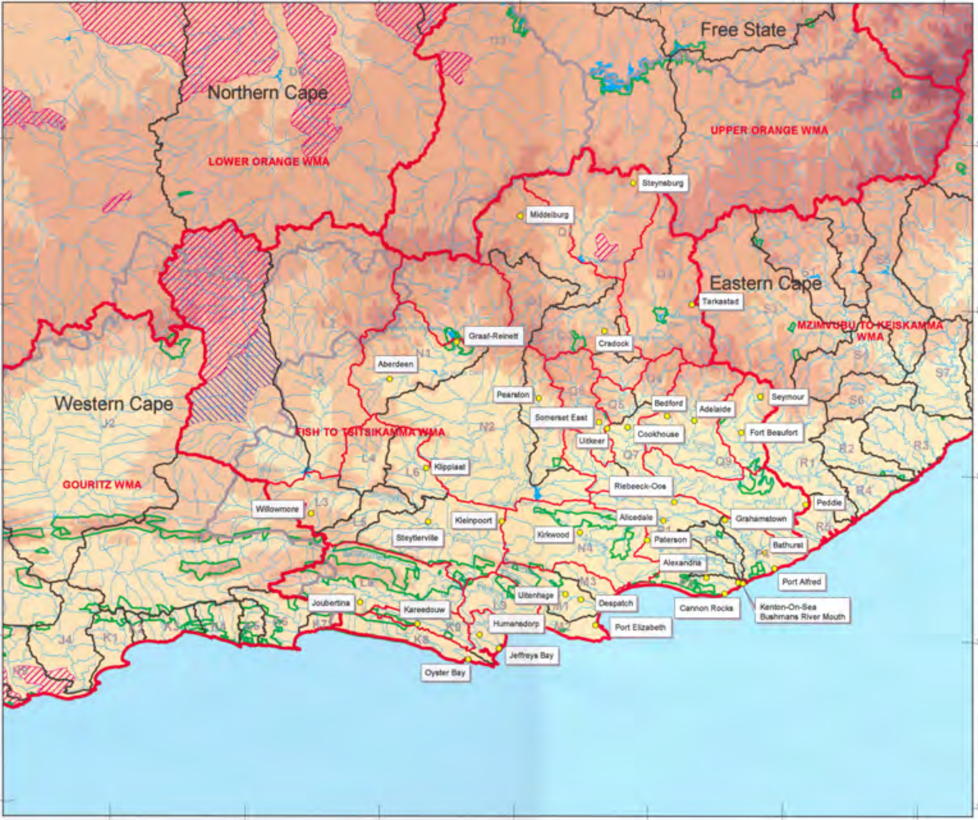
Rivers
Dams
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
FISH TO TSITSIKAMMA WMA
THE STUDY AREA
Prepared by: A Lawrence
Date: 08/2001
Figure 2.1.1



LOCALITY MAP:

LEGEND:	GIS COV:
WMA Boundaries	Watermon
Provincial Boundaries	Prov0897
Towns	Ivtp (Amended)
Rivers	Wri500
Dams	Ndams
Secondary Catchment	Drgand
Secondary Catchment Number	Drgand
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Endoreic Areas	Edo
Local	
Global	
Elevation	Elev_geo
0 - 400	
401 - 800	
801 - 1200	
1201 - 1600	
1601 - 2000	
2001 - 2400	
2401 - 2800	

PREPARED BY:

NINHAM SHAND
CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

ALBERS EQUAL AREA

SCALE : 1:2 000 000

40 0 40 Km

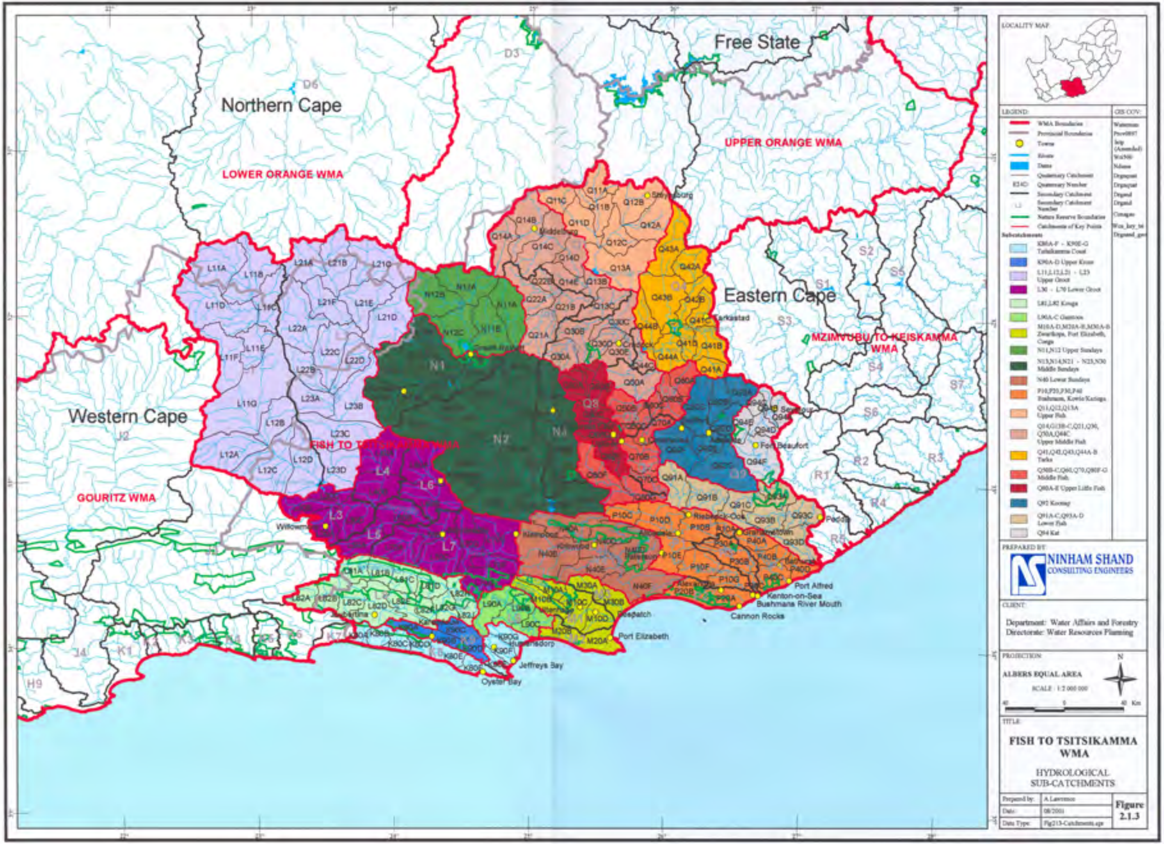
N

TITLE:

FISH TO TSITSIKAMMA WMA

TOPOGRAPHY AND RIVER CATCHMENTS

Prepared by:	A Lawrence	**Figure 2.1.2**
Date:	08/2001	
Data Type:	Fig212-Topography.apr	



Northern Cape
Free State
Western Cape
Eastern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
GOURITZ WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Middelburg
Steynsburg
Tarkastad
Cradock
Graaff-Reinet
Somerset East
Adelaide
Fort Beaufort
Riebeeck-Oos
Grahamstown
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Hankey
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Oyster Bay
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Cannon Rocks
Peddie
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Provincial Boundaries
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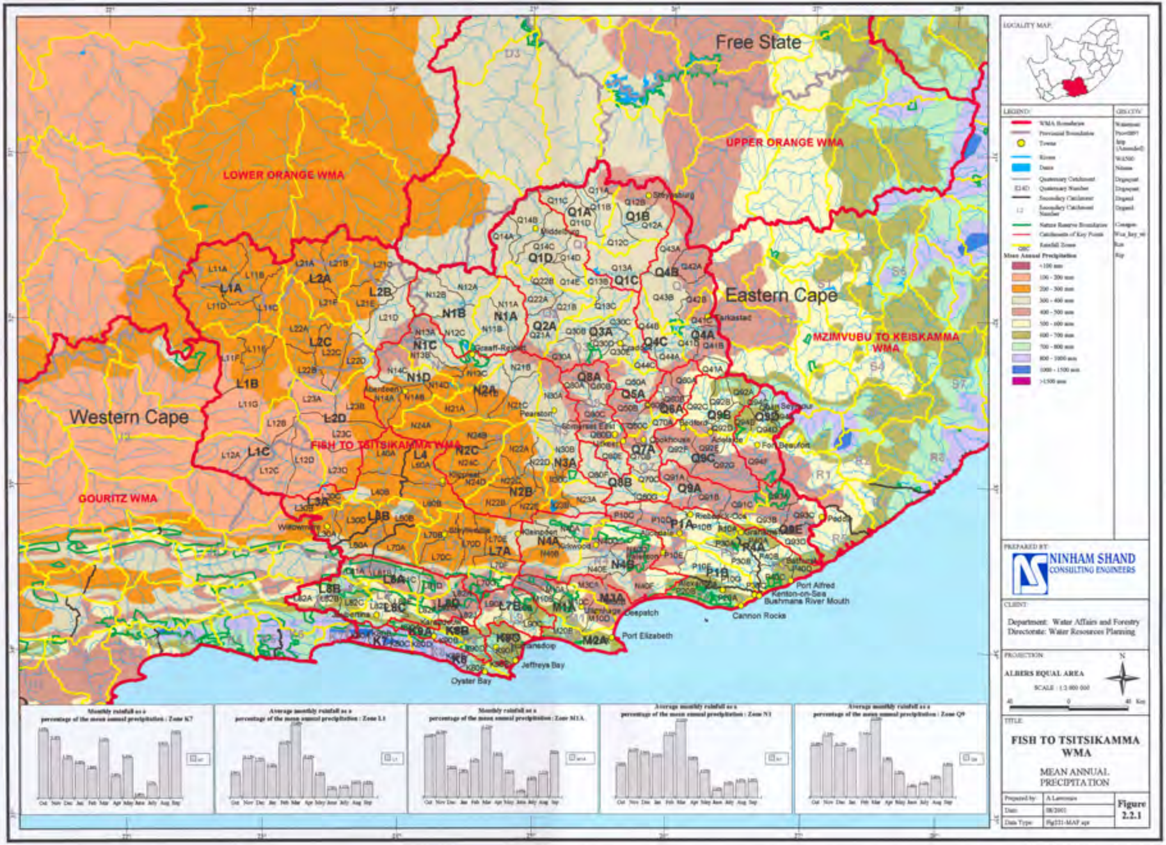
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Catchments of Key Points
Subcatchments
Q92 Koonap
Q91A-C,Q93A-D Lower Fish
Q94 Kat
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:2 000 000
N
40
0
40 Km
TITLE:
FISH TO TSITSIKAMMA WMA
HYDROLOGICAL SUB-CATCHMENTS
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig213-Catchments.apr
Figure 2.1.3



Free State
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Steynsburg
Middelburg
Tarkastad
Graaff-Reinet
Aberdeen
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Somerset East
Cookhouse
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Seymour
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Klipplaat
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Willowmore
Kleinpoort
Kirkwood
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Kenton-on-Sea
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Uitenhage
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Joubertina
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Quaternary Number
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Secondary Catchment Number
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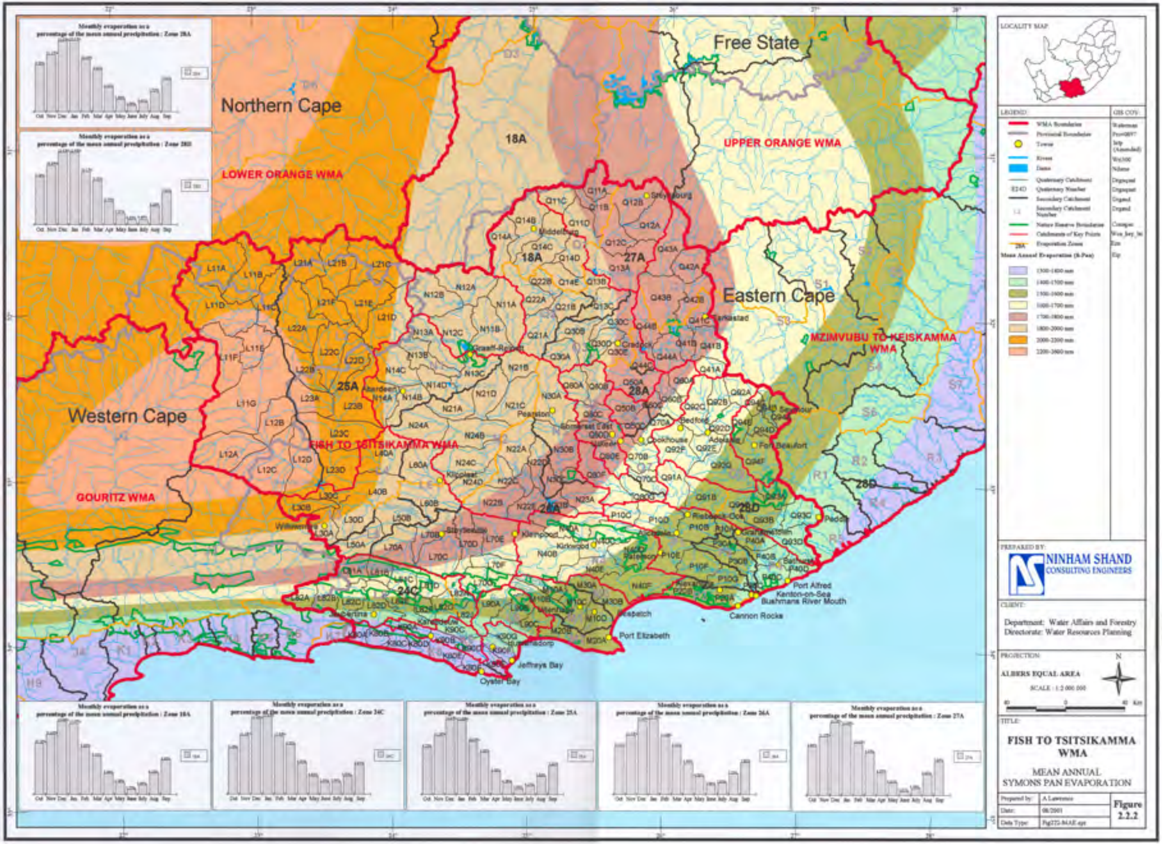
Mean Annual Precipitation
<100 mm
100 - 200 mm
200 - 300 mm
300 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
700 - 800 mm
800 - 1000 mm
1000 - 1500 mm
>1500 mm
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
MEAN ANNUAL PRECIPITATION
Prepared by:
Date:
Data Type:
Figure 2.2.1



Northern Cape
Free State
Eastern Cape
Western Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
GOURITZ WMA
18A
27A
25A
28A
26A
24C
28D
Middelburg
Steynsburg
Tarkastad
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Seymour
Riebeeck-Oos
Grahamstown
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
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Humansdorp
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Klipplaat
Kirkwood
Paterson
Alexandria
Despatch
Joubertina
Kareedouw
Monthly evaporation as a percentage of the mean annual precipitation : Zone 28A
Monthly evaporation as a percentage of the mean annual precipitation : Zone 28D
Monthly evaporation as a percentage of the mean annual precipitation : Zone 18A
Monthly evaporation as a percentage of the mean annual precipitation : Zone 24C
Monthly evaporation as a percentage of the mean annual precipitation : Zone 25A
Monthly evaporation as a percentage of the mean annual precipitation : Zone 26A
Monthly evaporation as a percentage of the mean annual precipitation : Zone 27A
Oct Nov Dec Jan Feb Mar Apr May June July Aug Sep
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Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Evaporation Zones
Mean Annual Evaporation (S-Pan)
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:2 000 000
N
TITLE:
FISH TO TSITSIKAMMA WMA
MEAN ANNUAL SYMONS PAN EVAPORATION
Prepared by: A Lawrence
Date: 08/2001
Figure 2.2.2

Free State
Northern Cape
Eastern Cape
Western Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Steynsburg
Middelburg
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Oyster Bay
Uitenhage
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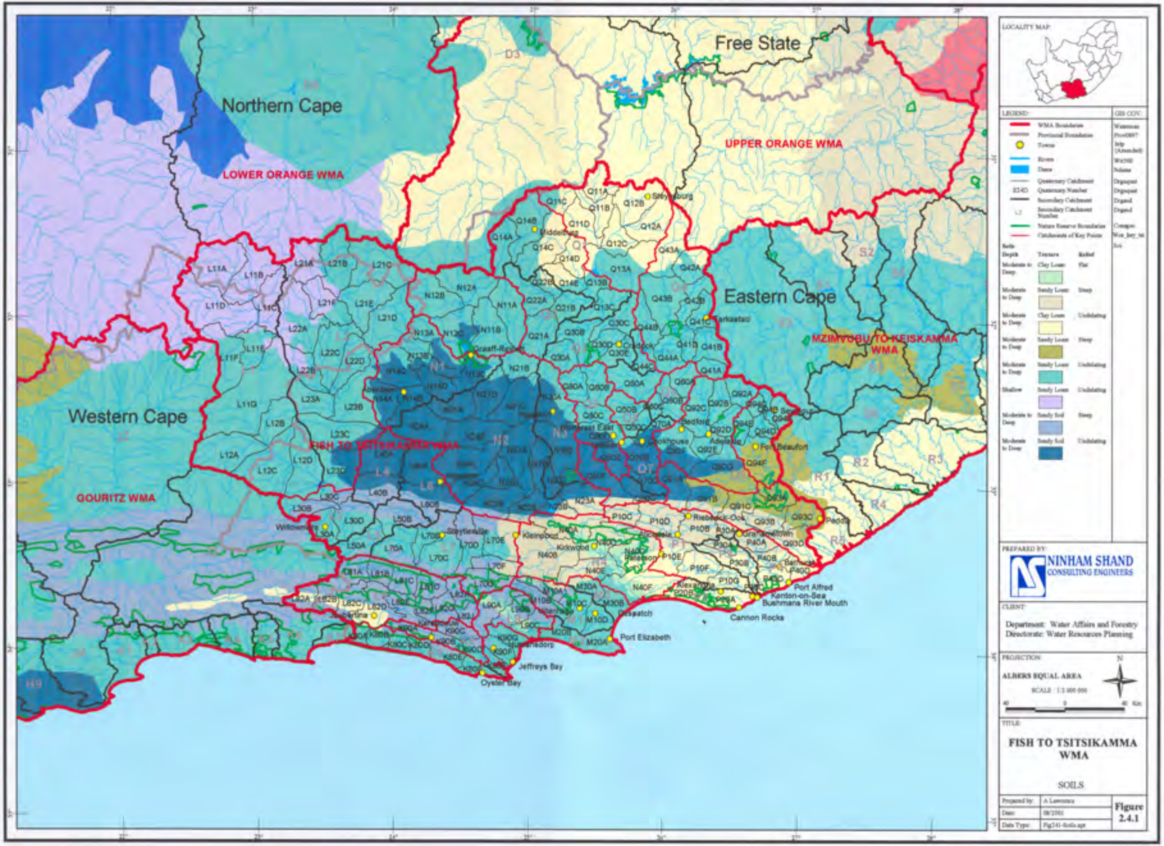
E24D Quaternary Number
Secondary Catchment
L7 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Geology
Compact arenaceous and argillaceous strata (Karoo Supergroup- Beaufort Group within WMA)
Compact sedimentary strata (Cape Supergroup)
Compact, dominantly arenaceous strata (Cape Supergroup)
Compact, dominantly argillaceous strata (Cape Supergroup within the WMA)
Consolidated porous or compact sedimentary strata (Uitenhage Group)
Mafic / basic lavas
Mainly compact tillite, shale and sandstone (Dwyka formation and Ecca Group)
Porous unconsolidated to semi-consolidated sediment
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
40 0 40 Km
TITLE:
FISH TO TSITSIKAMMA WMA
GEOLOGY
Prepared by:
Date:
Data Type:

Figure 2.3.1



Free State
Northern Cape
Eastern Cape
Western Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
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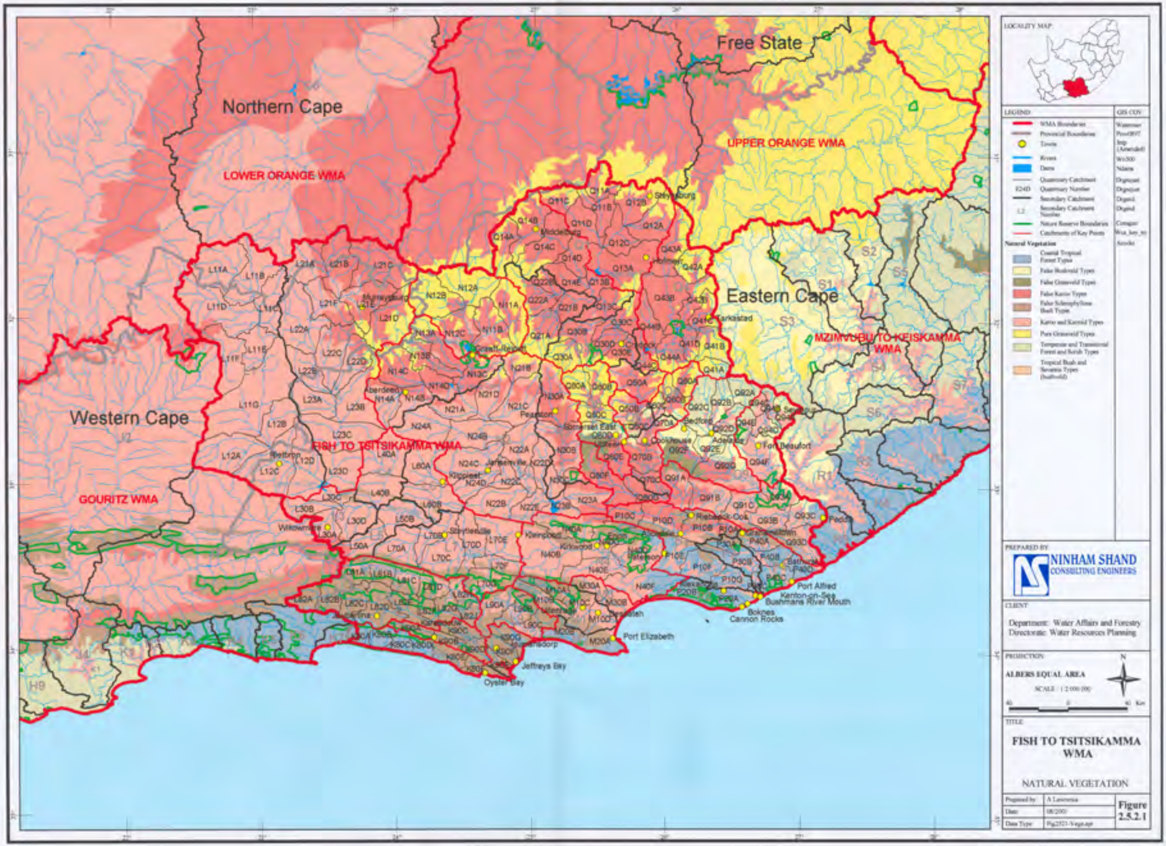
Soils
Depth
Texture
Relief
Moderate to Deep
Clay Loam
Flat
Sandy Loam
Steep
Undulating
Shallow
Sandy Soil
GIS COV.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
FISH TO TSITSIKAMMA WMA
SOILS
Prepared by:
A Lawrence
Date:
Data Type:
Figure 2.4.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Steynsburg
Tarkastad
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Bedford
Adelaide
Fort Beaufort
Cookhouse
Jansenville
Klipplaat
Steytlerville
Willowmore
Kirkwood
Riebeek-Oos
Grahamstown
Peddie
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Port Elizabeth
Jeffreys Bay
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E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
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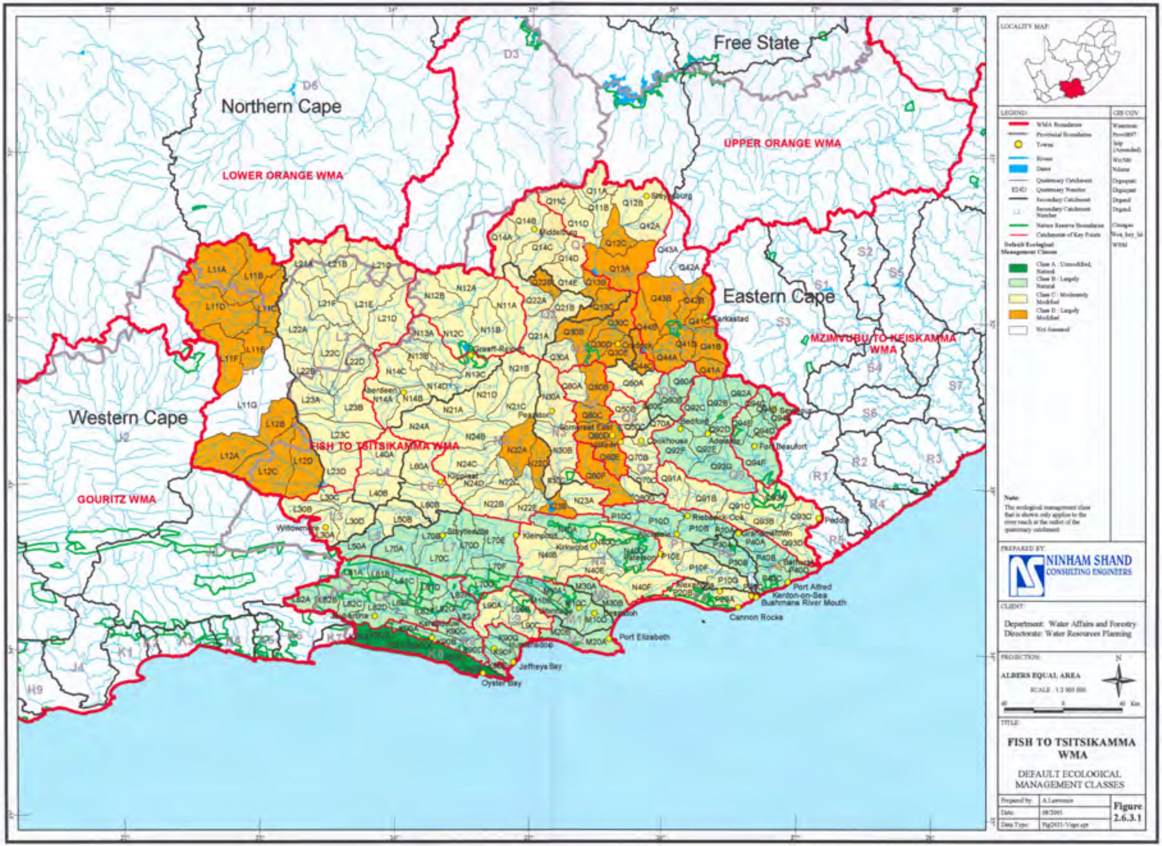
False Bushveld Types
False Grassveld Types
False Karoo Types
False Sclerophyllous Bush Types
Karoo and Karroid Types
Pure Grassveld Types
Temperate and Transitional Forest and Scrub Types
Tropical Bush and Savanna Types (bushveld)
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
NATURAL VEGETATION
Prepared by: A Lawrence
Figure 2.5.2.1



Free State
Northern Cape
Western Cape
Eastern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
GOURITZ WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Middelburg
Steynsburg
Tarkastad
Graaff-Reinet
Cradock
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Patterson
Riebeeck-Oos
Grahamstown
Alicedale
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Joubertina
Peddie
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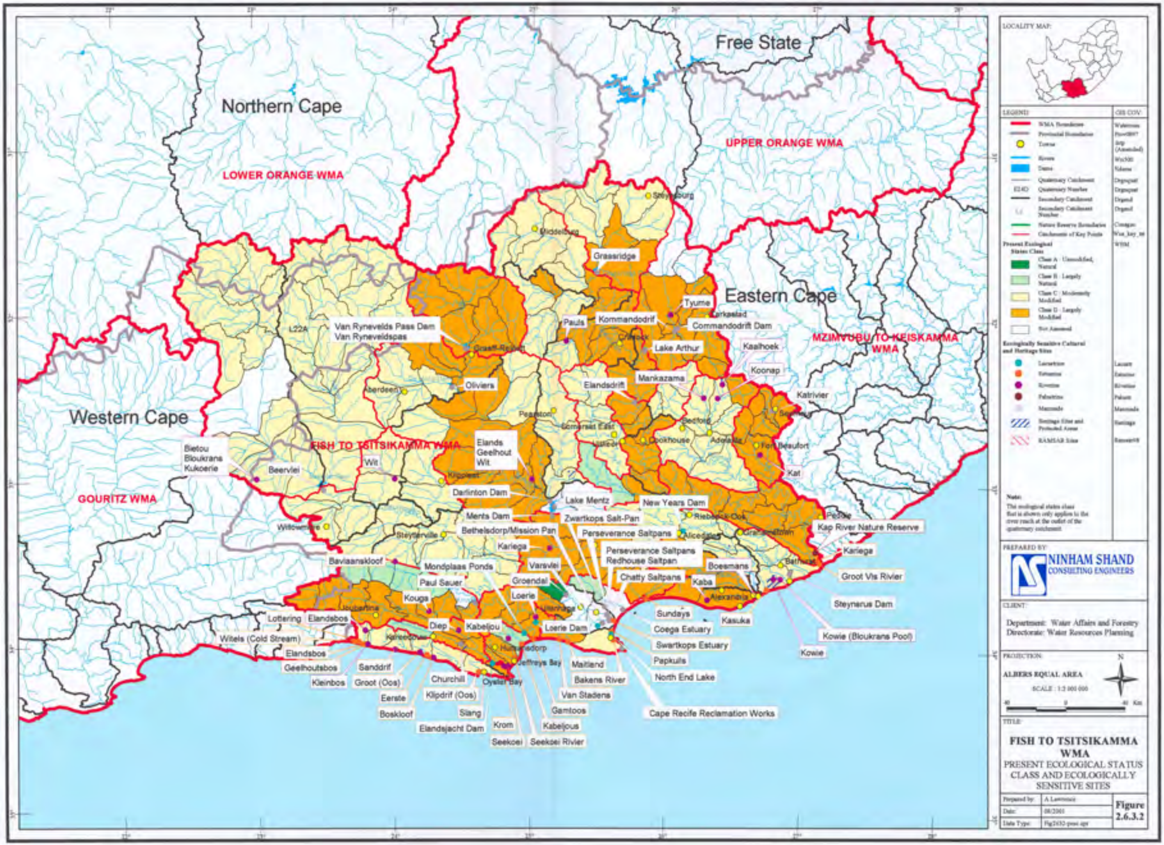
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Default Ecological Management Classes
Class A : Unmodified, Natural
Class B : Largely Natural
Class C : Moderately Modified
Class D : Largely Modified
Not Assessed
Note:
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Prepared by:
A Lawrence
Date:
08/2001
Data Type:
Figure 2.6.3.1



Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
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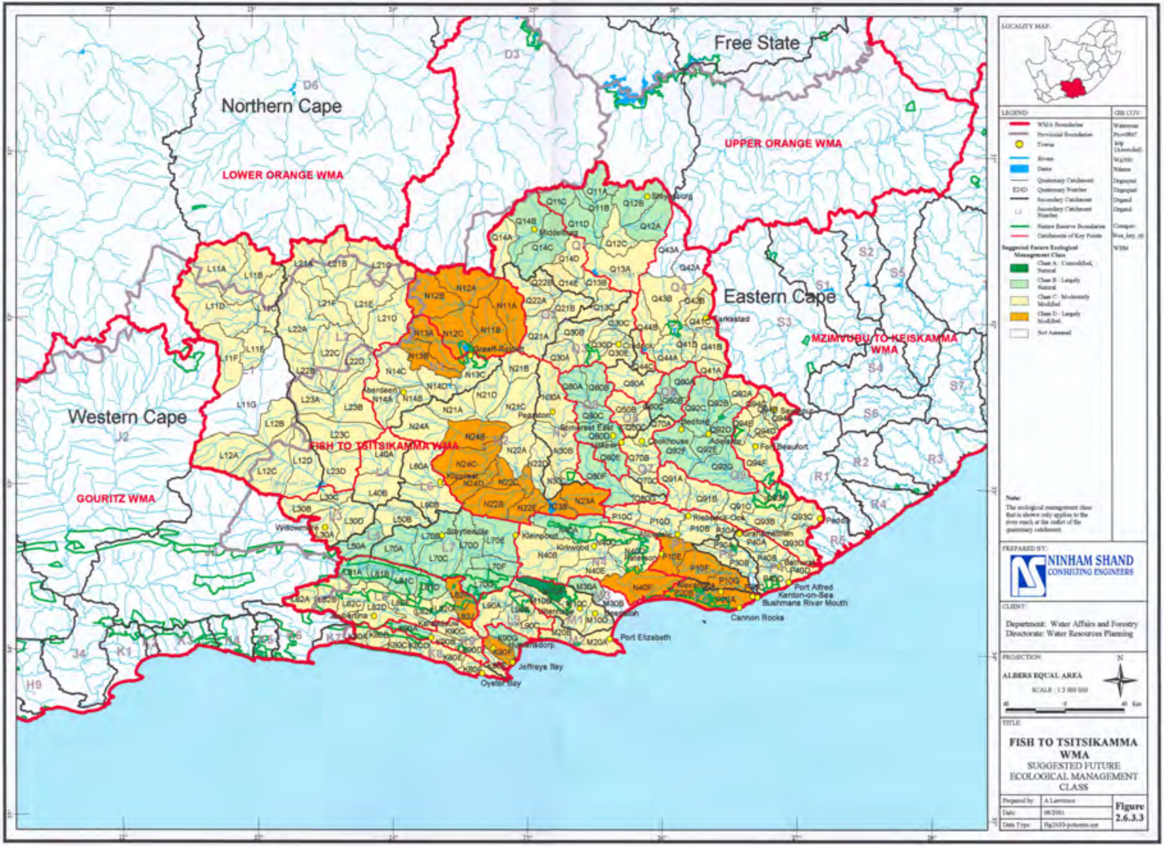
Tarkastad
Pauls
Kommandodrif
Commandodrift Dam
Cradock
Lake Arthur
Kaalhoek
Koonap
Van Rynevelds Pass Dam
Van Ryneveldspas
Graaff-Reinet
L22A
Aberdeen
Oliviers
Elandsdrift
Mankazana
Katrivier
Seymour
Pearston
Somerset East
Bedford
Adelaide
Cookhouse
Fort Beaufort
Kat
Bietou
Bloukrans
Kukoerie
Beervlei
Wit
Elands
Geelhout
Wit
Klipplaat
Darlinton Dam
Lake Mentz
New Years Dam
Riebeeck-Oos
Willowmore
Ments Dam
Zwartkops Salt-Pan
Peddie
Kap River Nature Reserve
Bethelsdorp/Mission Pan
Perseverance Saltpans
Alicedale
Grahamstown
Steytlerville
Kariega
Kariega
Perseverance Saltpans
Redhouse Saltpan
Bathurst
Baviaanskloof
Mondplaas Ponds
Varsvlei
Boesmans
Groot Vis Rivier
Paul Sauer
Groendal
Chatty Saltpans
Kaba
Loerie
Alexandria
Steynsrus Dam
Kouga
Uitenhage
Joubertina
Sundays
Kasuka
Lottering
Elandsbos
Diep
Kabeljou
Loerie Dam
Coega Estuary
Kareedouw
Kowie (Bloukrans Pool)
Witels (Cold Stream)
Humansdorp
Swartkops Estuary
Elandsbos
Kowie
Jeffreys Bay
Papkuils
Geelhoutsbos
Sanddrif
Maitland
Churchill
North End Lake
Kleinbos
Groot (Oos)
Oyster Bay
Bakens River
Eerste
Klipdrif (Oos)
Van Stadens
Boskloof
Slang
Gamtoos
Cape Recife Reclamation Works
Krom
Kabeljous
Elandsjacht Dam
Seekoei
Seekoei Rivier
LOCALITY MAP
LEGEND
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
PRESENT ECOLOGICAL STATUS CLASS AND ECOLOGICALLY SENSITIVE SITES
Figure 2.6.3.2



Free State
Northern Cape
Eastern Cape
Western Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Graaff-Reinet
Aberdeen
Middelburg
Steynsburg
Tarkastad
Cradock
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Seymour
Kirkwood
Riebeeck-Oos
Grahamstown
Alicedale
Paterson
Alexandria
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Humansdorp
Oyster Bay
Joubertina
Kareedouw
Steytlerville
Klipplaat
Willowmore
Kleinpoort
Uitenhage
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Towns
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Dams
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Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Suggested Future Ecological Management Class
Class A : Unmodified, Natural
Class B : Largely Natural
Class C : Moderately Modified
Class D : Largely Modified
Not Assessed
Note:
The ecological management class that is shown only applies to the river reach at the outlet of the quaternary catchment.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:2 000 000
N
TITLE:
FISH TO TSITSIKAMMA WMA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASS
Prepared by: A Lawrence
Date: 08/2001
Figure 2.6.3.3


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Steynsburg
Middelburg
Tarkastad
Graaf-Reinett
Cradock
Aberdeen
Pearston
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Adelaide
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Riebeeck-Oos
Willowmore
Kleinpoort
Alicedale
Grahamstown
Peddie
Steytlerville
Kirkwood
Paterson
Bathurst
Alexandria
Port Alfred
Uitenhage
Despatch
Cannon Rocks
Kenton-On-Sea
Bushmans River Mouth
Joubertina
Kareedouw
Humansdorp
Port Elizabeth
Jeffreys Bay
Oyster Bay
LOCALITY MAP
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Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Population
Rural
Urban
Population Quantity
100 000
500 000
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
FISH TO TSITSIKAMMA WMA
POPULATION DISTRIBUTION
Prepared by
Date
Data Type
Figure 3.2.4.1

BLOEM AREA
Free State
LESOTHO
BO KAROO
HANTAM
Northern Cape
Colesberg
UPPER ORANGE WMA
DRAKENSBERG
Steynsburg
Noupoort
LOWER ORANGE WMA
Victoria West
Richmond
Middelburg
Molteno
KEI
Eastern Cape
STORMBERG
Tarkastad
MZIMVUBU TO KEISKAMMA WMA
Graaff-Reinett
Cradock
Aberdeen
Cathcart
Beaufort West
Western Cape
Pearston
Somerset East
Seymour
Adelaide
Bedford
Fort Beaufort
AMATOLA
FISH TO TSITSIKAMMA WMA
Cookhouse
Uitkeer
CENTRAL KAROO
Klipplaat
WESTERN REGION
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Peddie
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Alicedale
Grahamstown
Paterson
Bathurst
KLEIN KAROO
Port Alfred
Alexandria
Uitenhage
Despatch
Cannon Rocks
Kenton-On-Sea
Bushmans River Mouth
Joubertina
Kareedouw
Humansdorp
Port Elizabeth
Jeffreys Bay
SOUTHERN CAPE
Oyster Bay
LOCALITY MAP
LEGEND
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS
Figure 3.4.9.1


Free State
Northern Cape
Western Cape
Eastern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
MZIMVUBU TO KEISKAMMA WMA
SENTRALE KAROO
BEAUFORT WEST
PRINCE ALBERT
EBOYA
STEYNSBURG
Steynsburg
MIDDELBURG
Middelburg
MOLTENO
HOFMEYER
STERKSTROOM
NIEU BETHESDA
MURRAYSBURG
TARKASTAD
GRAAFF-REINET
Graaf-Reinett
CRADOCK
Cradock
Aberdeen
ABERDEEN
PEARSTON
Pearston
SOMERSET EAST
Somerset East
BEDFORD
ADELAIDE
Adelaide
SEYMOUR
Seymour
KEISKAMMAHOEK
Amatola
Cookhouse
Fort Beaufort
FORT BEAUFORT
Uitkeer
JANSENVILLE
KLIPPLAAT
Klipplaat
RIEBEECK-EAST
Riebeeck-Oos
Peddie
PEDDIE
GRAHAMSTOWN
Grahamstown
WILLOWMORE
Willowmore
STEYTLERVILLE
Steytlerville
Kleinpoort
ALICEDALE
Kirkwood
PATERSON
Paterson
Bathurst
PORT ALFRED
Port Alfred
HAARLEM
UNIONDALE
JOUBERTINA
Joubertina
HANKEY
UITENHAGE
Uitenhage
Despatch
Alexandria
ALEXANDRIA
Albany
Kenton-On-Sea
Bushmans River Mouth
Kareedouw
KAREEDOUW
Humansdorp
HUMANSDORP
PORT ELIZABETH
Port Elizabeth
CANNON ROCKS
Jeffreys Bay
JEFFREYS BAY
OYSTER BAY
CAPE ST FRANCIS
SEAVIEW
HORIZON BAY
LOCALITY MAP
LEGEND
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
FISH TO TSITSIKAMMA WMA
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Figure 3.4.9.2

Free State
Northern Cape
Eastern Cape
Western Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Steynsburg
Tarkastad
Cradock
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Paterson
Riebeeck-Oos
Grahamstown
Alexandria
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Despatch
Port Elizabeth
Humansdorp
Jeffreys Bay
Oyster Bay
Joubertina
Peddie
LOCALITY MAP
LEGEND
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Catchments of Key Points
Afforestation
Eucalyptus
Indigenous
Pine
Wattle
Land Use
Dryland
Afforestation
Irrigation
Total Land Use (km²)
PREPARED BY
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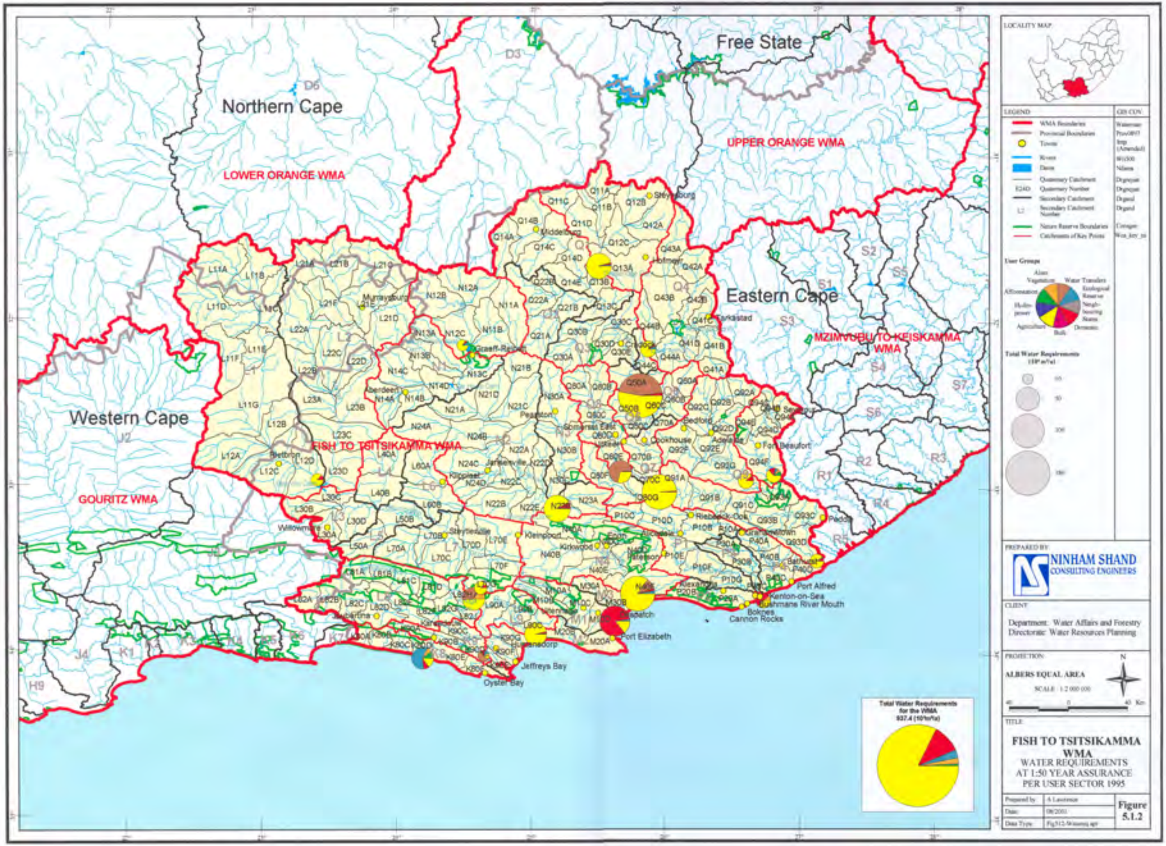
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:2 000 000
TITLE
FISH TO TSITSIKAMMA WMA
LAND USE
Prepared by A Lawrence
Date 08/2001
Figure 3.5.1.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Steynsburg
Tarkastad
Cradock
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Riebeeck-Oos
Grahamstown
Paterson
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Despatch
Port Elizabeth
Humansdorp
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Livestock
Livestock & Game Quantity (ELSU's)
7 000
15 000
41 000
98 000
WSAM
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:2 000 000
40 0 40 Km
N
TITLE
FISH TO TSITSIKAMMA WMA
LIVESTOCK AND GAME NUMBERS
Prepared by: A Lawrence
Date: 08/2003
Figure 3.5.4.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Steynsburg
Tarkastad
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Paterson
Riebeeck-Oos
Grahamstown
Peddie
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Alexandria
Port Elizabeth
Despatch
Uitenhage
Hankey
Humansdorp
Jeffreys Bay
Oyster Bay
Joubertina
Kareedouw
LOCALITY MAP
LEGEND
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
GIS COV
WSAM
Condensed Area Of Alien Vegetation (Km²)
10
50
150
300
PREPARED BY
NINHAM SHAND CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:2 000 000
N
TITLE
FISH TO TSITSIKAMMA WMA
ALIEN VEGETATION INFESTATION
Prepared by
A Lawrence
Date
Data Type
Figure 3.5.6.1

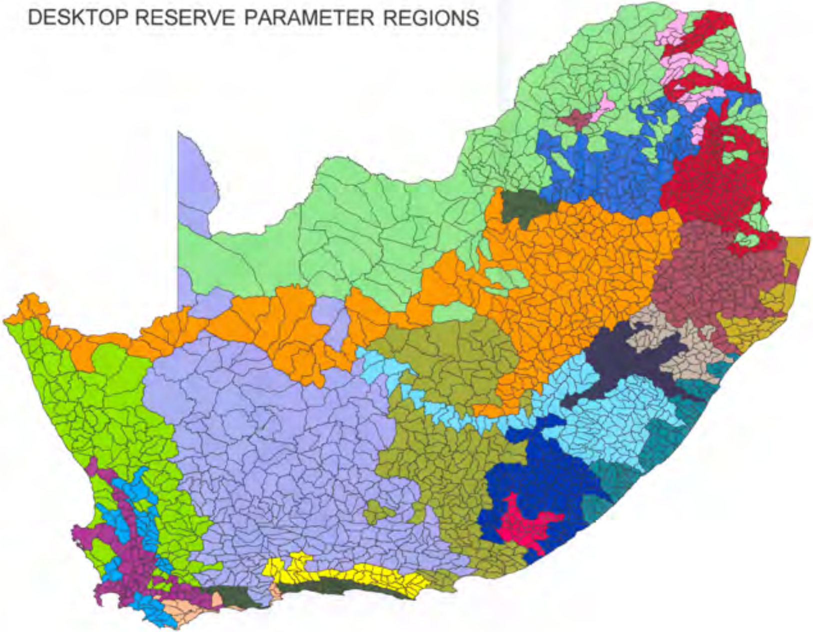
Free State
Northern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Steynsburg
Middelburg
Hofmeyr
Tarkastad
Murraysburg
Graaff-Reinet
Cradock
Aberdeen
Pearston
Somerset East
Bedford
Cookhouse
Adelaide
Fort Beaufort
Jansenville
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Riebeeck-Oos
Grahamstown
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Alexandria
Port Elizabeth
Jeffreys Bay
Humansdorp
Joubertina
Oyster Bay
LOCALITY MAP
LEGEND
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
FISH TO TSITSIKAMMA WMA
WATER RELATED INFRASTRUCTURE
Figure 4.1.1

Free State
Northern Cape
Western Cape
Eastern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
MZIMVUBU TO KEISKAMMA WMA
Orange-Fish 560 million m³/a
Great Fish/Little Fish 145 million m³/a
Little Fish/ Sundays 108 million m³/a
Great Fish/ Grahamstown 6,8 million m³/a
Van Stadens Dams/Port Elizabeth 0,1
Bulk/Sand River Dam to Port Elizabeth 4,0
Kouga Dam/Port Elizabeth 23,0
Churchill/Impofu Dams to Port Elizabeth 23,0
Sundays/Port Elizabeth 12,0 million m³/a
Port Elizabeth
Jeffreys Bay
Oyster Bay
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Tarkastad
Fort Beaufort
LOCALITY MAP
LEGEND
Total Water Requirements at 1:50 Year Assurance
Water Transfer
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
TOTAL EQUIVALENT WATER REQUIREMENTS 1995
Figure 5.1.1



Free State
Northern Cape
Western Cape
Eastern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
GOURITZ WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Steynsburg
Middelburg
Hofmeyr
Tarkastad
Murraysburg
Graaff-Reinet
Cradock
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Jansenville
Klipplaat
Steytlerville
Willowmore
Kleinpoort
Kirkwood
Riebeeck-Oos
Grahamstown
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Alexandria
Uitenhage
Port Elizabeth
Hankey
Humansdorp
Jeffreys Bay
Oyster Bay
Joubertina
Peddie
Total Water Requirements for the WMA
937.4 (10⁶m³/a)
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
L2 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
User Groups
Alien Vegetation
Water Transfers
Ecological Reserve
Neighbouring States
Domestic
Bulk
Agriculture
Hydro-power
Afforestation
Total Water Requirements (10⁶ m³/a)
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
SCALE : 1:2 000 000
40 0 40 Km
TITLE:
FISH TO TSITSIKAMMA WMA
WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE PER USER SECTOR 1995
Prepared by: A Lawrence
Date: 08/2001
Figure 5.1.2

DESKTOP RESERVE PARAMETER REGIONS



LEGEND

- 1: Western Cape (wet)
- 2: Western Cape (dry)
- 3: Western Karoo
- 4: Eastern Karoo
- 5: Southern Cape (dry)
- 6: Southern Karoo
- 7: Southern Cape (wet)
- 8: Eastern Cape (arid)
- 9: Eastern Cape
- 10: Amatole
- 11: T Drainage Region
- 12: T Drainage Region (coast)
- 13: Drakensberg
- 14: Southern Natal
- 15: Northern Natal
- 16: Zululand
- 17: Eastern Escarpment
- 18: Lowveld
- 19: Eastern Foothills
- 20: Vaal
- 21: Olifants

PREPARED BY:

NINHAM SHAND
CONSULTING ENGINEERS

CLIENT:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

SCALE : N.T.S

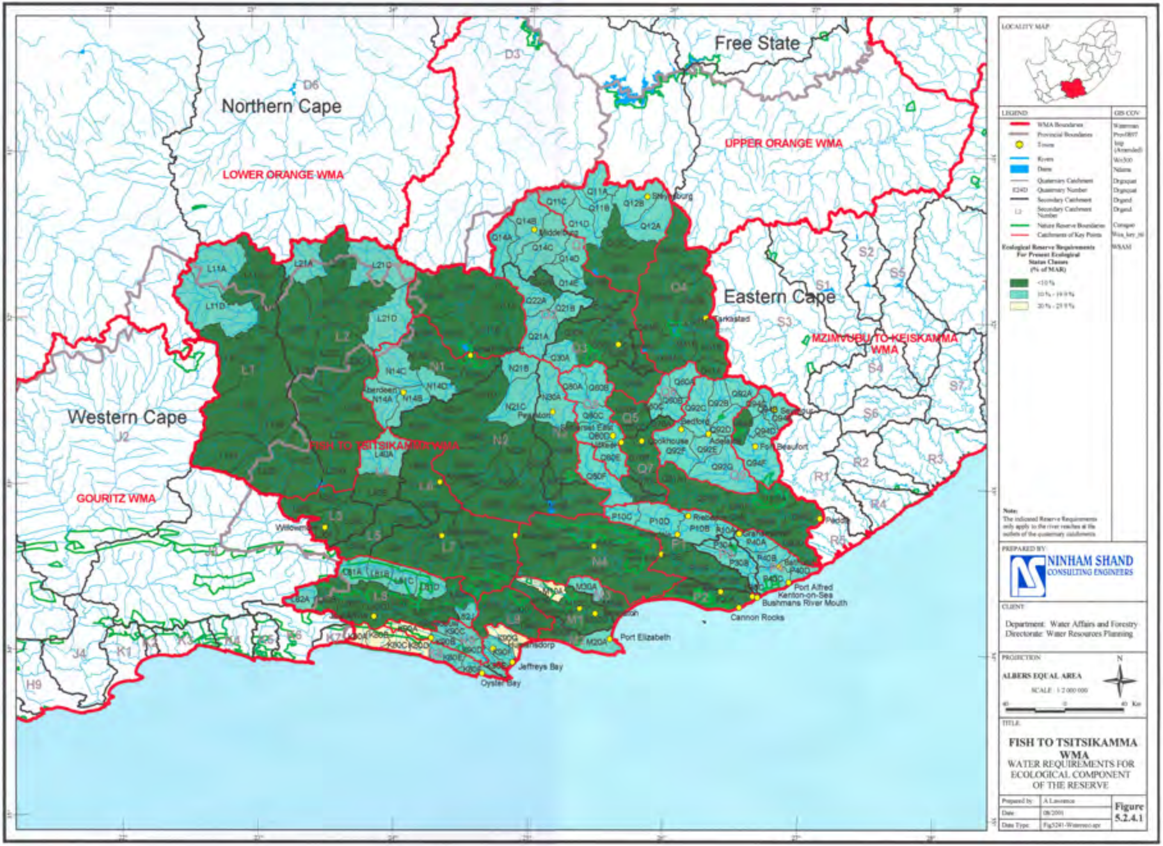
N

TITLE:

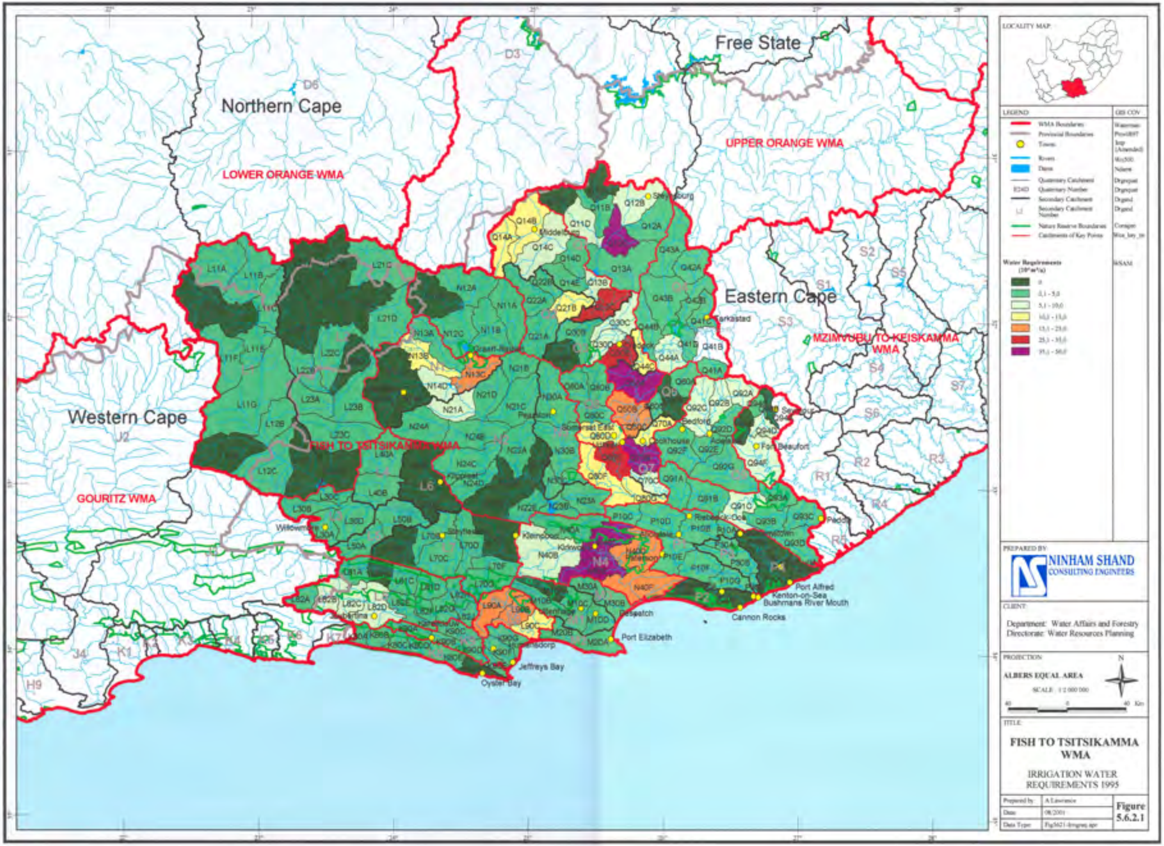
FISH TO TSITSIKAMMA WMA

DESKTOP RESERVE PARAMETER REGIONS

Prepared by:	A Lawrence	**Figure 5.2.1.1**
Date:	08/2001	
Data Type:	Fig5211-Model.apr	

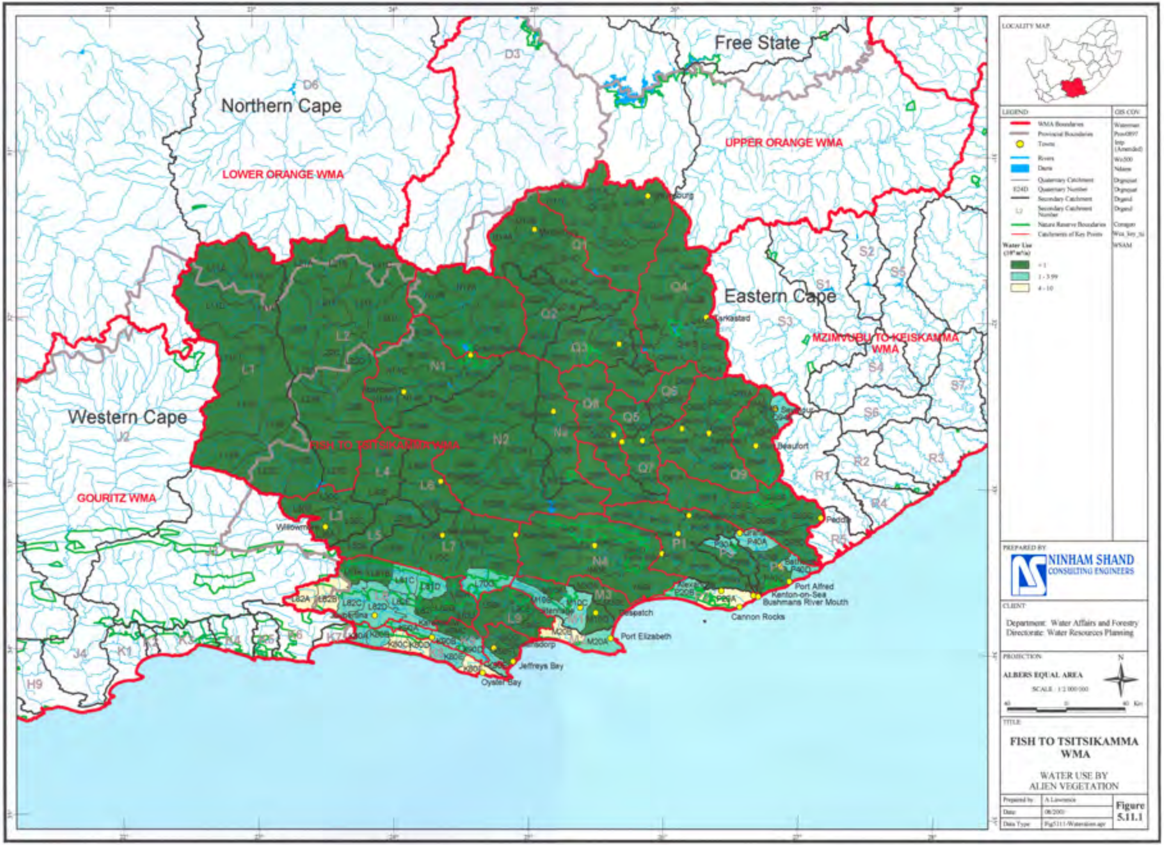

Northern Cape
Free State
Western Cape
Eastern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
GOURITZ WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Steynsburg
Middelburg
Tarkastad
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Seymour
Riebeeck East
Grahamstown
Willowmore
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Humansdorp
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Ecological Reserve Requirements For Present Ecological Status Classes (% of MAR)
Note:
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Prepared by
Date
Data Type
Figure 5.2.4.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Tarkastad
Fort Beaufort
Cookhouse
Willowmore
Humansdorp
Jeffreys Bay
Oyster Bay
Port Elizabeth
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Urban & Rural Total Water Requirements
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
URBAN & RURAL DOMESTIC WATER REQUIREMENTS IN 1995
Prepared by: A Lawrence
Figure 5.3.1.1



Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Steynsburg
Tarkastad
Graaff-Reinet
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Paterson
Riebeeck-Oos
Grahamstown
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Despatch
Uitenhage
Hankey
Humansdorp
Jeffreys Bay
Oyster Bay
Joubertina
LOCALITY MAP
LEGEND
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Water Requirements
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE:
FISH TO TSITSIKAMMA WMA
IRRIGATION WATER REQUIREMENTS 1995
Figure 5.6.2.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Fort Beaufort
Tarkastad
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Water Requirements
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:2 000 000
TITLE:
FISH TO TSITSIKAMMA WMA
WATER USE BY AFFORESTATION IN 1995
Figure 5.9.1



Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Port Elizabeth
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Jeffreys Bay
Oyster Bay
Despatch
Tarkastad
Beaufort
Willowmore
LOCALITY MAP
LEGEND
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
PREPARED BY
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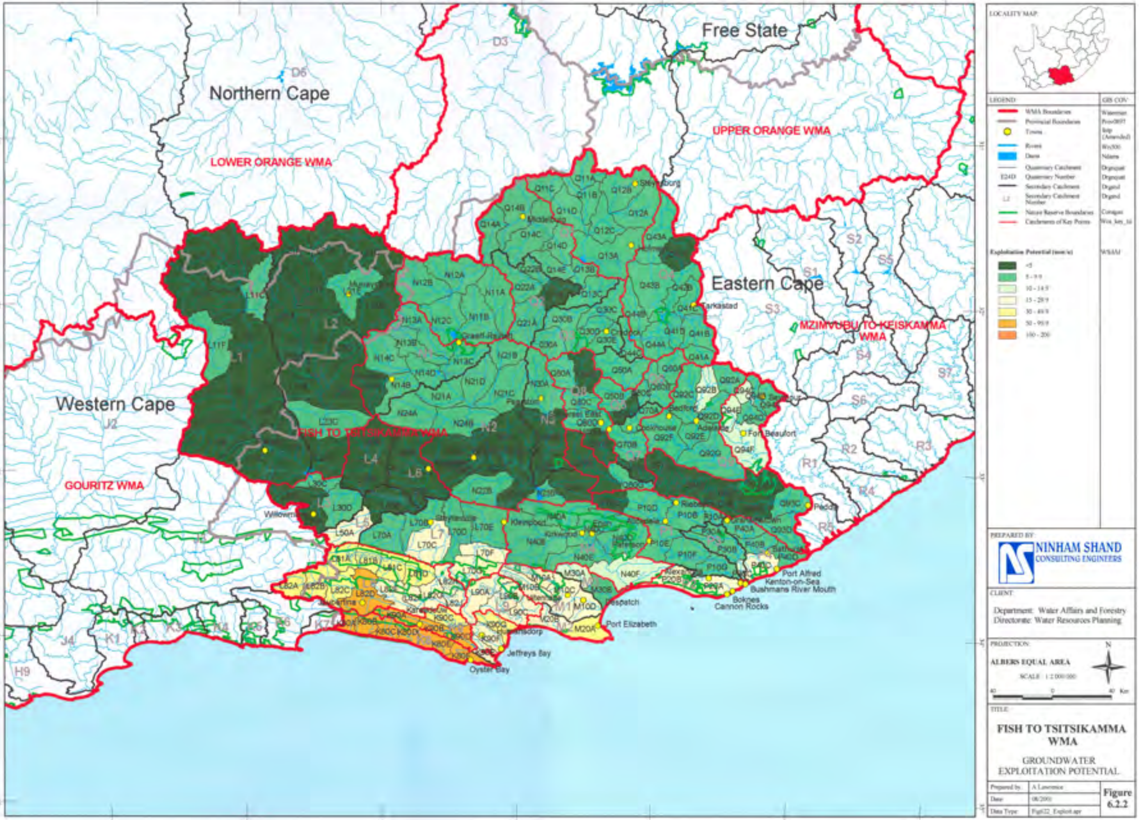
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
FISH TO TSITSIKAMMA WMA
WATER USE BY ALIEN VEGETATION
Figure 5.11.1

Free State
Northern Cape
Eastern Cape
Western Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Orange-Fish 560 million m³/a
Great Fish/Little Fish 146 million m³/a
Little Fish/ Sundays 198 million m³/a
Great Fish/ Grahamstown 6,8 million m³/a
Bulk/Sand River Dam to Port Elizabeth 4,0
Van Stadens Dam/Port Elizabeth 0,1
Kouga Dam/Port Elizabeth 23,0
Churchill/Impofu Dams to Port Elizabeth 23,0
Sundays/Port Elizabeth 12,0 million m³/a
Steynsburg
Middelburg
Tarkastad
Cradock
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Klipplaat
Willowmore
Kleinpoort
Riebeeck-Oos
Grahamstown
Peddie
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Alexandria
Port Elizabeth
Humansdorp
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
Water Transfer
Delivery
Source
PREPARED BY
NINHAM SHAND CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
WATER TRANSFER SCHEMES
Figure 5.14.1

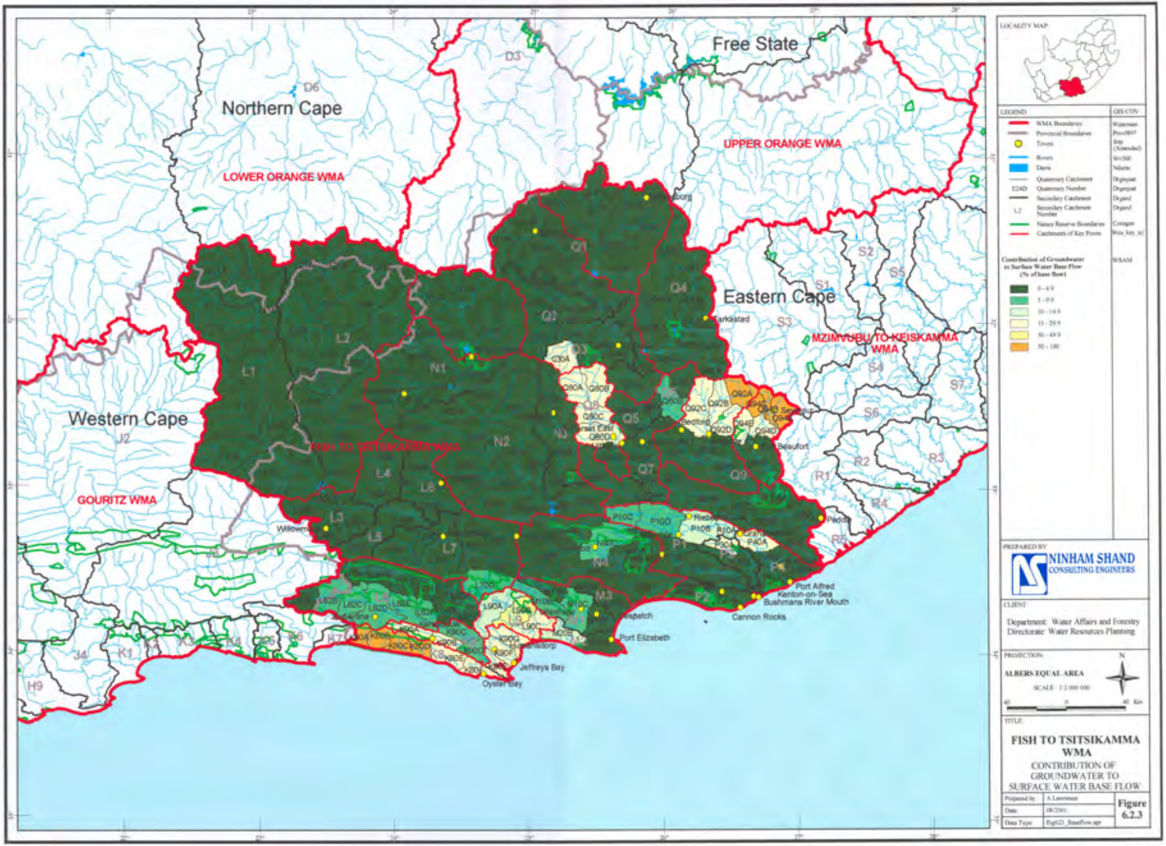
Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Graaff-Reinet
Aberdeen
Tarkastad
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Grahamstown
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Despatch
Port Elizabeth
Humansdorp
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
Total Water Resource
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE: 1:2 000 000
TITLE:
FISH TO TSITSIKAMMA WMA
1:50 YEAR YIELD OF
THE TOTAL WATER RESOURCE
AS DEVELOPED IN 1995
Figure
6.1.1

Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Port Elizabeth
Jeffreys Bay
Oyster Bay
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Graaff-Reinet
Middelburg
Steynsburg
Tarkastad
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Grahamstown
Riebeeck-Oos
Alicedale
Kirkwood
Paterson
Kleinpoort
Klipplaat
Steytlerville
Willowmore
Joubertina
Hankey
Humansdorp
Uitenhage
Despatch
Alexandria
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Total Water Resource
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
1:50 YEAR YIELD OF
THE TOTAL WATER RESOURCE IF
DEVELOPED TO FULL POTENTIAL
Prepared by
A Lawrence
Date
Data Type
Figure
6.1.2

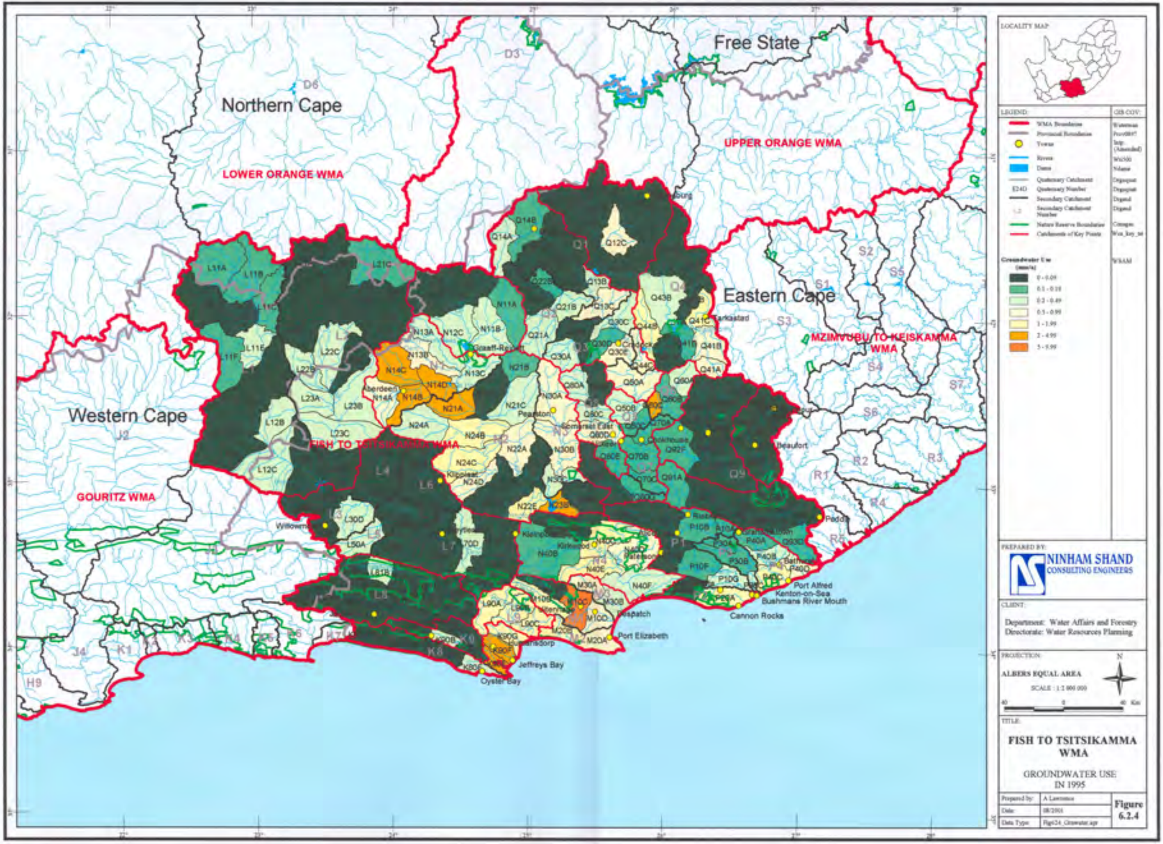

Free State
Northern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Steynsburg
Hofmeyr
Tarkastad
Cradock
Murraysburg
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Seymour
Jansenville
Klipplaat
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Paterson
Alicedale
Riebeeck-Oos
Grahamstown
Peddie
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Alexandria
Boknes
Cannon Rocks
Port Elizabeth
Despatch
Uitenhage
Hankey
Humansdorp
Jeffreys Bay
Oyster Bay
Joubertina
Kareedouw
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Harvest Potential (mm/a)
WSAM
<5
5 - 9.9
10 - 14.9
15 - 29.9
30 - 49.9
50 - 99.9
100 - 200
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
N
TITLE:
FISH TO TSITSIKAMMA WMA
GROUNDWATER HARVEST POTENTIAL
Prepared by: A Lawrence
Date: 08/2001
Figure 6.2.1



Free State
Northern Cape
Western Cape
Eastern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
GOURITZ WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Humansdorp
Despatch
Tarkastad
Fort Beaufort
Cookhouse
Bedford
Adelaide
Graaff-Reinet
Middelburg
Steynsburg
Kirkwood
Jansenville
Willowmore
Steytlerville
Joubertina
Riebeeck East
Pearston
Somerset East
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
L2 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Exploitation Potential (mm/a)
<5
5 - 9.9
10 - 14.9
15 - 29.9
30 - 49.9
50 - 99.9
100 - 200
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
40 0 40 Km
N
TITLE:
FISH TO TSITSIKAMMA WMA
GROUNDWATER EXPLOITATION POTENTIAL
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig622_Exploit.apr
Figure 6.2.2



Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Tarkastad
Bedford
Beaufort
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Contribution of Groundwater to Surface Water Base Flow (% of base flow)
WSAM
0 - 4.9
5 - 9.9
10 - 14.9
15 - 29.9
30 - 49.9
50 - 100
PREPARED BY
NINHAM SHAND CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:2 000 000
N
TITLE
FISH TO TSITSIKAMMA WMA
CONTRIBUTION OF GROUNDWATER TO SURFACE WATER BASE FLOW
Prepared by
A Lawrence
Date
08/2001
Figure 6.2.3



Free State
Northern Cape
Eastern Cape
Western Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Graaff-Reinet
Aberdeen
Pearston
Somerset East
Cradock
Tarkastad
Beaufort
Willowmore
Kirkwood
Patensie
Riebeek
Grahamstown
Peddie
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Despatch
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
GIS COV
Towns
Rivers
Dams
Groundwater Use (mm/a)
0 - 0.09
0.1 - 0.19
0.2 - 0.49
0.5 - 0.99
1 - 1.99
2 - 4.99
5 - 9.99
WSAM
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:2 000 000
TITLE:
FISH TO TSITSIKAMMA WMA
GROUNDWATER USE IN 1995
Prepared by: A Lawrence
Figure 6.2.4

LOCALITY MAP

LEGEND		GIS COV
	WMA Boundaries	Watermstr
	Provincial Boundaries	Prov2017
	Towns	Imp (Amended)
	Rivers	Riv500
	Dams	Ndams
	Quaternary Catchment	Drgnquat
E24D	Quaternary Number	Drgnquat
	Secondary Catchment	Drgnsd
L1	Secondary Catchment Number	Drgnsd
	Nature Reserve Boundaries	Consgov
	Catchments of Key Points	Wrsa_key_ta

Groundwater Utilisation — WSAM

- Over Utilised
- Heavily Utilised
- Moderately Utilised
- Under Utilised

PREPARED BY

NINHAM SHAND
CONSULTING ENGINEERS

CLIENT

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION

ALBERS EQUAL AREA

SCALE 1:2 000 000

40 0 40 Km

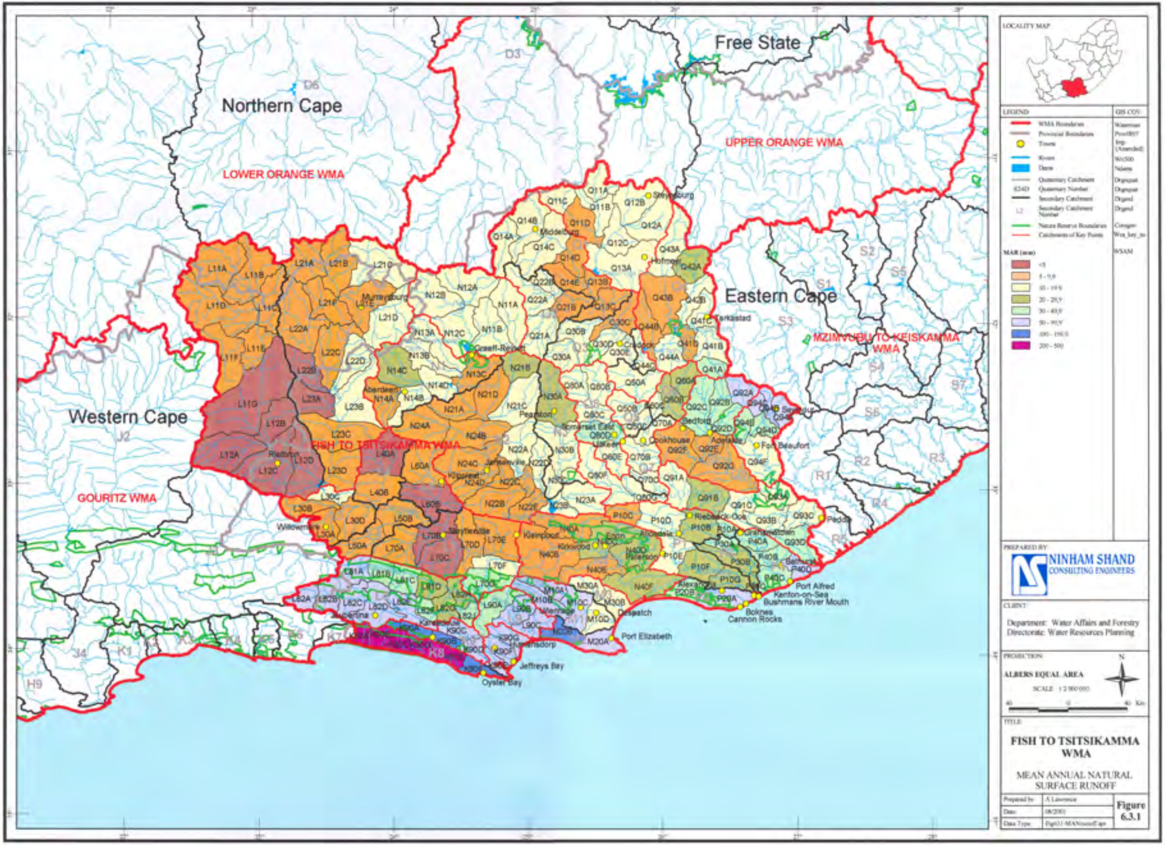
N

TITLE

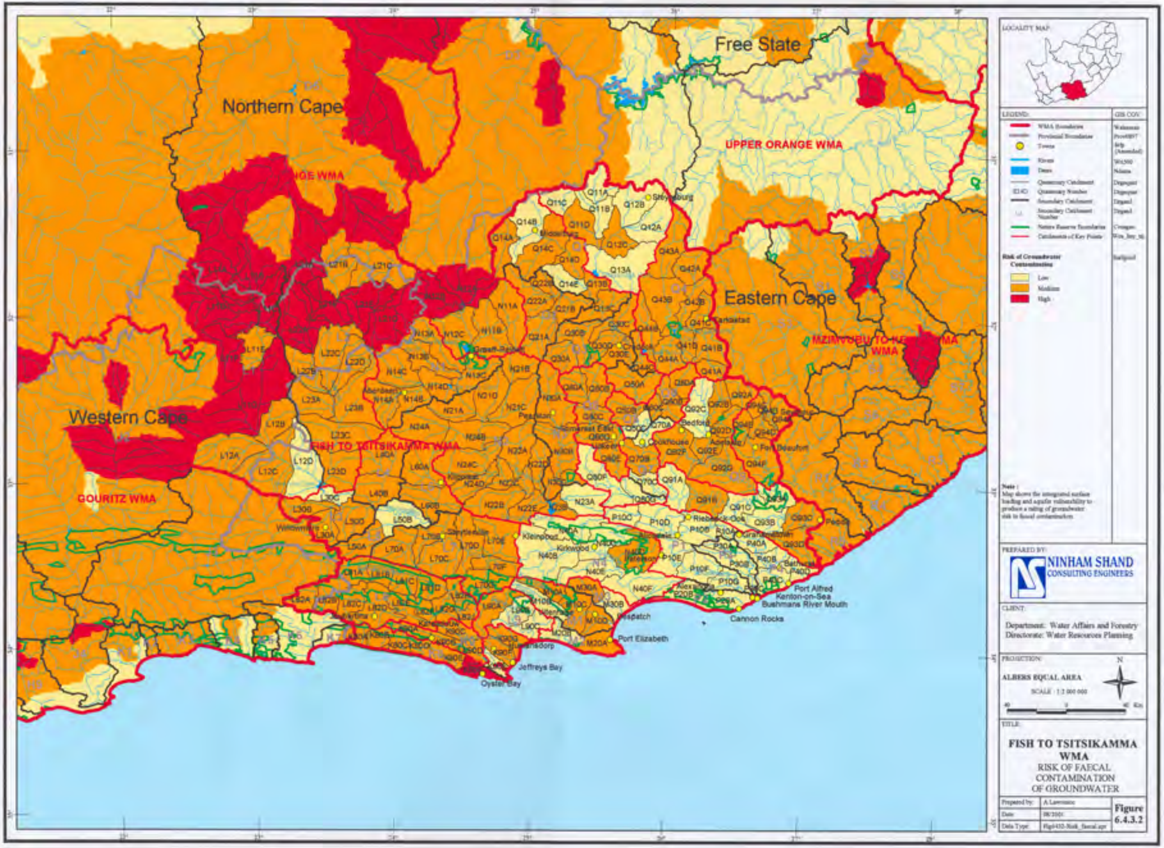
FISH TO TSITSIKAMMA WMA

EXTENT OF GROUNDWATER UTILISATION IN 1995

Prepared by	A Lawrence	**Figure 6.2.5**
Date	08/2001	
Data Type	Fig625_Util.apr	

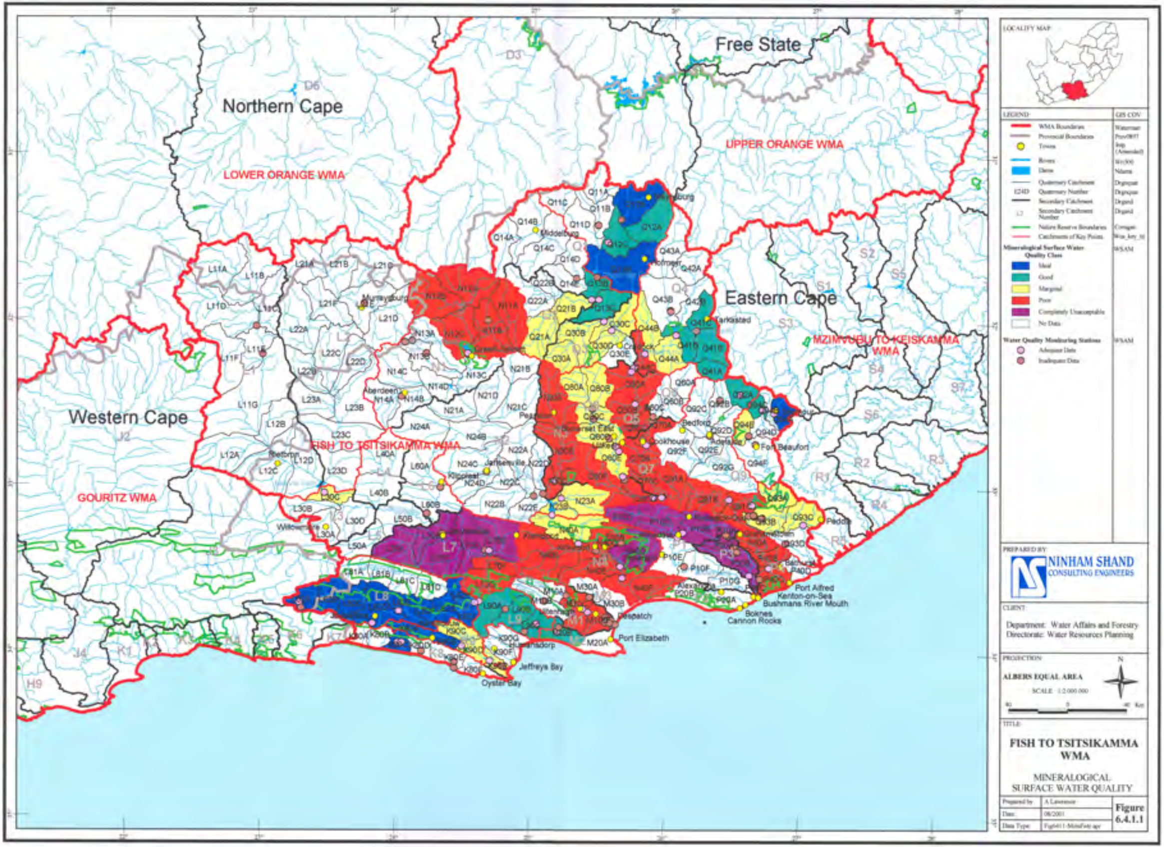


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Graaff-Reinet
Aberdeen
Murraysburg
Middelburg
Steynsburg
Hofmeyr
Tarkastad
Cradock
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Jansenville
Klipplaat
Steytlerville
Willowmore
Kleinpoort
Kirkwood
Paterson
Alicedale
Riebeeck-Oos
Grahamstown
Peddie
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Alexandria
Port Elizabeth
Uitenhage
Despatch
Jeffreys Bay
Humansdorp
Oyster Bay
Joubertina
Kareedouw
LOCALITY MAP
LEGEND
GIS COV.
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
MAR (mm)
<5
5 - 9,9
10 - 19,9
20 - 29,9
30 - 49,9
50 - 99,9
100 - 199,9
200 - 500
WSAM
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
MEAN ANNUAL NATURAL SURFACE RUNOFF
Prepared by
A Lawrence
Date
08/2001
Figure 6.3.1

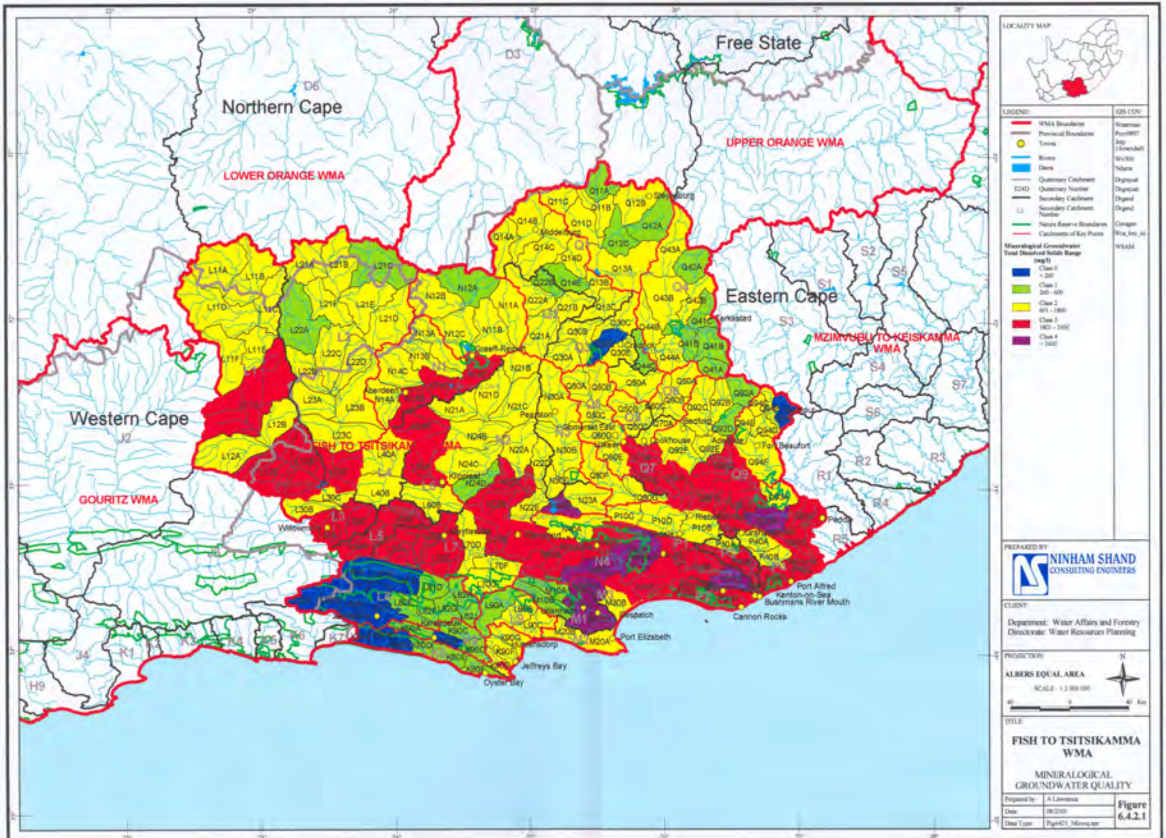


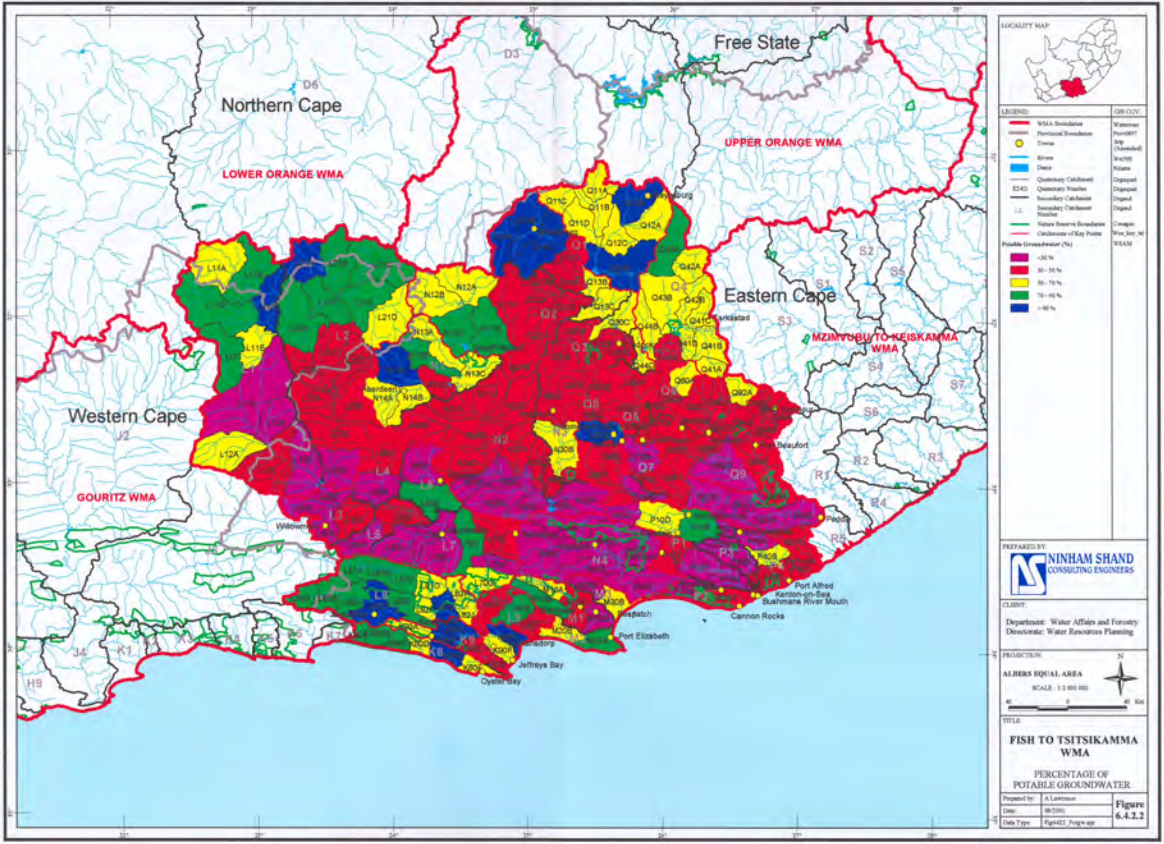
FISH TO TSITSIKAMMA WMA
RISK OF FAECAL CONTAMINATION OF GROUNDWATER

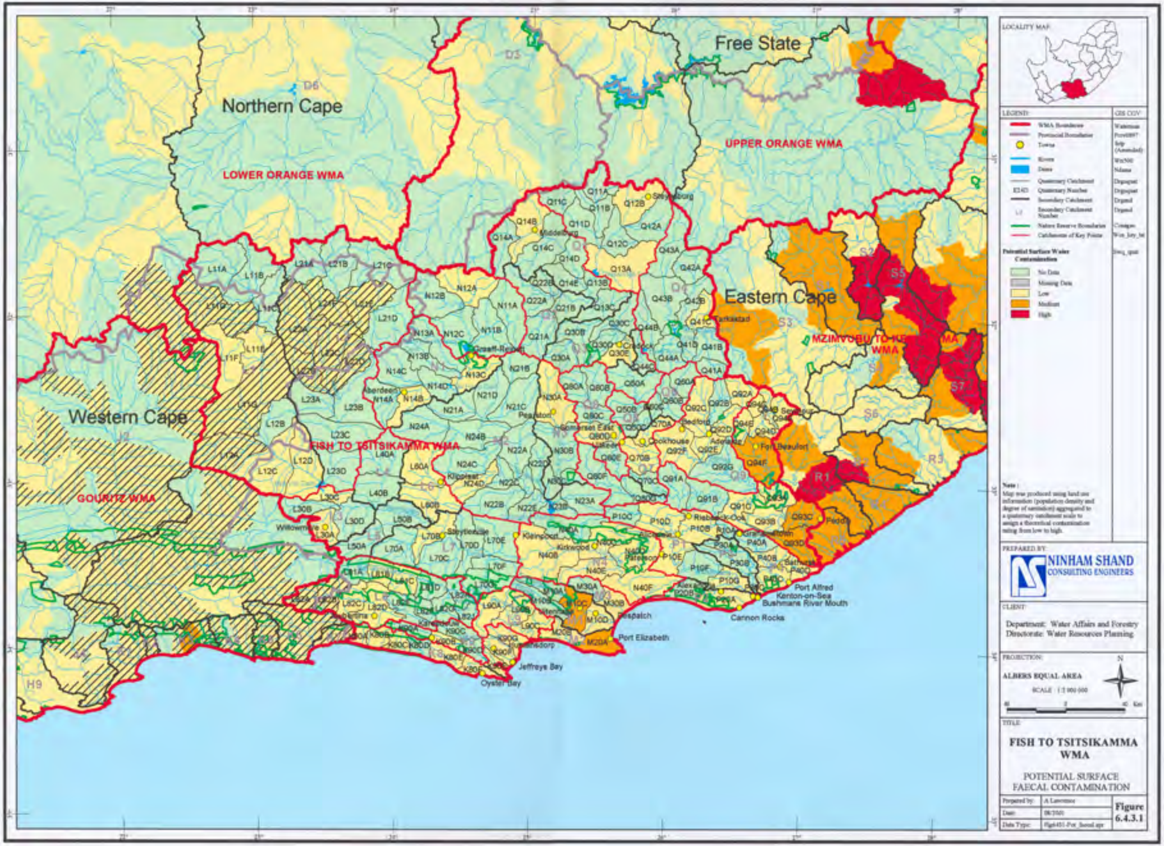
Figure 6.4.3.2



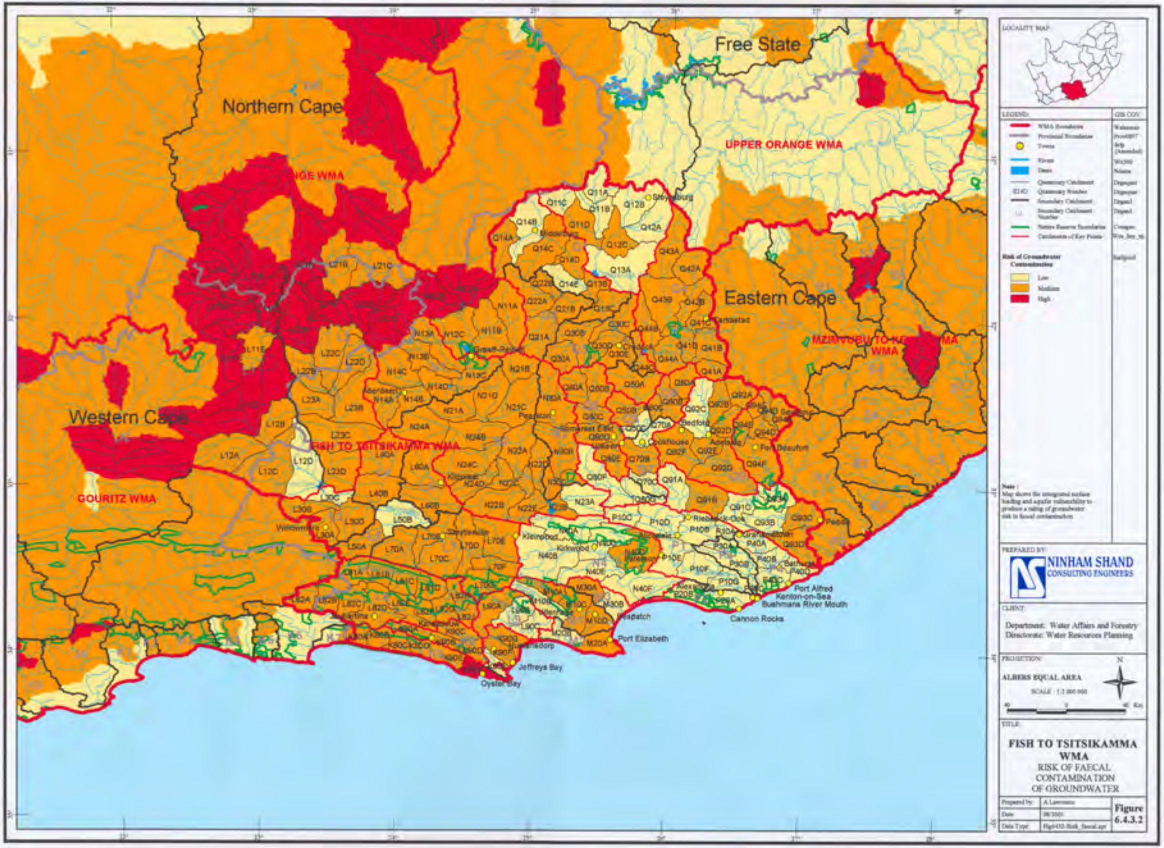
Free State
Northern Cape
Eastern Cape
Western Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Middelburg
Cradock
Tarkastad
Bedford
Adelaide
Cookhouse
Fort Beaufort
Aberdeen
Jansenville
Klipplaat
Willowmore
Kirkwood
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Despatch
Port Elizabeth
Humansdorp
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Mineralogical Surface Water Quality Class
Ideal
Good
Marginal
Poor
Completely Unacceptable
No Data
Water Quality Monitoring Stations
Adequate Data
Inadequate Data
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:2 000 000
N
TITLE:
FISH TO TSITSIKAMMA WMA
MINERALOGICAL SURFACE WATER QUALITY
Prepared by: A Lawrence
Date: 08/2001
Figure 6.4.1.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
GOURITZ WMA
Graaff-Reinet
Middelburg
Steynsburg
Tarkastad
Cradock
Aberdeen
Pearston
Somerset East
Bedford
Adelaide
Cookhouse
Fort Beaufort
Willowmore
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Mineralogical Groundwater Total Dissolved Solids Range (mg/l)
Class 0 < 260
Class 1 260 - 600
Class 2 601 - 1800
Class 3 1801 - 3400
Class 4 > 3400
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
40 0 40 Km
TITLE:
FISH TO TSITSIKAMMA WMA
MINERALOGICAL GROUNDWATER QUALITY
Prepared by: A Lawrance
Figure 6.4.2.1


Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
GOURITZ WMA
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Beaufort
Tarkastad
Aberdeen
LOCALITY MAP
LEGEND:
GIS COV:
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE : 1:2 000 000
N
TITLE:
FISH TO TSITSIKAMMA WMA
PERCENTAGE OF POTABLE GROUNDWATER
Prepared by: A Lawrence
Date: 08/2001
Figure 6.4.2.2

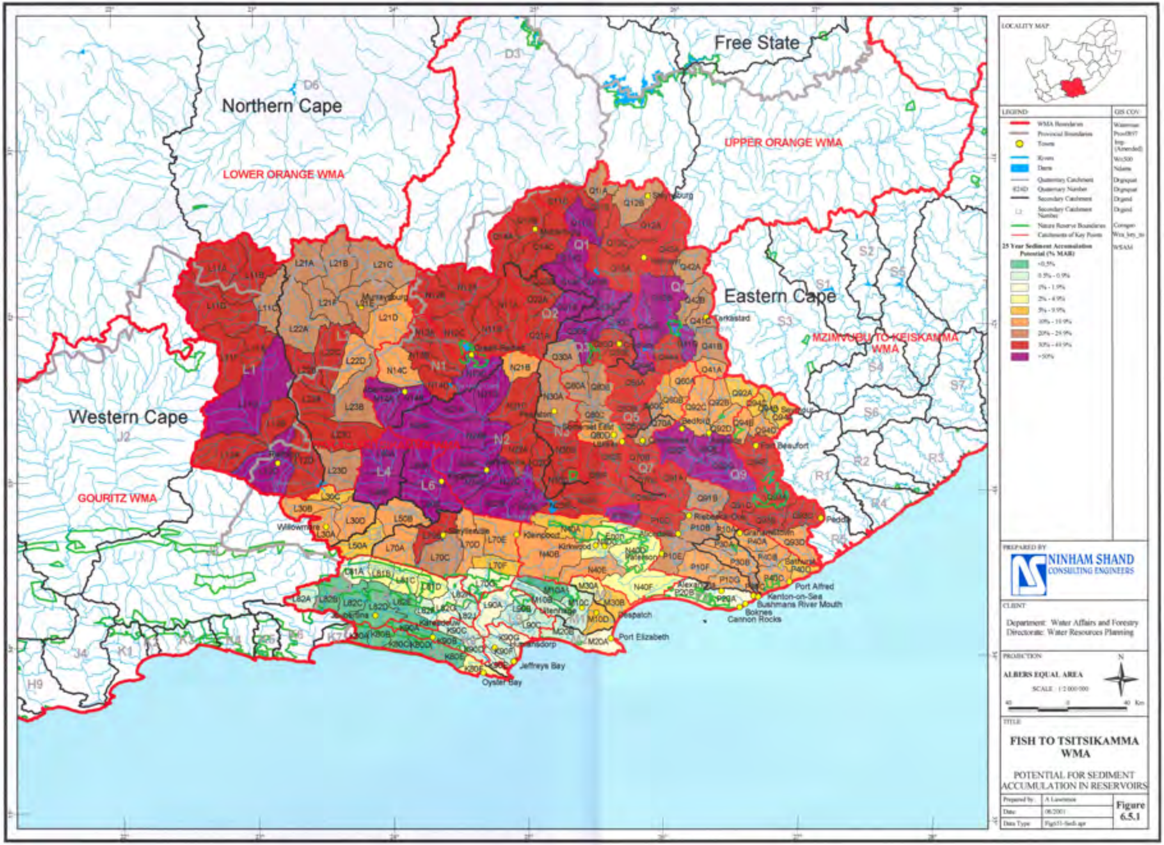


Free State
Northern Cape
Western Cape
Eastern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Willowmore
Aberdeen
Graaff-Reinet
Cradock
Tarkastad
Steynsburg
Middelburg
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Kirkwood
Patterson
Alexandria
Grahamstown
Despatch
Humansdorp
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Potential Surface Water Contamination
No Data
Missing Data
Low
Medium
High
Note :
Map was produced using land use information (population density and degree of sanitation) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
POTENTIAL SURFACE FAECAL CONTAMINATION
Prepared by:
A Lawrence
Date:
Data Type:
Figure 6.4.3.1

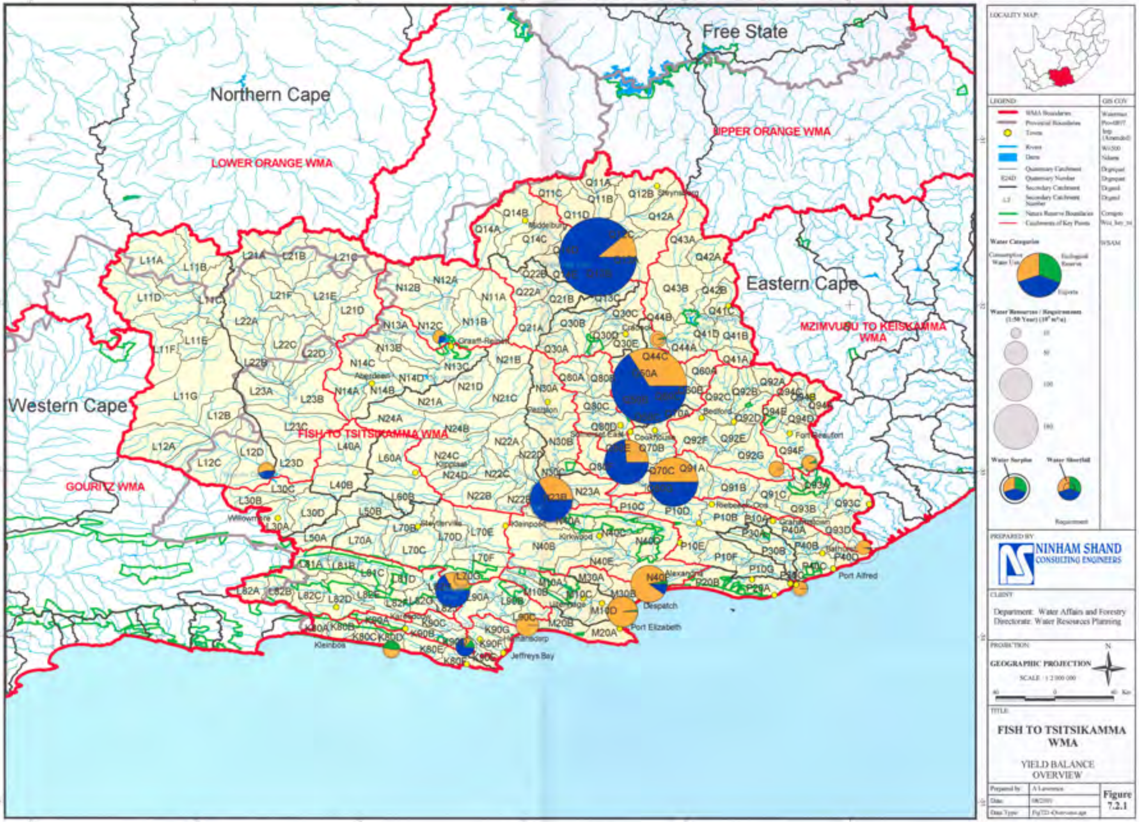


Free State
Northern Cape
Eastern Cape
Western Cape
UPPER ORANGE WMA
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
MZIMVUBU TO KEISKAMMA WMA
Port Elizabeth
Jeffreys Bay
Humansdorp
Oyster Bay
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Grahamstown
Graaff-Reinet
Cradock
Somerset East
Middelburg
Steynsburg
Tarkastad
Bedford
Adelaide
Fort Beaufort
Cookhouse
Pearston
Aberdeen
Willowmore
Steytlerville
Kleinpoort
Kirkwood
Alexandria
Uitenhage
Despatch
Riebeeck-Oos
Peddie
Bathurst
LOCALITY MAP
LEGEND:
GIS COV:
Risk of Groundwater Contamination
Low
Medium
High
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
FISH TO TSITSIKAMMA WMA
RISK OF FAECAL CONTAMINATION OF GROUNDWATER
Prepared by:
Date:
Data Type:
Figure 6.4.3.2

Northern Cape
Free State
Western Cape
Eastern Cape
LOWER ORANGE WMA
UPPER ORANGE WMA
GOURITZ WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Natural dissolution of salts and flouride which influences domestic use (treatment costs).
Natural dissolution of salts and flouride which increases the impact of irrigation return flows on water quality.
Natural dissolution of salts and suspended solids has localised impacts on agriculture.
Further water resource development in the Kouga River could have a negative impact on the dilution of high salinities in the Gamtoos River.
Natural release of dissolved organic carbon which affects THM formation in treated water and increases potable water treatment costs.
Urban, industrial and agricultural runoff influence all water use sectors as well as aquatic ecosystems.
Middelburg
Graaff-Reinet
Aberdeen
Cradock
Tarkastad
Pearston
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Kleinpoort
Kirkwood
Grahamstown
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Cannon Rocks
Port Elizabeth
Jeffreys Bay
Oyster Bay
Willowmore
Steytlerville
LOCALITY MAP
LEGEND
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
FISH TO TSITSIKAMMA WMA
WATER QUALITY ISSUES
Figure 6.4.4.1



Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
GOURITZ WMA
Tarkastad
Willowmore
Kleinpoort
Kirkwood
Paterson
Grahamstown
Peddie
Bathurst
Port Alfred
Kenton-on-Sea
Bushmans River Mouth
Boknes
Cannon Rocks
Despatch
Uitenhage
Port Elizabeth
Humansdorp
Jeffreys Bay
Oyster Bay
Fort Beaufort
Bedford
Somerset East
Riebeeck-Oos
Steytlerville
Graaff-Reinet
Murraysburg
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
25 Year Sediment Accumulation Potential (% MAR)
<0.5%
0.5% - 0.9%
1% - 1.9%
2% - 4.9%
5% - 9.9%
10% - 19.9%
20% - 29.9%
30% - 49.9%
>50%
PREPARED BY
NINHAM SHAND CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
FISH TO TSITSIKAMMA WMA
POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS
Prepared by: A Lawrence
Date: 06/2001
Figure 6.5.1



Free State
Northern Cape
UPPER ORANGE WMA
LOWER ORANGE WMA
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Western Cape
FISH TO TSITSIKAMMA WMA
GOURITZ WMA
Graaff-Reinet
Aberdeen
Middelburg
Steynsburg
Cradock
Bedford
Fort Beaufort
Cookhouse
Somerset East
Pearston
Kirkwood
Riebeeck-Oos
Grahamstown
Port Alfred
Alexandria
Despatch
Uitenhage
Port Elizabeth
Hankey
Humansdorp
Jeffreys Bay
Kareedouw
Kleinbos
Joubertina
Steytlerville
Klipplaat
Willowmore
LOCALITY MAP
LEGEND
Water Categories
Water Resources / Requirements
Water Surplus
Water Shortfall
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
GEOGRAPHIC PROJECTION
N
TITLE
FISH TO TSITSIKAMMA WMA
YIELD BALANCE OVERVIEW
Figure 7.2.1