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DEPARTMENT: WATER AFFAIRS AND FORESTRY

Directorate: Water Resources Planning

BREEDE
WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

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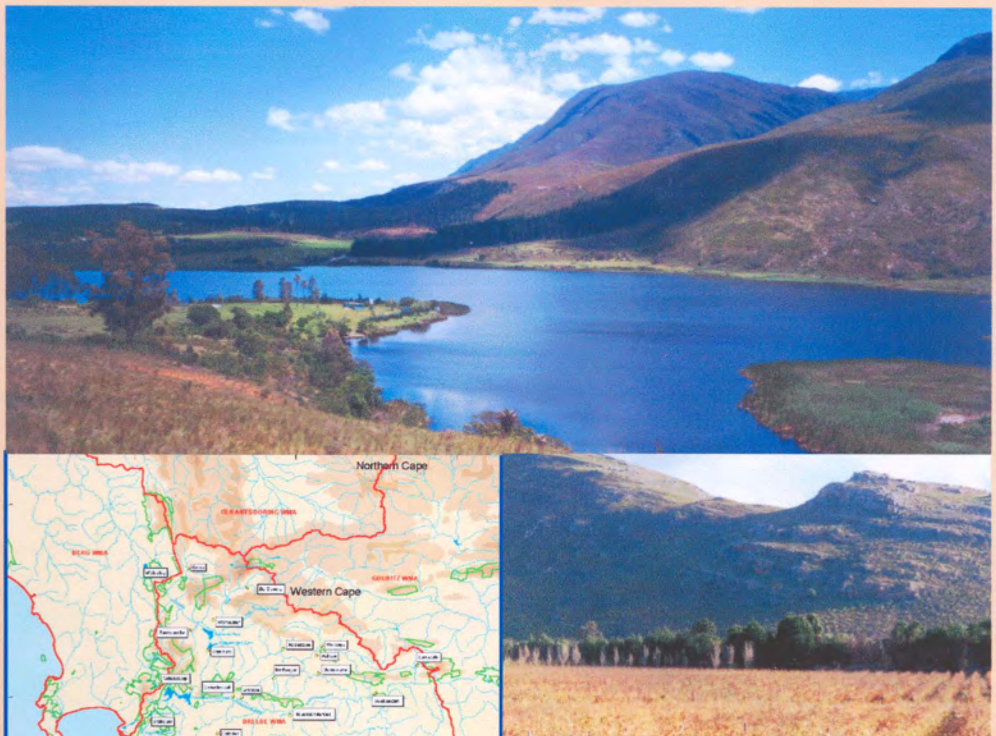

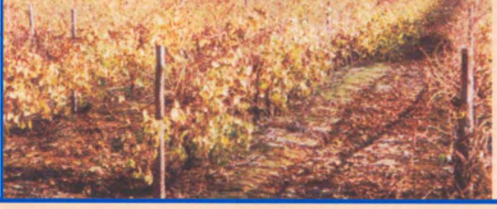

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BREEDE WATER MANAGEMENT AREA

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 Breede Water Management Area, which occupies a portion of the Western 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 Breede Water Management Area.

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 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 Breede 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 Breede Water Management Area, is included in the appropriate sections of this report.

2. CHARACTERISTICS OF THE WMA

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

Physical Characteristics

- The Breede WMA covers an area of 19 668 km^2 in which the mean annual precipitation ranges from 1 500 mm in the high mountains to less than 400 mm in parts of the main river valleys. The north-western portion of the WMA is a winter rainfall region, but rainfall occurs throughout the year in the southern and eastern portions.

- The Breede WMA falls entirely within the Western Cape Province.

- The geology of the WMA is dominated by strata of the Cape Supergroup with the mountain ranges comprising mainly Table Mountain Sandstone. The main river valleys and the coastal hills consist of tillites, sandstones, shales and mudstones, with porous unconsolidated to semi-consolidated sediments in parts. Extensive areas of limestone occur along the coastal strip.

- The present ecological status classes of the rivers of the WMA are nearly all moderately modified or largely modified, but many of them are of high to very high ecological importance and sensitivity, and, consequently, the ecological flow requirements to maintain their existing condition are high.

Development

- The population of the WMA in 1995 was approximately 382 000 people, 66% of whom lived in towns.

- Much of the economic activity is concentrated in the western part of the WMA, with the Worcester and Caledon Magisterial Districts between them contributing 64% of the GGP in 1997. The GGP for the whole WMA was R4,3 billion in 1997, with the most important economic sectors, in terms of contributions to GGP, being Agriculture (32%), Trade (18,5%) and manufacturing (12,4%). The agricultural sector has a high comparative advantage relative to other WMAs.

Land-use

- Land-use is predominantly for agriculture and large areas of wheat are grown under dryland conditions in the southern part of the WMA. Approximately 33% of the total land area of the WMA is cultivated. Some 860 km^2 is irrigated, 68 km^2 is under timber plantations, and approximately 5 560 km^2 is used for dryland crops. Urban areas occupy about 0,6% of the total land area, and nature reserves 10%. The remaining 56% is used mainly for rough grazing for livestock.

- There were about 1 100 000 head of livestock in the WMA in 1995. Sheep and goats made up 92% of the livestock numbers, with sheep predominating.

- Parts of the WMA are severely infested by alien vegetation which causes significant reductions in streamflow.

Water Related Infrastructure

- Water related infrastructure is well developed with 21 large dams and 320 smaller farm dams providing 1 118 million m^3 of storage, which is 45% of the natural MAR.

- Town bulk water supply schemes were generally adequate in 1995, but a number of towns will need to augment their raw water supplies in the near future to keep pace with growing requirements. Within the Breede River Basin, sources of additional raw water are available close to the towns, but sources of additional supplies are more of a problem in the Overberg East and West areas.

- In the Greater Hermanus area in Overberg West a successful water conservation and demand management programme has postponed the need for the development of an additional raw water source by several years, but it is expected that additional supplies will be required within a few years. It appears that these will have to be obtained from some distance away and detailed investigations are required to determine the most appropriate source of supply for the area.

- Similarly, in the coastal area to the south of Bredasdorp, the small but rapidly growing water requirements of the coastal resort towns are approaching the maximum capacities of the existing schemes. As the development of surface water resources in this area is not economical, groundwater has been identified as the probable source of supplementary water supplies. However, the groundwater resources have not been proved by means of a drilling programme and it would be prudent for this to be done before the development occurs of erven which cannot adequately be supplied by the existing water supply schemes.

- Infrastructure for supplying irrigation water is very well developed and there are numerous water supply schemes, both State owned and privately owned. Included amongst these are two large schemes (one only commissioned in 1998) and four smaller schemes, all owned by the State, that transfer water out of the WMA.

Water Requirements

- Water requirements in 1995 were estimated to total 1 124 million m^3/a, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. With the ecological Reserve requirements added, the total becomes 2 016 million m^3/a. The equivalent total requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by afforestation and alien vegetation all included as impacts on the yield, was 953 million m^3/a. The values of the impacts on yield of the ecological Reserve, afforestation and alien vegetation have been determined at a low level of confidence and may be under-estimated.

- The major water user sector was agriculture, which required 684 million m^3/a, or 61% of the total consumptive water requirement (i.e. excluding the ecological Reserve). The next biggest water user was alien vegetation, at 16% of the total consumptive water requirement, followed by water transfers out of the WMA (15%), urban and rural domestic requirements (4%), and afforestation, hydro-power, bulk supplies and river freshening releases which together accounted for the remaining 4%.

- While the quantities of water supplied to irrigation from government water schemes are accurately known, data on use from other sources is of low reliability. As the available data suggests that less than 60% of irrigation water requirements in the WMA as a whole are supplied from government water schemes, it is apparent that other sources contribute significant quantities. The quantities contributed by these sources under average conditions and under 1:50 year drought conditions in the Breede River basin, particularly, are not accurately known. The information is more reliable for the Palmiet catchment where more detailed gathering of information and modelling has been carried out.

Water Resources

- The geology of the Breede River Basin has a strong effect on the quality of the water resources in that much of the runoff is generated in the sandstones of the mountain ranges, and is generally of a high quality with a low total dissolved salts content. However, its quality deteriorates when it reaches the main river channels because it mixes with saline water draining from shales and mudstones of the lower lying ground. Consequently, flow in the lower reaches of the Breede River during the dry summer months is naturally of high salinity. Return flows from irrigated lands increase the salinity.

- Surface water quality in the Palmiet and Rooi Els River catchments, where the geological strata consist mainly of sandstone, is of low salinity, and in the Overberg East and West areas it is variable, with high natural salinities occuring in much of the area because of the effects of the geological strata.

- The potential for faecal contamination of surface water is low throughout the WMA, but the risk to groundwater is medium to high in most areas.

- The natural MAR of the Breede WMA was 2 472 million m^3 and the utilisable yield from the surface water resources in 1995 was 834 million m^3/a at 1:50 year assurance. Some 58% of the utilisable yield was from major dams, 12% from farm dams and small municipal dams, 22% from run-of-river abstractions, and 8% was the impact on the yield of water use by alien vegetation and afforestation. In addition, groundwater resources with a yield of 109 million m^3/a had been developed, bringing the total utilisable yield to 943 million m^3/a at 1:50 year assurance.

- It is estimated that, after allowing for the requirements of the ecological Reserve, a maximum additional quantity of utilisable yield of 263 million m^3/a could be developed. This value, added to the utilisable yield in 1995 of 943 million m^3/a, gives a total potential yield of 1 206 million m^3/a. This estimate is at a low level of confidence because of uncertainty regarding the true impact of the ecological Reserve on the yield.

Water Balance

- Comparison of the equivalent 1:50 year water requirements of 951 million m^3/a with the utilisable 1:50 year yield of 943 million m^3/a shows a deficit of 8 million m^3/a. Re-usable return flows of 71 million m^3/a change this to a surplus of 63 million m^3/a.

- The unused yield from Theewaterskloof, Stettynskloof and Kogelberg Dams totalled 63 million m^3/a in 1995 and accounts for the surplus referred to above. However, the yield of these dams has all been allocated either to irrigation or to expected increases in urban requirements.

- Additional minor surpluses in some parts of the Breede River Basin may be a result of over-estimation of run-of-river yield. These are offset in the overall yield balance for the WMA by deficits in the Overberg East, Overberg West and Warm Bokkeveld areas. These deficits are attributed to irrigation requirements which can accommodate water supplies at less than 1:50 year assurance.

Costs of Water Resources Development

- The capital cost of developing an additional 263 million m^3/a of yield at 1:50 year assurance, in order to fully utilise the water resources of the WMA, was estimated to be R1 260 million at year 2000 prices, including VAT.

3. CONCLUSIONS AND RECOMMENDATIONS

The above information led to the conclusions set out below.

- The developed yield of the Breede WMA was not fully utilised in 1995, but the unutilised portion was fully allocated to urban or agricultural requirements and is likely to be fully utilised in the near future.

- Confidence in the estimates of the yields of farm dams and run-of-river abstractions is low and, as they constitute a significant portion of the total yield, it is essential that they be reliably determined to improve the level of confidence of the yield balance determination.

- The likely water requirements of the ecological component of the Reserve, and their impact on the 1:50 year yield of the water resources, have been determined at a low level of confidence in this study. It is only in the Palmiet River, where detailed work has been done in earlier studies, that the estimates of ecological flow requirements used in this study are considered to be reliable. As the quantity of water available for consumptive use cannot be reliably determined before the requirements of the ecological Reserve are known, both the yield balance and the estimate, given above, of 263 million m^3/a of potential additional yield from the water resources of the WMA are of uncertain reliability. (The uncertainties regardign the requirements of the ecological Reserve are being addressed in the current Breede River Basin Study where the ecological flow requirements at a representative selection of sites on the Breede River and its tributaries are being determined at the technical "comprehensive" level (i.e. without the stakeholder involvement) and the freshwater flow requirement of the Breede River estuary is being determined at the intermediate level).

- Parts of the Breede WMA are severely infested by alien vegetation which causes significant reductions in streamflow. Presently, available data on the extent of the infestation and its effect on the hydrology of the WMA is of low reliability and needs to be improved. This is being addressed for the Breede and Riviersonderend River catchments in the current Breede River Basin Study, but it also needs to be addressed in the Overberg East and West areas where there is severe infestation. From the planning point of view, the priority for addressing the problem is higher in the Breede River Basin than in the Overberg area because little further development of the water resources in the latter area is envisaged, but urgent action for eradication of alien vegetation may be required to protect existing development.

- Large quantities of water are at present exported to the Berg WMA for agricultural use and for the steadily increasing requirements of the Cape Metropolitan Area. In time, much of the surplus water in the Breede WMA is likely to be required to meet the growing urban requirements in the Berg WMA. For the planning for this to be carried out on a sound basis, it is necessary that the potential yield of the water resources of the Breede WMA, as well as present and probable future water requirements within the WMA, be reliably determined.

It became apparent in the course of carrying out this assessment that the available data on the following aspects, in addition to those mentioned above, is inadequate :

- Hydrological data is generally adequate except for a lack of rainfall data for the high lying mountainous areas where much of the runoff of the WMA originates. This additional data is required to improve understanding of the distribution of streamflow in the WMA.

- Water quality data is sparse for the lower Breede River catchment and a routine monitoring point is required in this area to improve the water quality database. This is not of high priority.

- The areas of crops grown under irrigation in the Breede River Basin, and hence the water requirements for irrigation, are not accurately known, but more accurate information is being collected as part of the current Breede River Basin Study.

- No information was obtained in this study on the quantity of untreated "leiwater" used in towns for irrigation of gardens. While the quantity is likely to be small in relation to total irrigation requirements, it may be a significant part of urban water requirements. Therefore, it needs to be determined for information on urban water requirements to be comprehensive.

- Similarly, no information on the numbers and types of game, or the number of ostriches in the catchment, was obtained. The need to obtain this information 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.

Areas of uncertainty that are currently being addressed by the Breede River Basin Study are :

- The requirement for improved data on alien vegetation and its effect on streamflow in the Breede River Basin

- More reliable determination of run-of-river yields in the Breede River Basin, and of quantities of irrigation water supplied from farm dams.

- The requirement for improved data on the areas of crops irrigated and the quantities of water used.

- Reliable data on the ecological component of the Reserve in the Breede River Basin.

Areas of uncertainty that will not be covered by the Breede River Basin Study are :

- The quantities of "leiwater" used for irrigation in towns.
- Water requirements of game and ostriches.
- Water use by alien vegetation in the Overberg area.

This data is not critical to the reliability of the water balance, but it is recommended that, for completeness, it should be collected in due course.

It is recommended that the yield balance performed in this study be reviewed once the improved data from the Breede River Basin Study is available.

At the more localised level of urban water supplies in the Overberg area, it is recommended that :

- Alternative schemes for augmenting the water supply to the Greater Hermanus Area should be investigated at feasibility study level to identify the most appropriate scheme for implementation.

- A borehole drilling programme should be carried out to establish a groundwater supply for the future requirements of the coastal towns to the south of Bredasdorp. This should include the establishment of a groundwater monitoring network to ensure that water quality in the De Hoop Vlei and in Soet Vlei is not adversely affected by groundwater abstraction.

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DIAGRAMS

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
d/s	downstream
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
u/s	upstream
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
$10^6 m^3$	million cubic metres
Mℓ	Megalitres
Mℓ/d	Megalitres per day
$10^6 m^3/a$	million cubic metres per year
%	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.
DEMC	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.
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 dimished 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.
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.
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.
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 Breede Water Management Area, which occupies a portion of the Western 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 Breede 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 Breede 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 Breede 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

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 Breede Water Management Area which is shown on Figure 2.1.1 and covers an area of 19 668 km^2. The entire Breede River drainage basin lies within the boundaries of the water management area, as well as the catchments of the smaller rivers that lie between that basin and the Indian Ocean.

The Breede Water Management Area is bounded in the west by the Berg Water Management Area, by the Olifants/Doring and Gouritz Water Management Areas in the north and east respectively, and the Indian Ocean in the south.

The topography is mountainous in the northern and western portions, and consists of rolling hills and sand dunes in the southern portion (see Figure 2.1.2). There are large areas in the southern portion from which there is normally very little flow of surface water to downstream catchments or the sea. These are referred to as "endoreic areas".

The main rivers are the Breede and its major tributary, the Riviersonderend.

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 H60C, may be interpreted as follows. The letter H denotes Drainage Region H (sometimes referred to as a primary catchment). The number 6 denotes secondary catchment 6 of Drainage Region H. The number 0 shows that the secondary catchment has, in this case, not been sub-divided into tertiary catchments. The letter C shows that the quaternary catchment is the third in sequence downstream from the head of secondary catchment H60. In the Breede WMA, the pattern of the rivers is such that no tertiary catchments were assigned and the secondary catchments are sub-divided directly into quaternary catchments.

The WMA consists of most of drainage region H (H8 and H9 are excluded) and portions of drainage region G. It contains a total of 79 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 2.1.2. Many of the features themselves are not shown on the figure because the scale of mapping is too small.

The Breede River drains an area of 12 600 km^2, bounded by the Skurweberge (H10C) to the north and the Indian Ocean to the south. The Breede River itself is 322 km long from its source in the Skurweberge near Ceres (H10C) to the coast between Infanta and Witsand where it enters the Indian Ocean (H70K). There are six sub-basins, as described below.

- The Ceres Basin (H10A to C) where the river rises in the mountain catchments to the west and south-west of the Warmbokkeveld.

- The Upper Breede River where the river is joined in the vicinity of Michell's Pass (H10D) by the Witels tributary before it flows into the relatively wide and flat upper Breede River valley in the vicinity of Wolseley (H10F). The river flows southwards until it is joined by the Wit River, which rises in the Slanghoek Mountains above Bainskloof (H10E). Thereafter, it flows south-east towards Worcester and Brandvlei (H10G and H10L). In this area it is joined by the Smalblaar River, which rises in the Du Toit's Mountains as the Molenaars River (H10J). The Holsloot (H10K) joins the Smalblaar before its confluence with the Breede River.

- The Hex River Basin (H2), where another of the tributaries of the Breede River drains part of the Warm Bokkeveld, cuts through high mountains and flows through the intensively cultivated Hex River valley to join the Breede River near Brandvlei Dam (H20H).

- The Middle Breede River (H4, H3, H5), which extends from below Brandvlei Dam (H40E) to the confluence with the Riviersonderend (H50E). The main stem of the river along this 100 km long reach is joined by numerous tributaries rising in the mountains that line the edges of the wide river valley.

- The Riviersonderend Basin (H6), where the river rises in the Hottentots Holland (H60A) and Franschhoek Mountains (H60B) upstream of Theewaterskloof Dam (H60C). Downstream of Theewaterskloof Dam, a number of tributaries originate in the Riviersonderend Mountains along the northern side of the valley (H60D to L) and join the main stem of the river along its course to its confluence with the Breede River (H60L). Both the channels of the tributaries and the main river are heavily infested with alien vegetation.

- The Lower Breede River (H7) where the salinity of the river water is high during the summer months. The river banks are heavily infested with alien vegetation. The main tributary in this reach is the Buffelsjagt River, which rises in the Langeberg Mountains (H70C to E) and is regulated by Buffelsjagt Dam.

The area between the Breede River Basin and the coastline (G4 and G5) is known as the Overberg. A number of smaller rivers flow from this area into the sea. Descriptions of these follow :

- The Palmiet River rises in the Hottentots Holland Mountains (G40C). The Palmiet and its tributary, the Kromme River, flow through the fertile and intensively cultivated Elgin basin (G40C and D) before passing through the pristine Kogelberg State Forest area (G40D) and into the sea.

- The western upper reaches of the Bot River (G40E) flow through well developed agricultural land. The land surrounding the eastern reaches (G40F) has not been developed, probably because of elevated salinities in the water and low runoff. The lower portion of its catchment, before the river enters the Bot River Lagoon (G40G), is also undeveloped.

- The Onrus River (G40H) supports some irrigation and supplies water to Hermanus from the De Bos Dam.

- The Klein River rises in the rolling hills of the Ruensveld north of the coastal mountain range (G40J and K). It flows into a valley that cuts through the mountain range and enter the Kleinriviers Vlei to the east of Hermanus (G40L).

- The Uilkraals River (G40M) near Gansbaai (G40L) was recently dammed and is used for irrigation and to supply water for urban use to Gansbaai and the nearby coastal resort towns (G40L and M).

- The Nuwejaars River catchment (G50B and C) has low runoff. The river feeds the environmentally important Soutendalsvlei (G50B). The outflow from this vlei joins the Kars River (G50D and E), which is relatively saline, and flows into the sea as the Heuningnes Vlei River between Struisbaai and Arniston (G50F).

- The Sout River drains the eastern sector of the Ruensveld (G50G and H) into the De Hoop Nature Reserve and the De Hoopvlei (G50J), which has no outlet to the sea. This river, as its name suggests, is highly saline.

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 Breede 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 BREEDE WMA

CATCHMENT					DESCRIPTION
PRIMARY		SECONDARY		QUATERNARY	
No.	Description	No.	Area	No.	
G (Part)	Eastern part of Drainage Region G	G40 (Part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast
		G40 (Part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei
H (Part)	Breede	H10 (Part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres
		H10 (Part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam
		H20	Hex	H20A to H	Hex River Valley
		H30 to H50	Middle Breede	H30A to D H40A to L H50 A, B	Breede between Riviersonderend confluence and Brandvlei Dam
		H60 (Part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment
		H60 (Part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence

The boundaries of these key areas are shown on Figure 2.1.3 and on most of the other figures in the report. The key areas are also used in many of the tables.

2.2 CLIMATE

Temperature

The mean annual temperature ranges between 17ºC in the east to 15ºC along the south-west coast, with an average of 17ºC for the catchment as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. Table 2.2.1 summarises temperature data for the Breede WMA. The sub-zero temperatures experienced regularly during the winter in some areas allow high quality stone fruit to be grown.

TABLE 2.2.1: TEMPERATURE DATA

MONTH	TEMPERATURE (ºC)	AVERAGE (ºC)	RANGE (ºC)
January	Mean temperature	22	18 - 24
	Maximum temperature	37	33 - 39
	Minimum temperature	9	6 - 11
	Diurnal range	14	10 - 15
July	Mean temperature	11	9 - 12
	Maximum temperature	25	22 - 27
	Minimum temperature	0	-1 - 3
	Diurnal range	12	7 - 14

Frost occurs throughout the inland part of the WMA in winter, typically over the period of mid-May to late August.

Rainfall

The north-western part of the Breede WMA is a winter rainfall region, with a large proportion of annual precipitation falling between May and August. In the south and east, rainfall occurs throughout the year, with 50% of the annual rainfall occurring between October and March. Occasional snowfalls occur on the mountains during most winters. The mean lighting flash density is 0 - 1 per km^2 per annum.

The overall feature of mean annual rainfall over the WMA is that it decreases fairly uniformly eastwards from the western region, but as Figure 2.2.1 shows, the rainfall is high in the Riviersonderend Mountains (H60E, H60F, H60H, H60J) and the Langeberg Mountains (H70A, H70B, H70D, H70E, H70F). The summer rainfall that occurs in these mountains contributes most of the summer flow in the rivers. The mean annual precipitation ranges from 1 500 mm in the high mountains to the west to 400 mm in the east. In parts of the Breede River valley the mean annual precipitation is between 300 mm and 400 mm (H40F, H50A). The average coefficient of variation (CV) ranges from 20% to 38%.

Humidity and Evaporation

In accordance with the rainfall pattern, the relative humidity is higher in winter than in summer. Humidity is highest in June (the daily mean over the Breede WMA ranges from 69% in the south to 66% in the north), and the lowest in January (daily means over the Breede WMA range from 62% in the north to 66% in the south).

The average potential gross mean annual evaporation (as measured by Symons-pan) ranges from 1 800 mm in the south to 2 100 mm in the northern parts (see Figure 2.2.2).

The highest monthly Symons-pan evaporation is in January (range 290 mm to 310 mm) and the lowest in June (60 mm to 70 mm).

The gross irrigation requirement (based on rainfall and A-pan evaporation) ranges from 1 200 mm/annum in the western parts to 1 700 mm/annum in the eastern portion. The minimum monthly requirement is in June (ranging from 25 mm to 35 mm) and the maximum monthly requirement is in January (ranging from 225 mm to 375 mm).

2.3 GEOLOGY

The geology of the area is shown in simplified form on Figure 2.3.1. It is dominated by compact arenaceous and argillaceous strata of the Cape Supergroup. Along the coast and in the valley floors in the north-west, porous unconsolidated to semi-consolidated sediments are found. Extensive areas of limestone occur along the coastal strip.

The mountains along the western edge of the WMA, and the Langeberg range in the north, consist of Table Mountain Sandstone, as do the Riviersonderend Mountains (H60D, E, F, H, J) and the coastal mountains in the vicinity of Hermanus (G40H, J, G50B, E). The Potberg (G50K) to the south of the Breede River estuary is also a large outcrop of sandstone.

The floors of the valleys of the Riviersonderend and Breede Rivers consist of tillites, sandstones and mudstones of the Dwyka Group, sandstones, shales and mudstones of the Ecca Group, and deposits of cretaceous clayey conglomerate.

The rolling hills of the Overberg consist of Bokkeveld shales.

The geology has a strong effect on water quality in the WMA in that much of the runoff is generated in the sandstones of the mountain ranges, and is generally of high quality with a low total dissolved salt content. However, its quality deteriorates when it reaches the main river channels because it mixes with saline water draining from the shales and mudstones of the lower lying ground. As a result, runoff in the lower reaches of the Breede River during the dry summer months is naturally of high salinity.

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 Breede Water Management Area :

- Moderately deep to deep sandy soils that occur in undulating terrain in a 10 to 20 km wide coastal strip along the southern edge of the WMA.
- Shallow sandy loam in the mountainous areas in the west of the WMA, in the mountainous areas that separate the Breede and Riviersonderend valleys, in the Riviersonderend valley itself and in the coastal mountain range between Hermanus and Bredasdorp.

- Moderately deep to deep clayey loam in the undulating terrain between the mountain ranges and between the sandy coastal strip and the interior.
- Moderately deep to deep sandy loam on the steep slopes of the high mountains in the north-west of the WMA.
- Moderately deep to deep sandy loam in the undulating terrain along the northern boundary of the WMA.

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 edaphic (soil) conditions. For the purposes of identifying and managing the heterogenous range 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 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 is rather broad.

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	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
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	**Karoo and Karroid**
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	
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 Sweetveld	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**

2.5.2 Natural Vegetation Types within the Breede WMA

The Breede WMA is located within the Western Cape, and the vegetation within this province is dominated by Karoo and Karroid Types, Temperate and Transitional Forest and Scrub Types, and Sclerophyllous Bush Types. In addition to the aforementioned veld types, False Karoo Types can also be found within this WMA. The veld types occurring within the Breede WMA are described in more detail below and illustrated in Figure 2.5.2.1.

Karoo and Karroid

A large and continuous clump of this vegetation type occurs centrally along the north-western boundary of the Breede 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, but does reach a maximum of up to 900 mm in some of the river valleys. Karoo and Karroid vegetation occurs at any altitude from sea level to 1 700 m above mean sea level (MSL).

False Karoo

Isolated patches occur predominantly in the north-west of the Breede WMA, with a small patch also occurring centrally within this WMA. Similar to Karoo and Karroid vegetation, the False Karoo vegetation type is typified by low vegetation, but in contrast contains more grassy elements. The areas occupied by this veld type are typically arid and in parts may receive less than 300 mm of rainfall per annum. This veld type generally occurs below 1 200 m in elevation.

Temperate and Transitional Forest and Scrub

This veld type dominates within the Breede WMA, occupying some 60% to 70% of its area. 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 1 350 m. Rainfall is typically high ranging from 650 to 1 150 mm per annum, although it 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.

Sclerophyllous Bush

Sclerophyllous Bush occurs in a broad band along the eastern border of this WMA, and finger-like projections of this veld type extend into its interior. This vegetation type, also referred to as Fynbos, contains a bewildering array of species which are characteristically small leafed (hence the term Sclerophyllous Bush). No single species dominates and there is a tremendous spatial turnover in species composition. The areas occupied by the Sclerophyllous Bush veld type are typically fairly mesic, receiving in excess of 500 mm, and up to 1 500 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 basic 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 fulfil.

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 in 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 1999). 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.

The procedure for establishing the Reserve requires each water resource to be classified and the resource quality objectives to be set as initial steps towards determining the Reserve.

As estimates of the quantity of water required for the ecological component of the Reserve are an essential requirement if a meaningful assessment of water resources is to be carried out, and the process of classifying all the water resources has not yet been completed, rapid preliminary classifications were made and used to make rough estimates of the Reserve for purposes of the situation assessments. It should be noted that these preliminary classifications may lead to the ecological requirements in this area being under-estimated, and that the classifications are currently under review.

The procedure followed to classify the rivers is described in Section 2.6.2, below, and the use of the classifications to make rough estimates of the quantity of water required for the ecological component of the Reserve for each of the quaternary catchments in the WMA is described in Section 5.2.

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 methods used to estimate the water requirements are described in Section 5.2.

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.

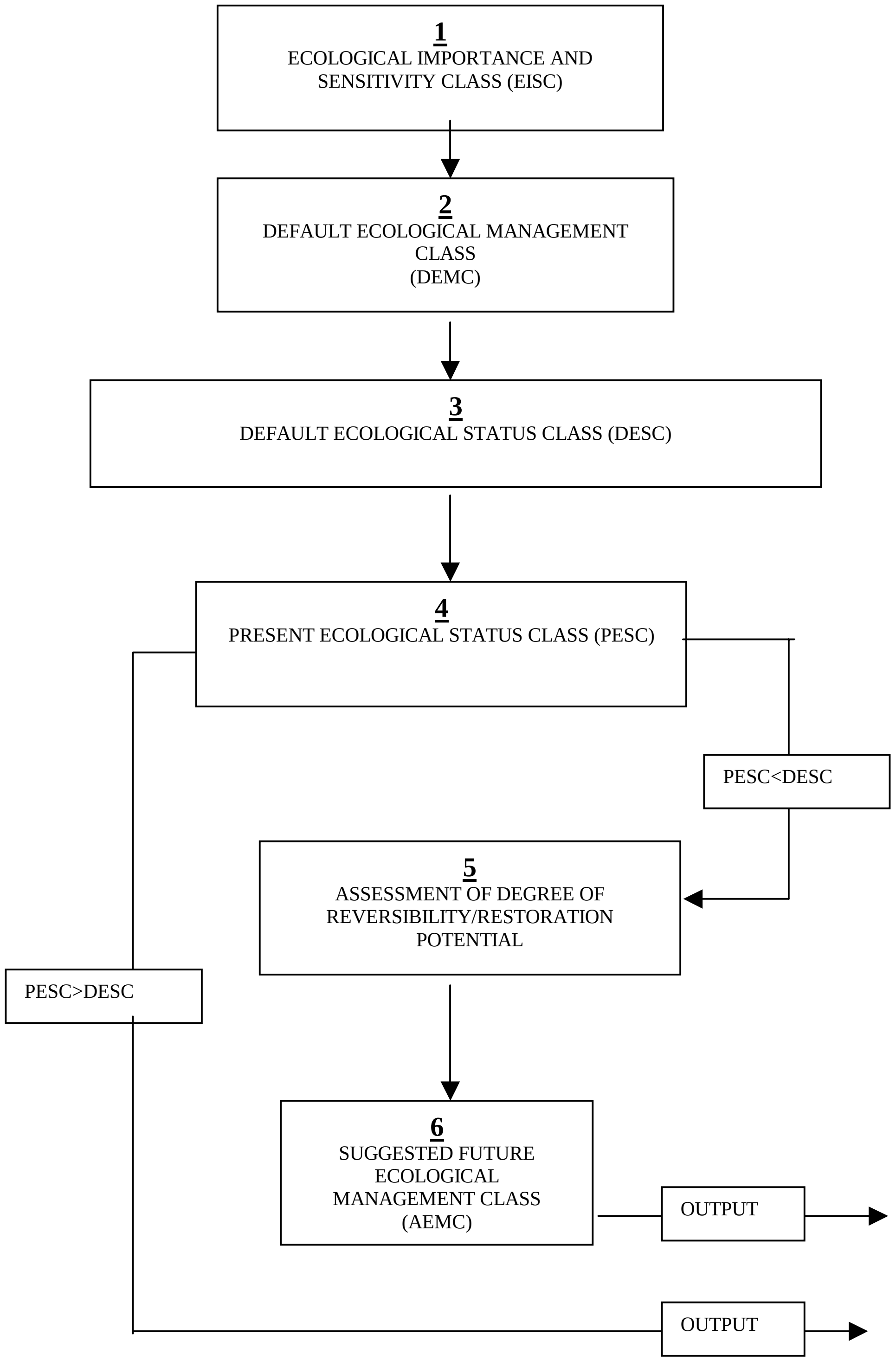


Diagram 2.6.2.1: Procedure followed to determine the river classifications

EISC

Very high → No human induced hazards

High → Small risk allowed

Moderate → Moderate risk allowed

Low/marginal → Large risk allowed

DEMC and DESC

→Class A: Unmodified natural

→Class B: Largely natural

→Class C: Moderately modified

→Class D: Largely modified

PESC

Class A: Unmodified natural

Class B: Largely natural

Class C: Moderately modified

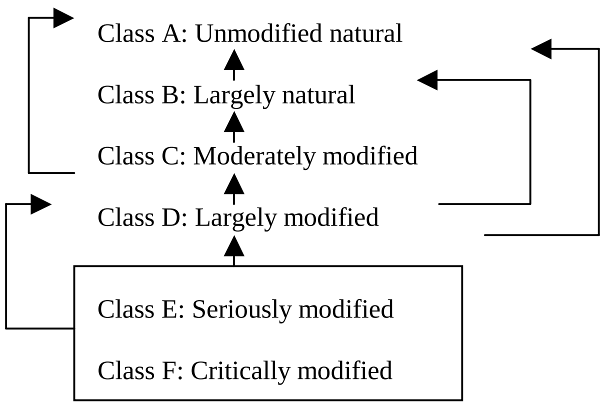
Class D: Largely modified

Class E: Seriously modified

Class F: Critically modified

PESC: SUGGESTED ATTAINABLE IMPROVEMENT

Acceptable range of AEMC:



→ : 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 Breede WMA derives its name from the Breede River which is the dominant river system within the WMA. The Breede River Basin drains an area of approximately 12 600 km^2, and the main stem of the river is 322 km in length.

The ecological significance/conservation importance of the river systems falling within the Breede 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 2.6.3.2. 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 Breede WMA exhibit a range of EISCs from "moderate" to "very high", and associated DEMCs ranging from Class C : moderately modified to Class A : unmodified natural. Any future human manipulation of those river reaches exhibiting a "high" or "very high" EISC (namely H10H, H10L, H40E, H40D, H60B, H60D, H60E, H60F, H60G, H60H, H60J, H60K, H60L, H70B, H70C, H70D, H70E, H70F, G40M, G50B, G50C, G50D, G50E, G50F, G50G, G50H, G50K, Figure 2.6.3.1) would require very strong motivation. The remaining river reaches within the Breede WMA have a moderate EISC corresponding to a DEMC of "moderately modified". The following modifications are evidently the most important in the degradation of the habitat integrity of the rivers within the Breede WMA :

- abstraction of surface and groundwater;
- releases from dams during summer, to supply water for irrigation, with the concomitant impairment in the seasonality of the river system;
- the extensive development of farm dams, both on- and off-channel;
- the Theewaterskloof Dam on the Riviersonderend River;
- the removal of indigenous riparian vegetation;
- invasion of alien vegetation;
- saline and nutrient enriched agricultural return flow, especially in the middle and lower catchment;
- manipulation of the river channel through bulldozing, the construction of berms and infilling to extend cultivated lands; and
- the development of cultivated lands immediately adjacent to the river edge.

These modifications have resulted in the Present Ecological Status Classes (PESC) of Class C : moderately modified and Class D : largely modified that predominate in the WMA, as shown on Figure 2.6.3.2.

Figure 2.6.3.3 shows Future Ecological Management Classes that the assessment carried out for this study suggested that it would be practical to achieve through management of the flow in the rivers. Comparison of this figure with the PESCs depicted on Figure 2.6.3.2 shows that, with the exceptions of the areas in the north of the WMA (H10, H20) that have been permanently affected by agricultural development, it was considered to be practical to improve the status of all the other "largely modified" (Class D) areas. It was also considered practical to improve the status of several areas from "moderately modified" (Class C) to "largely natural" (Class B).

This overview of the ecological significance and conservation importance of the river systems within the Breede WMA is of necessity superficial. However, the assessment of the EISC and Default Ecological Management 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 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 wetlands and groundwater systems, has to date not been assessed within the Breede WMA. Similarly, the estuarine system until recently had not been well studied, but is ecologically important and sensitive to reduced flows and changes in water quality. In this regard, the Breede River estuary is still in a relatively pristine condition and is of considerable importance from floral, piscifaunal and avifaunal perspectives. Accordingly, it is imperative that if any future development of the water resources in the Breede River catchment is considered, a comprehensive study of the freshwater requirements of the estuary be undertaken to ascertain the environmental acceptability of the development. In this regard, the Breede River Basin Study, which is currently underway, provides further information with respect to the ecological status and importance of the rivers, wetlands and estuary within the Breede River basin. Moreover, Reserve determinations for the water quantity, quality, wetlands, groundwater and the estuary, provide crucial information for effective water resource management within this WMA.

2.6.4 Natural Heritage Sites, Proclaimed Game and Nature Reserves, 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 Breede 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 2.6.4.1 contains a list of the protected areas within the Breede WMA and Figure 2.6.3.2 shows the positions of some of them. In addition to the protected areas listed in Table 2.6.4.1, there are a number of private conservation initiatives in the catchment, including various conservancies. The Kogelberg area was declared a biosphere nature reserve in about the year 2000. All water resource development and utilisation should take cognisance of these sites and it is the developer's responsibility 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.

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 he is familiar with the most recent status of protected areas within the Breede WMA.

2.7 CULTURAL AND HISTORICAL SITES

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 Breede 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.

TABLE 2.6.4.1: PROTECTED NATURAL AREAS AND NATURAL HERITAGE SITES WITHIN THE BREEDE WMA

AREA NAME	CATEGORY	GRID REFERENCE
Bainskloof	National Monument	33º 35'S 19º 08'E
Barkai	Natural Heritage Sites	34º 14'S 19º 07'E
Blomboschfontein State Forest	Habitat and Wildlife Management Areas	34º 25'S 19º 15'E
Boesmansbos Wilderness Area	Habitat and Wildlife Management Areas	33º 56'S 20º 53'E
Bontebok National Park	National Parks and Equivalent Reserves	34º 05'S 20º 26'E
Boontjieskraal	Natural Heritage Sites	34º 12'S 19º 19'E
Brandfontein Private Nature Reserve	Natural Heritage Sites	34º 46'S 19º 50'E
De Hoop Marine Reserve	Habitat and Wildlife Management Areas	34º 32'S 20º 30'E
De Mond Nature Reserve	Habitat and Wildlife Management Areas	34º 45'S 20º 12'E
De Mond State Forest	RAMSAR Sites	34º 43'S 20º 07'E
De Hoop Vlei	RAMSAR Sites	34º 27'S 20º 24'E
De Hoop Nature Reserve	Habitat and Wildlife Management Areas	34º 30'S 20º 28'E
Drayton Siding	Natural Heritage Sites	34º 13'S 19º 32'E
Dyer Island	Habitat and Wildlife Management Areas	34º 40'S 19º 25'E
Geyser Island	Natural Monuments and Areas of Cultural Significance	34º 41'S 19º 25'E
Groot Hagelkraal	Natural Heritage Sites	34º 41'S 19º 34'E
HF Verwoerd Coastal Reserve	Habitat and Wildlife Management Areas	34º 23'S 18º 55'E
Karoo National Botanical Garden	Natural Monuments and Areas of Cultural Significance	33º 35'S 19º 27'E
Kogelberg State Forest	Habitat and Wildlife Management Areas	34º 15'S 18º 55'E
Krabbefontein	Natural Heritage Sites	34º 14'S 19º 04'E
Langeberg East Nature Reserve	Habitat and Wildlife Management Areas	34º 40'S 21º 00'E
Maanschynkop Nature Reserve	Habitat and Wildlife Management Areas	34º 22'S 19º 19'E
Marloth Nature Reserve	Habitat and Wildlife Management Areas	33º 58'S 20º 25'E
Paapekuilfontein	Natural Heritage Sites	34º 48'S 19º 56'E
Perdefontein	Natural Heritage Sites	33º 20'S 19º 20'E
Purgatory Outspan (Portion 1)	Natural Heritage Sites	33º 57'S 19º 10'E
Quoin Rock	Natural Monuments and Areas of Cultural Significance	34º 47'S 19º 39'E
Renosterkop Private Nature Reserve	Natural Heritage Sites	34º 46'S 19º 56'E
Salmonsdam Nature Reserve	Habitat and Wildlife Management Areas	34º 25'S 19º 37'E
Sonderend State Forest	Habitat and Wildlife Management Areas	34º 00'S 19º 30'E
Vogelgat Private Nature Reserve	Natural Heritage Sites	34º 23'S 19º 19'E
Vrolijkheid Nature Reserve	Habitat and Wildlife Management Areas	33º 54'S 19º 52'E
Walker Bay State Forest	Habitat and Wildlife Management Areas	34º 40'S 19º 20'E
Witsands Nature Reserve	Habitat and Wildlife Management Areas	34º 25'S 20º 50'E

No general listing of the sites of palaeontological, archaeological and historical significance within the Breede 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 on discovering sites or artefacts of palaeontological, archaeological or historical significance.

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

Most of the towns in the Breede WMA are fairly small and are situated close to plentiful sources of raw water with the result that complex bulk water supply infrastructure was not required in the early days of their development. Initially, therefore, the more complex infrastructure was developed for the supply of irrigation water, and some of the diversion weir and canal distribution schemes that are still in use in the valleys of some of the tributaries of the Breede River were constructed towards the end of the nineteenth century. The first known irrigation works on the Breede River itself date back to 1864, but most of the bigger canals that today carry water from the main stem of the Breede River were constructed early in the twentieth century.

The oldest registered farm dam was constructed near Grabouw in 1920. Since then, some 320 farm dams with a combined capacity of about 114 million m^3 have been constructed.

Lake Marais, which after two raisings, was joined to Kwaggaskloof Dam to become the Greater Brandvlei Dam, was initially constructed in 1922 to store winter runoff for use in summer by irrigators along the Breede River, as the natural summer flow was no longer sufficient for the growing requirements.

The growing requirements for irrigation water resulted in the construction of several large dams by irrigation boards or private landowners. These included Keerom Dam, constructed in 1954 by the Nuy River Irrigation Board, Nuweberg Dam, constructed in 1972 by private landowners, and Arieskraal and Eikenhof Dams also constructed by private landowners in 1967 and 1977 respectively. The State also constructed several dams for the provision of additional irrigation water. These were Poortjieskloof (1955), Buffelsjags (1967), Roode Elsberg (1968), Pietersfontein (1968), Lakenvallei (1974) and Elandskloof (1975). The Sanddrift Government Water Scheme, which conveys water from Roode Elsberg Dam to the Hex River Valley for irrigation purposes was also completed in 1974.

Growing populations in the towns eventually required some dams to be constructed for urban water supplies. Hermanus constructed two small dams before 1949 and the bigger De Bos Dam in 1976. Ceres Dam was originally constructed in 1952 to serve the town, but a larger dam (called Koekedouw) was constructed on the same site in 1998 to serve irrigators and the town. Worcester constructed Stettynskloof Dam in 1954 and raised it in 1980. In 1984, Fairy Glen Dam was constructed, also by Worcester Municipality.

The growing water requirements of the Cape Metropolitan Area have resulted in major schemes being constructed to transfer water from the Breede WMA to the Berg WMA : the Riviersonderend/Berg River Government Water Scheme, with Theewaterskloof Dam as the main storage, was completed in 1978 to provide water for irrigation and urban supplies and the Palmiet Government Water Scheme was completed in 1998 to supply water to Cape Town.

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.

TABLE 3.2.4.1: POPULATION IN 1995

CATCHMENT						POPULATION IN 1995		
PRIMARY		SECONDARY		QUATERNARY		URBAN	RURAL	TOTAL
No.	Description	No.	Description	No.	Description			
G (Part)	Eastern part of Drainage Region G	G40 (Part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast	14 300	10 750	25 050
		G40 (Part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	42 500	8 560	51 060
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	17 250	5 770	23 020
		TOTAL IN PALMIET AND OVERBERG				**74 050**	**25 080**	**99 130**
H (Part)	Breede	H10 (Part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	1 850	10 090	11 940
		H10 (Part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	28 300	19 740	48 040
		H20	Hex (including Worcester)	H20A to H	Hex River Valley	82 500	15 380	97 880
		H30 to H50	Middle Breede	H30A to D H40A to L H50 A, B	Breede between Riviersonderend confluence and Brandvlei Dam	41 300	32 280	73 580
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**153 900**	**77 490**	**231 390**
		H60 (Part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	3 300	6 540	9 840
		H60 (Part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	7 000	10 860	17 860
		TOTAL RIVIERSONDEREND				**10 300**	**17 400**	**27 700**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	15 900	8 250	24 150
		TOTAL IN BREEDE BASIN				**180 100**	**103 140**	**283 240**
TOTAL IN BREEDE WMA						**254 150**	**128 220**	**382 370**

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 the census data that the average growth rate of the population in the WMA between 1980 and 1990 was about 2% per year. In most parts the urban populations increased by about 2% per year, but in Bredasdorp and Caledon they increased by 3,5% per year, and by 4,7% per year in the Hermanus Magisterial District.

The rural population growth rates varied widely from 3,1% per year in the Caledon area to -1,4% per year in the vicinity of Montagu.

The overall population growth rate between 1990 and 1995 fell to an average of 1% per year.

3.2.4 Population Size and Distribution in 1995

Approximately 382 000 people lived in the WMA in 1995. About 254 000 lived in urban areas, and the other 128 000 in rural areas. The distribution of the population is shown in Table 3.2.4.1 and on Figure 3.2.4.1. The greatest densities of both urban and rural populations occur in the Hex key area which contains the urban area of Worcester.

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 Breede Water Management Area (WMA) in terms of the following aspects:

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

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

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 applying 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 GGP 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 of the 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 black people to non-productive areas, and the immigration of mainly Mozambicans, especially to Mpumalanga and the Northern Province, 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 non-black 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 non-black 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 Breede WMA was R4,3bn in 1997. The most important magisterial districts in terms of contribution to GGP in the Breede WMA are shown below:

- Worcester 38,3%
- Caledon 25,6%
- Swellendam 9,1%
- Robertson 7,2%
- Bredasdorp 5,8%

- Ceres 3,5%
- Other 10,5%

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

- Agriculture 32,0%
- Trade 18,5%
- Manufacturing 12,4%
- Finance 10,3%
- Government 10,0%
- Other 17,0%

The Breede WMA economy is fairly diversified, therefore providing a strong economic base.

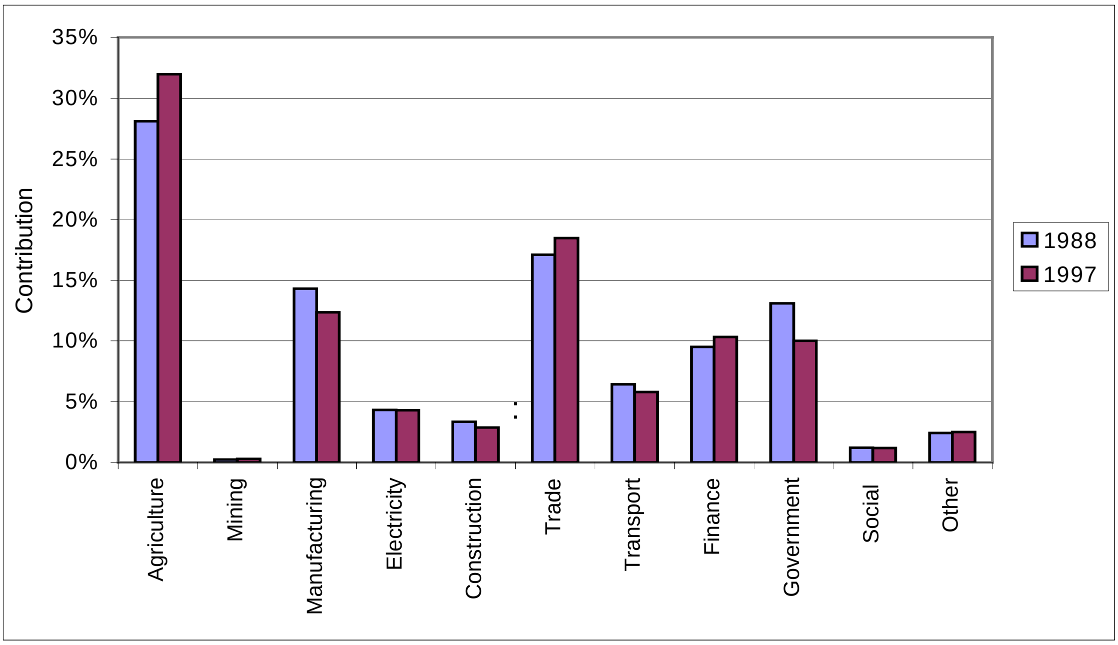


Diagram 3.3.4.1: Contribution by Sector to Economy of Breede Water Management Area, 1988 and 1997 (%)

In the agricultural sector the production of fruit and wine is important. Since there is a strong domestic and international demand for the products from this region, it is expected that the agricultural sector will remain strong.

Agricultural production is also based on grain production which includes an important grain belt in Caledon, Swellendam and Bredasdorp. This area has been experiencing some difficulties due to South Africa's entry into the international wheat market, although more lucrative crops such as barley and hops are becoming more prominent in these areas. Many farmers are diversifying their activities to produce products for higher value niche markets, such as floriculture, conola and ostriches.

The manufacturing sector is also strongly linked to the region's agricultural activities. The majority of manufacturing activities are located in the food and beverage sub-sectors.

There are also a few manufacturing concerns operating in metal products and motor parts, timber and furniture as well as other non-metal industries.

Trading activities are concentrated on wholesale wine, fruit, wheat and other agricultural products, retail services to the WMA community and on tourism.

The financial services sector is supported by a relatively strong property market. An increase in business services as well as the increased demand for real estate in towns along the coast play a part in the relatively strong performance of this sector.

The government sector is supported by a wide variety of national, provincial, regional and local public institutions.

Economic Growth

Compound annual economic growth by sector is shown in Diagram 3.3.4.2. The following sectors recorded the highest average annual growth rates between 1988 and 1997:

- Agriculture : 3,0%
- Mining : 4,5%
- Finance : 2,5%
- Construction : 2,4%

The agricultural sector is expected to remain strong and continue to expand as the most prominent economic activity and employment provider in this region.

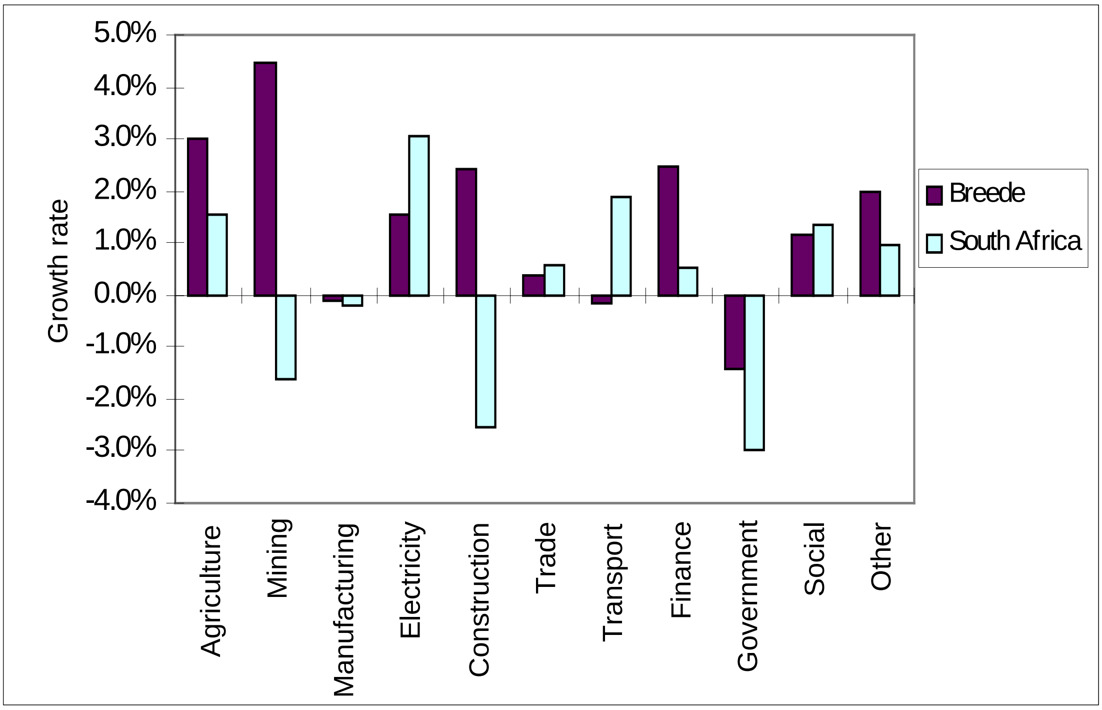


Diagram 3.3.4.2: Compound Annual Economic Growth by Sector of Breede Water Management Area and South Africa, 1988-1997

Labour

Of the total labour force of 155 000 persons in 1994, 19.1% were unemployed, which is lower than the national average of 29,3%. Sixty two percent (62%) are active in the formal economy. Forty two percent (42,6%) of the formally employed labour force work in the agricultural sector. The second largest percentage, 21,5%, are involved in the government sector, and 13,2% in the manufacturing sector.

Significant employment growth was recorded in the mining sector (8,0% per annum but from a very low base); financial services (3,9% per annum); and agricultural (2,6% per annum from a very large base).

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 tends 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.

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

- Agriculture : 6,9
- Electricity : 1,1
- Trade : 1,2
- Other : 1,3.

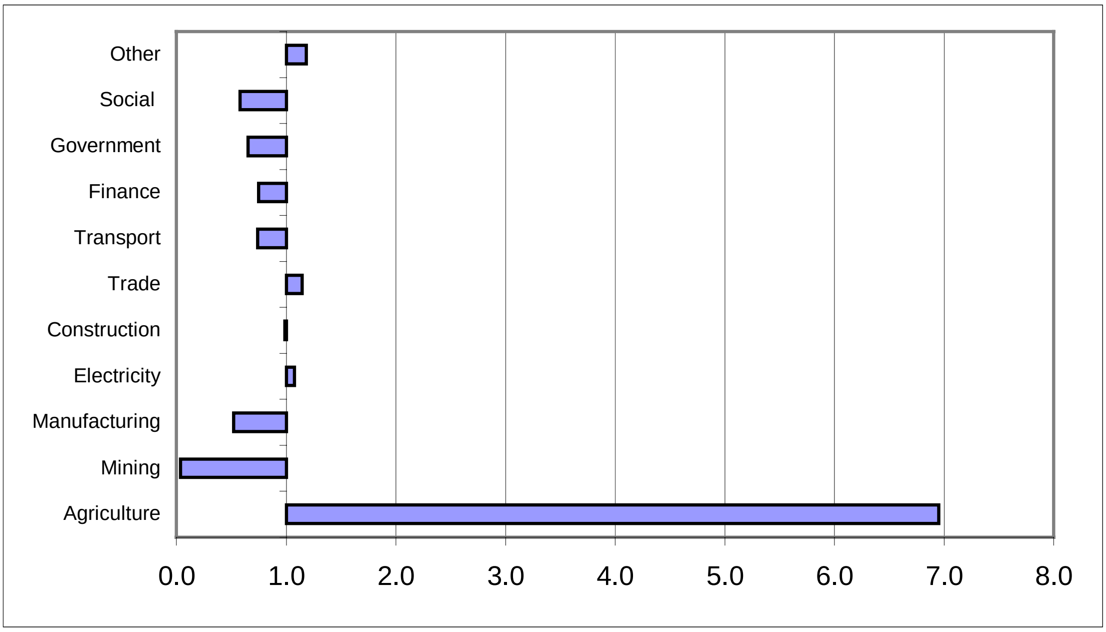


Diagram 3.3.5.1: Breede Gross Geographic Product Location Quotient by Sector, 1997

The only sector with a significant comparative advantage is the agricultural sector. The comparative advantage of the agricultural sector in a national context can largely be attributed to the large domestic and international demand for products from this WMA. The trade sector includes tourism, which is strong in the area and may account for the slight advantage shown by the sector.

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 19^{th} 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.

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.

3.4.7 Other Legislation

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 users 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, (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, only the institutional arrangements prior to the re-structuring are reported on here.

The Breede WMA was fortunate in that 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 3.4.9.2.

The areas that did not fall within the jurisdiction of the transitional local councils fell under the transitional rural councils that are also shown on Figure 3.4.9.2. These areas are generally nature reserves or farmland where the owners of the land are responsible for their own water supplies or, in the case of a large part of the Riviersonderend valley, are supplied by the Overberg Water Board. Thus, neither the transitional rural councils nor the district councils were Water Services Authorities. The Overberg Water Board is the only water board in the Breede WMA. It was established primarily to provide domestic water supplies to farming communities, but now provides bulk water supplies to several of the towns in the area as well.

The district councils provided other services such as roads and clinics. The boundaries of the areas of jurisdiction of the district councils are shown on Figure 3.4.9.1, which also shows magisterial districts. The magisterial districts are generally sub-divisions of the district councils for general administrative purposes, but they can also fall within more than one district council and have no connection with water supplies.

None of the district council areas fell fully within the Breede WMA, and, similarly, several of the magisterial districts extend outside the WMA.

The district council areas and their associated magisterial districts are :

- The Overberg District Council containing the magisterial districts of :

  - Caledon
  - Hermanus
  - Bredasdorp
  - Swellendam (part)

And very small sections of

- Strand
- Somerset West
- Stellenbosch
- Paarl

- The Breede River District Council containing the magisterial districts of :

  - Tulbagh (part)
  - Ceres (part)
  - Worcester (part)
  - Montagu (part)
  - Robertson
  - Swellendam (part)

- Southern Cape District Council containing part of the magisterial district of Heidelberg.

- Winelands District Council containing the magisterial districts of

  - Paarl (part)
  - Wellington (part)

- The Cape Metropolitan Council, containing a small part (31 km^2) of the magisterial district of Somerset West.

3.5 LAND-USE

3.5.1 Introduction

The Breede WMA covers an area of 19 668 km^2. Land-use is predominantly for agriculture and large areas of wheat are grown under dryland conditions in the southern half of the WMA. Based on information derived from satellite images (CSIR, 1999), it appears that approximately 33% of the total land area of the WMA is cultivated. Of this, 860 km^2 is irrigated, 68 km^2 is under timber plantations, and the remaining approximately 5 560 km^2 is used for dryland crops.

Urban areas occupy about 0,6% of the total land area and nature reserves 10%. The remaining 56% is used mainly for rough grazing for livestock, predominantly sheep. Land-use is summarised in Tables 3.5.1.1 and 3.5.1.2 and shown on Figure 3.5.1.1.

3.5.2 Irrigation

Table 3.5.2.1 shows the distribution of irrigated land within the WMA and an estimate of the areas of the different types of crops grown. The areas were obtained from initial data gathered for the Breede River Basin Study, for catchments H10 to H50, from data gathered for investigations for the Skuifraam Scheme (DWAF, 1999b) for catchments H60A to C, and from CSIR land-use maps (CSIR, 1999) for the remaining areas.

The Breede River Basin Study is currently being undertaken by DWAF and more detailed information on irrigated areas is being collected for the whole of the Breede River Basin (H10 to H70). This information, once finalised, will be more reliable than the information shown in Table 3.5.2.1.

TABLE 3.5.1.1: LAND USE BY DRAINAGE AREAS IN km^2

DRAINAGE AREA	IRRIGATION	DRYLAND SUGAR CANE	OTHER DRYLAND CROPS [(3)]	AFFORESTATION [(1)]	NATURE [(2)] RESERVES	URBAN	OTHER	TOTAL AREA
Palmiet (G40B, C, D)	76	0	0	(33)	505	10	3	594
Overberg West (G40E to M)	37	0	817	(12)	156	23	1 359	2 392
Overberg East (G50A to K)	1	0	1 743	0	175	12	2 197	4 128
Sub-total : Palmiet and Overberg	**114**	**0**	**2 560**	**(45)**	**836**	**45**	**3 559**	**7 114**
Warm Bokkeveld (H10A, B, C)	70	0	67	(1)	51	8	460	656
Upper Breede (H10D to L)	142	0	6	(7)	410	3	830	1 391
Hex (H20A to H)	52	0	13	0	9	22	736	832
Middle Breede (H30 to H50)	339	0	402	0	130	13	3 628	4 512
Sub-total : Breede above Riviersonderend confluence	**603**	**0**	**488**	**(8)**	**600**	**46**	**5 654**	**7 391**
Upper Riviersonderend (H60A, B, C)	49	0	24	(6)	211	2	214	500
Lower Riviersonderend (H60D to L)	36	0	861	(2)	154	5	685	1 741
Sub-total : Whole Riviersonderend	**85**	**0**	**885**	**(8)**	**365**	**7**	**899**	**2 241**
Lower Breede (H70)	52	0	1 631	(7)	127	8	1 104	2 922
Sub-total : Whole Breede Basin	**740**	**0**	**3 004**	**(23)**	**1 092**	**61**	**7 657**	**12 554**
TOTAL IN BREEDE WMA	**854**	**0**	**5 564**	**(68)**	**1 928**	**106**	**11 216**	**19 668**

NOTES :
1. Areas of afforestation are not included in the total areas because they lie mainly within State Forest Nature Reserves which are included in "Nature Reserves" and in the total areas.
2. "Nature Reserves" include National Parks, Wilderness Areas, State Forest Nature Reserves, etc.
3. These areas were derived from satellite images and are at a low level of confidence. True areas may be up to 50% lower.

TABLE 3.5.1.2: LAND-USE BY DISTRICT COUNCIL AREA

TYPE OF LAND-USE	BREEDE RIVER DISTRICT COUNCIL (km^2)	CAPE METROPOLITAN COUNCIL (km^2)	OVERBERG DISTRICT COUNCIL (km^2)	SOUTHERN CAPE DISTRICT COUNCIL (km^2)	WINELANDS DISTRICT COUNCIL (km^2)	TOTAL AREA (km^2)
Irrigation	672	0	179	3	0	854
Dryland sugarcane	0	0	0	0	0	0
Other dryland crops (3)	488	0	4 376	700	0	5 564
Afforestation (1)	(8)	(1)	(52)	(7)	0	(68)
Nature Reserves (2)	600	13	1 108	7	200	1 928
Urban areas	46	0	60	0	0	106
Other	5 500	18	5 330	362	6	11 216
TOTALS	**7 306**	**31**	**11 053**	**1 072**	**206**	**19 668**

NOTES

1. Areas of afforestation are not included in the total areas because they lie mainly within State Forest Nature Reserves which are included in "Nature Reserves" and in the total areas. They are shown in brackets to indicate that they are not included in the tables.
2. "Nature Reserves" include National Parks, Wilderness Areas, State Forest Nature Reserves, etc.
3. These areas were derived from satellite images and are at a low level of confidence. True areas may be up to 50% lower.

TABLE 3.5.2.1: IRRIGATION LAND USE

CATCHMENT						STONE FRUIT (km^2)	APPLES, PEARS (km^2)	GRAPES (WINE, TABLE, JUICE) (km^2)	LUCERNE (km^2)	VEGETABLES (km^2)	OTHER CROPS (km^2)	TOTAL IRRIGATED LAND AREA (km^2)
PRIMARY		SECONDARY		QUATERNARY								
No.	Description	No.	Description	No.	Description							
G (Part)	Eastern part of Drainage Region G	G40 (Part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast	5,3	68,0	0,8			2,2	76,3
		G40 (Part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	2,6	32,8	0,4			1,0	36,8
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei						0,6	0,6
		TOTAL IN PALMIET AND OVERBERG				**7,9**	**100,8**	**1,2**			**3,8**	**113,7**
H (Part)	Breede	H10 (Part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	62,7		7,0				69,7
		H10 (Part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	14,2		127,6				141,8
		H20	Hex	H20A to H	Hex River Valley			46,6			5,2	51,8
		H30 to H50	Middle Breede	H30A to D H40A to L H50 A, B	Breede between Riviersonderend confluence and Brandvlei Dam			187,0	34,0	17,0	101,5	339,5
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**76,9**		**368,2**	**34,0**	**17,0**	**106,7**	**602,8**
		H60 (Part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	3,8	37,5	1,9		1,5	4,0	48,7
		H60 (Part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	1,2	11,3	12,5	2,2	1,5	7,7	36,4
		TOTAL RIVIERSONDEREND				**5,0**	**48,8**	**14,4**	**2,2**	**3,0**	**11,7**	**85,1**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence			26,2	5,2	2,6	18,3	52,3
		TOTAL IN BREEDE BASIN				**81,9**	**48,8**	**408,8**	**41,4**	**22,6**	**136,7**	**740,2**
TOTAL IN BREEDE WMA						**108,1**	149,6	410,0	**41,4**	**22,6**	140,**5**	**853,9**

Predominant irrigation method	Micro system	Micro system	Sprinkler	Sprinkler	Sprinkler	Sprinkler

A factor of 0,75 was applied to the areas obtained from the land-use maps to allow for uncultivated areas that are too small to be identified from the satellite images used to develop the land-use maps, but that fall within the areas identified as irrigated. The factor of 0,75 was obtained from comparison of the land-use map data with more detailed studies carried out in the Berg River catchment for the Voëlvlei Augmentation Feasibility Study (DWAF, 1999c). However, the accuracy of the values is uncertain and they should, therefore, be used with caution.

The distribution of crop types shown in Table 3.5.2.1 was derived from information provided by the Western Cape Province Department of Agriculture. It is indicative of typical crop mixes and is not necessarily accurate for the individual sub-catchments.

It can be seen from Table 3.5.2.1 that roughly half of the irrigated land in the WMA is under vineyards for the production of wine, table grapes and juice. About 20% of the area of vineyards is used to produce table grapes, with the remainder producing grapes for wine or juice.

About 18% of the irrigated area is under apple or pear orchards and 13% under stone fruit (peaches, apricots, plums) orchards. Relatively small quantities of lucerne and vegetables are grown and 150 km^2, or 14% of the total irrigated area is shown as being under other crops. These are areas for which information on the type of crops grown was not readily available. It is probable that some of these crops fall into the other categories shown in the table.

It is generally recognised that future growth in irrigation will be severely limited by the availability of water and economic efficiency. In more water-scarce areas it may even become necessary to curtail some irrigation to meet the growing requirements of domestic and urban water use. In order to do this, it will be necessary to base such decisions on sound economic principles that include the economic return per unit of water. Although acknowledged to be fairly generalised, it is suggested that only three income categories of irrigated crops be used for this purpose. These income categories also represent an appropriate grouping for the purpose of assurance of irrigation water supply. Table 3.5.2.2 shows the typical crops within each category.

TABLE 3.5.2.2: ASSURANCE CATEGORIES OF IRRIGATION WATER FOR CROP TYPES

CATEGORY	CROP EXAMPLES
Low	Lucerne and pasture for small stock
Medium	Vegetables, lucerne and pasture for dairying and ostrich
High	Stone fruit, grapes, and speciality vegetables

The predominant irrigation methods for the various types of crops are shown on Table 3.5.2.1, where it can be seen that micro systems are generally used for orchards and sprinklers for other crops. The nature of irrigation practices is influenced by variations in soils, topography and climate within the WMA, as the following discussion shows.

The Overberg Area

In the western part of the Overberg the valleys of the Kromme River (G40D) and the upper portion of the Palmiet River (G40C) are intensively cultivated with apple orchards irrigated from about 60 farm dams. The high rainfall of more than 1 000 mm per year, the clayey soils and the cold winters make this area particularly suitable for the cultivation of apples.

The western upper reaches of the Bot River (G40E) also contain extensive apple orchards irrigated from farm dams, whereas the eastern upper reaches (G40F), and the lower reaches (G40G) have not been developed, probably because of elevated salinities and lower rainfall. There is little irrigation in the central and eastern parts of the Overberg (GK to M, G40A to K) where conditions are better suited to the dryland cultivation of wheat and other grain crops.

The Warmbokkeveld
The Warmbokkeveld (H10A to C), also known as the Ceres Basin, is intensively cultivated with stone fruit orchards (peaches, apricots and plums), also irrigated from about 60 farm dams.

The Upper Breede Valley
The Upper Breede Valley is relatively wide and flat in the vicinity of Wolseley (H10F) where intensive irrigation of stone fruit orchards and vineyards takes place from run of river flow. Further downstream, the flow from several tributaries rising in the mountains along the western and northern sides of the valley (H10E, G, H, J and K) is used for the cultivation of big areas of irrigated vineyards in the broad, flat valley area (H10J, K and L).

The Hex River Valley
The Hex River Valley (H20A, B, F) is intensively cultivated, the predominant crop being vines for the production of table grapes. The vineyards are irrigated using summer runoffs from undammed tributaries (H20E, F) of the Hex River, groundwater (H20E, F), winter runoff stored in the Lakenvallei and Roode Elsberg Dams (H20C and D), and in some 16 farm dams.

The Middle Breede
The Middle Breede River region is predominantly a wine and table grape growing area, but lucerne, pasture and vegetables are also grown under irrigation, which is mainly by sprinkler.

In the Worcester East area (H40C), water for irrigation is obtained from the Breede River itself, and is also imported by canal from the Hex River (H20G) and by pipeline from Keerom Dam (H40B) on the Nuy River.

In the Koo Valley (H40A) upstream of Keerom Dam, and in the catchment of the Kingna River (H30A to D) vineyards and stone fruit orchards are grown under irrigation from run-of-river flow and from winter runoff stored in about 20 farm dams.

Large irrigated areas on both banks of the Breede River from Worcester to beyond Bonnievale (H40D to L and H50A, B) obtain water mainly from releases from Brandvlei Dam (H10L and H40E). The small mountain tributaries are also fully utilised for irrigation of mainly stone fruit orchards in their valleys. The irrigation return flows to the Breede River from the underlying shales are highly saline and freshening releases from Brandvlei Dam are required in summer to maintain acceptable water quality downstream of Robertson (H40J).

The Riviersonderend Catchment

The Riviersonderend River rises in the Hottentots Holland (H60A) and Franschhoek Mountains (H60B) upstream of Theewaterskloof Dam (H60C). Intensive irrigation of fruit orchards takes place in the Vyeboom (H60A and B) and Villiersdorp (H60C) areas upstream of this dam. Water is supplied from Elandskloof Dam (H60B), from some 20 farm dams, and also from Theewaterskloof Dam (to areas in H60B and C).

Irrigation of fruit orchards, vineyards and pastures occurs in the Riviersonderend Valley downstream of Theewaterskloof Dam from compensation releases from the dam and from winter runoff stored in about 15 small farm dams.

The Lower Breede

The Buffelsjagt tributary of the Breede River rises in the Langeberg Mountains (H70C to E). Intensive irrigation of stone fruit orchards takes place in the valley of the Tradouw tributary (H70C) of the Buffelsjagt River on the northern side of the mountains. The Buffelsjagt River itself is dammed to provide water for the irrigation of stone fruit orchards in the area (H70F) between the dam and the confluence of the river with the Breede River.

There is only a little irrigation along the main stem of the Breede River downstream of its confluence with the Riviersonderend because of the high salinity of the water in summer, and there is limited irrigation of stone fruit orchards along the small tributaries near Swellendam (H70A, B).

3.5.3 Dryland Farming

Dryland farming, particularly of wheat and other grain crops, is practised on a large scale in the Breede WMA. No information on the areas of different types of crops grown under dryland conditions was obtained in this study. However, information obtained from land-use maps derived from satellite images (CSIR, 1999), showed a total area of 556 000 ha under dryland cultivation. Because of the small scale of the images used, this area probably includes roads and other uncultivated areas between the fields, and the area actually under crops is likely to be between half and three quarters of the area shown. The distribution of dryland farming areas within the WMA is shown in Table 3.5.1.1.

As explained earlier, the dryland crop that is known to cause a significant reduction in streamflow if grown over large areas is sugar cane, but none is grown in the Breede WMA.

3.5.4 Stock 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.

TABLE 3.5.4.1: LIVESTOCK IN 1995

CATCHMENT							NUMBERS OF LIVESTOCK AND GAME (1)				NO. OF ELSU
PRIMARY		SECONDARY		QUATERNARY			Cattle	Horses/Donkeys/ Mules	Sheep and Goats	Pigs	
No.	Description	No.	Description	No.	Description	Area (km^2)					
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay coast	594	3 868	186	59 092	2 266	14 123
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	2 392	9 909	249	123 256	1 022	45 833
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	4 128	18 322	813	306 010	822	68 819
		TOTAL IN PALMIET AND OVERBERG				**7 114**	**32 099**	**1 248**	**488 358**	**4 110**	**128 775**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	656	485	82	11 608	537	2 372
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	1 391	5 560	403	24 391	5 954	12 907
		H20	Hex	H20A to H	Hex River Valley	832	2 313	93	7 072	1 611	4 274
		H30 to H50	Middle Breede	H30A to D H40A to L H50A, B	Breede between Rivier-sonderend confluence and Brandvlei Dam	4 512	8 950	1 705	61 478	1 445	28 434
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**7 391**	**17 308**	**2 283**	**104 549**	**9 547**	**47 987**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	500	3 283	101	48 393	1 110	11 984
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	1 741	8 892	252	140 621	1 164	36 001
		TOTAL RIVIERSONDEREND				**2 241**	**12 175**	**353**	**189 014**	**2 274**	**47 985**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	2 922	14 364	451	225 520	762	54 767
TOTAL IN BREEDE BASIN						**12 554**	**43 847**	**3 087**	**519 083**	**12 583**	**150 739**
TOTAL IN BREEDE WMA						**19 668**	**75 946**	**4 335**	**1 007 441**	**16 693**	**279 514**

(1) Ostriches and game are not included as no data could be found. Numbers were small in 1995 but the DWAF Western Cape Regional Office reports that numbers of ostriches have increased considerably since 1995.

The census contained no data on game or ostriches, but it is known that these were farmed in small numbers in the WMA prior to 1995 and that the numbers have increased significantly since then. It is probable that, because of their small numbers, their water consumption in 1995 was insignificant.

It can be seen from Table 3.5.4.1 that "sheep and goats" is the category containing the largest number of livestock. There are about 21 000 goats and 986 000 sheep, while the total number of livestock in the WMA is approximately 1 100 000. Thus, sheep make up 90% of the total.

The distribution of livestock, expressed in terms of ELSUs, is shown diagrammatically on Figure 3.5.4.1.

3.5.5 Afforestation

Approximately 68 km^2 of land is under commercial timber plantations in the WMA. The distribution of the afforestation is shown on Figure 3.5.1.1 and details of areas are shown in Table 3.5.5.1.

The timber plantations consist mainly of pine trees, with very small areas of eucalyptus and most of them are situated in the mountains along the western edge of the WMA. Smaller areas of pine plantations occur in the mountains of the north-eastern corner of the WMA. There are also patches of indigenous forest, totalling 7,5 km^2 in area, in the vicinity of Stellenbosch. Areas of afforestation per quaternary catchment are shown in Appendix F5.

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.

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						AREAS OF AFFORESTATION				
PRIMARY		SECONDARY		QUATERNARY		EUCALYPTUS (km^2)	PINE (km^2)	WATTLE (km2)	TOTAL (km^2)	INDIGENOUS [(1)] FOREST (km^2)
No.	Description	No.	Description	No.	Description					
G (Part)	Eastern part of Drainage Region G	G40 (Part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast	0,2	32,2	0	32,4	-
		G40 (Part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	0	12,3	0	12,3	-
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0	0	0	0	-
		TOTAL IN PALMIET AND OVERBERG				**0,2**	**44,5**	**0**	**44,7**	**-**
H (Part)	Breede	H10 (Part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0	1,2	0	1,2	-
		H10 (Part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	0,1	7,0	0	7,1	-
		H20	Hex	H20A to H	Hex River Valley	0	0	0	0	-
		H30 to H50	Middle Breede	H30A to D H40A to L H50 A, B	Breede between Riviersonderend confluence and Brandvlei Dam	0	0	0	0	-
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**0,1**	**8,2**	**0**	**8,3**	**-**
		H60 (Part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	0	5,6	0	5,6	-
		H60 (Part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	0	1,8	0	1,8	-
		TOTAL RIVIERSONDEREND				**0**	**7,4**	**0**	**7,4**	**-**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	0	7,5	0	7,5	7,5
		TOTAL IN BREEDE BASIN				**0,1**	**23,1**	**0**	**23,2**	**7,5**
TOTAL IN BREEDE WMA						**0,3**	**67,6**	**0**	**67,9**	**7,5**

(1) Small areas of indigenous forest occur in the mountain ranges throughout the WMA, but details are not available.

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. 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.

The distribution of alien vegetation in the catchment is shown diagrammatically on Figure 3.5.6.1, where it can be seen that the most severe infestation occurs along the coastal strip between Hermanus (G40H) and the Breede River mouth (H70K). It is estimated that 70% of the total quantity of alien vegetation in the WMA occurs in this area.

The estimated distribution of alien vegetation per quaternary catchment is shown in Appendix F5.

TABLE 3.5.6.1: INFESTATION BY ALIEN VEGETATION

CATCHMENT						CONDENSED AREA OF ALIEN VEGETATION (km^2)
PRIMARY		SECONDARY		QUATERNARY		
No.	Description	No.	Description	No.	Description	
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast	4,3
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	627,9
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	1 088,0
		TOTAL IN PALMIET AND OVERBERG				1 720,2
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	19,2
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	79,1
		H20	Hex	H20A to H	Hex River Valley	10,3
		H30 to H50	Middle Breede	H30A to D H40A to L H50A, B	Breede between Riviersonderend confluence and Brandvlei Dam	44,3
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				152,9
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	57,8
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	123,2
		TOTAL RIVIERSONDEREND				181,0
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend catchment	77,9
		TOTAL IN BREEDE BASIN				411,8
TOTAL IN BREEDE WMA						2 132,0

3.5.7 Urban Areas

Urban areas, obtained from the CSIR land-use maps (CSIR, 1999) total 106 km^2, which is 0,6% of the area of the WMA. In the Palmiet and Overberg areas (G40, G50) 75% of the population live in urban areas. In the upper and middle Breede River valley 67% of the population is urbanised. The figure is 37% for the Riviersonderend Valley (H60). In the WMA as a whole, 66% of the population lives in urban areas.

The main towns are shown on Figure 3.5.1.1. Worcester (H20H), with a population of 76 000 people, is the biggest town.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

Industries in the WMA are small to medium sized and the majority of them are concerned with the processing of agricultural products. While some of them use significant quantities of water (see Section 5.4), none can be classified as a major "wet" industry.

The only powerstation in the WMA is the Palmiet Pumped Storage Scheme, which is described in Table 3.6.1.

TABLE 3.6.1: POWER STATIONS IN THE BREEDE WMA

QUATERNARY CATCHMENT	NAME	TYPE	GENERATING CAPACITY (MW)	OWNER
G40D	Palmiet	Pumped Storage	400	Eskom

3.7 MINES

There are no large mines in the WMA, mining activities being restricted to quarrying operations for limestone and other building materials.

3.8 WATER RELATED INFRASTRUCTURE

The urban and rural domestic water supplies in the Breede WMA were generally adequate in 1995, but some needed improvement in the near future to meet expected increases in water requirements.

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

Water related infrastructure is well developed in the Breede WMA, with 21 large dams and some 320 smaller farm dams providing 1 100 million m^3 of storage. About 73% of this storage is provided by two major dams, namely Theewaterskloof with a live storage capacity of 480 million m^3, and Greater Brandvlei Dam with a live storage volume of 319 million m^3.

Theewaterskloof Dam is the main storage component of the Berg River/Riviersonderend Government Water Scheme. It stores runoff from its own catchment as well as water that is diverted into it during the winter months from the Berg River catchment by means of a sophisticated system of diversion weirs and tunnels. During the summer months some of the water stored in Theewaterskloof is transferred to the Berg WMA by means of the same tunnel system. In addition, water from the dam is provided in summer for the irrigation of approximately 7 400 ha of land in the Riviersonderend Valley. The Berg River/ Riviersonderend Scheme is described in more detail in Section 4.2.1.

Greater Brandvlei Dam is an off-channel impoundment that is filled by canal from nearby tributaries of the Breede River. The facility to pump water into the dam from the Breede River exists, but is seldom used at present. Winter runoff is stored in the dam and distributed in summer by means of canals, pumpstations, and releases into the Breede River to irrigate approximately 21 800 ha of land in the Breede River Valley.

It is apparent from Table 4.1.1, where some statistics on the main dams in the WMA are listed, that the other main dams are much smaller than the two discussed above.

Kogelberg and Rockview Dams, each with a capacity of approximately 17 million m^3, are the storage components of the Palmiet Pumped Storage Scheme. Rockview Dam is connected to the Upper Steenbras Dam in the Berg River WMA by a canal and, since 1998, the Scheme has been used to transfer water to the Berg WMA for urban supplies (see Section 4.2.2 for further details).

The Lakenvallei and Roode Elsberg Dams, with a combined capacity of 18 million m^3, are the storage components of the Sanddrift Government Water Scheme which supplies water for irrigation in the Hex River Valley. The water is distributed by means of a tunnel through the mountain range that separates the dams from the Hex River Valley, and a network of pipelines within the valley. An area of some 3 550 ha of land is irrigated.

Most of the dams shown in Table 4.1.1 are for the provision of water for both irrigation and urban supplies. While some of them are owned by the State, many of them are privately owned, or owned by irrigation boards.

TABLE 4.1.1: MAIN DAMS IN THE BREEDE WMA

QUATERNARY CATCHMENT	NAME	LIVE STORAGE (million m^3)	NATURAL MAR (million m^3)	YIELD (million m^3/a) (1)				OWNER	NOTES	SOURCE OF DATA
				DOMESTIC	IRRIGATION	OTHER	TOTAL			
G40C	Nuweberg	3,9	17,2	0,5	4,2	0	4,7	Nuweberg Dam Syndicate	Yield includes releases of 0,5 million m^3/a for abstraction at Wesselsgat Weir	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40C	Eikenhof	25,5	66,6	0,0	30,8	0	30,8	Groenland Irrigation Board	Yield includes 27,8 million m^3/a abstracted from the dam and 3 million m^3/a released to river in summer	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40C	Grootvlei	1,6	3,1	0,0	1,7	0	1,7	Elgin Orchards		Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40C	Applethwaite	3,5	116,8	0,0	2,1	0	2,1	Elgin Orchards	8,3 million m^3/a compensation flows released in winter not included in yield.	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40D	Kogelberg	17,28	137,8	24,5	0,0	0	22,5	DWAF	Not a true yield as absractions made only when the dam is overflowing.	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40H	De Bos	6,3	8,4	2,8	0,5	0	3,3	Hermanus	0,5 million m^3/a for irrigation is a compensation flow release	Report to Greater Hermanus Municipality on Provision of Bulk Water. Ninham Shand Report No. 2790/8142, September 1999.
G40D/G40A	Rockview	17,5	Off channel	0,0	0,0	0	0,0	DWAF	Upper reservoir of hydro-power scheme	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40D	Arieskraal	4,4	143,4	0,0	3,6	0	3,6	Arieskraal Farm		Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
H10C	Koekedouw	22,5	Not known	7,0	10,0	0	17,0	Ceres Municipality	Completed in 1998. Assurance of yield not known.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H10K	Stettynskloof	15,5	60,2	25,0	0,0	0	25,0	Worcester Municipality	The yield is not fully utilised by Worcester at present and water is stored in the dam for the Holsloot Irrigation District by agreement with the Municipality.	Report on Augmentation of the Stettynskloof Water Supply Scheme (Ninham Shand, 1977)
H10L/H40E	Greater Brandvlei (2)	319,3	Off channel	0,0	152,0	0	152,0	DWAF	Live storage is for current operating level of 207,12 masl. Live storage at maximum possible operating level of 210,5 masl is 453,0 million m^3. Dead storage is 22,8 million m^3.	Yield from DWAF Report No. PH100/00/0690 (DWAF, 1990), Capacity data from a report on the Integration of Raw Water Sources Supplying the Cape Metropolitan Area (City of Cape Town, 2001)
H20D	Lakenvallei	10,3	8,8	0,6	8,4	0	9,0	DWAF	Actual allocation to irrigation at lower assurance is 11,9 million m^3/a.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H20C	Roode Elsberg	7,7	12,3							
H30A	Poortjieskloof	9,2	7,5	0,0	2,0	0	2,0	DWAF	Dam operated by Kingna Irrigation Board	Yield estimated by Ninham Shand for this study.
H30B	Knipes Hope	3,1	Not known	--	---	0	---	Cogmanskloof Irrigation Board	Storage dam for water pumped from the Breede River.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H30C	Pietersfontein	2,0	3,0	0,0	0,7	0	0,7	DWAF		Yield estimated by Ninham Shand for this study.

TABLE 4.1.1 Continued

QUATERNARY CATCHMENT	NAME	LIVE STORAGE (million m^3)	NATURAL MAR (million m^3)	YIELD (million m^3/a) [1]				OWNER	NOTES	SOURCE OF DATA
				DOMESTIC	IRRIGATION	OTHER	TOTAL			
H40B	Keerom	10,4	8,7	0,0	3,8	0	3,8	Nuy Irrigation Board	MAR is present day and not natural. 1:20 year yield estimated to 4,17 million m^3/a. 1:50 year yield estimated from WR90 as 90% of this.	Yield Analysis of Keerom Dam. Ninham Shand Report No. 1678/4537, June 1990.
H40E	Moordkuil/ Draaivlei	1,07	Not known	0,0	2,6	0	2,6	Moordkuil Irrigation Board	Assurance of yield not known.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H40K	Klipberg	2,0	Not known	0,0	0,63	0	0,6	DWAF		Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H60C	Elandskloof	11,4	26,6	0,7	11,3	0	12,0	DWAF	Allocation to irrigation at lower assurance than 1:50 year is 12,9 million m^3/a.	Yield from White Paper H-72. Other data from Breede River Basin Study draft report on infrastructure (DWAF, 2001).
H60D	Theewaterskloof	480,2	290,7	95,0	109,0	0	204,0	DWAF	Allocations total 245 million m^3/a supplied at less than 1:50 year assurance.	Skuifraam Dam Feasibility Study. DWAF Report No. P G100/00/0896.
H70E	Buffelsjags	5,2	79,0	0,0	8,8	2,2	11,0	DWAF	2,2 million m^3/a of yield is not allocated at present.	Breede River Basin Study draft report on infrastructure (DWAF, 2001). Yield calculated by DWAF.
TOTALS		979,9	---	156,1	352,13	14,5	520,73			

1) Yields are at 1:50 year assurance unless stated otherwise in the notes column. The allocation shown under the "Yield" column are what was available at 1:50 year assurance under catchment development conditions at the time when the yield was determined. The true allocations to irrigation are generally greater quantities supplied at lower, but unspecified, assurance.
2) Greater Brandvlei Dam incorporates the original Lake Marais and Kwaggaskloof Dam.

Irrigation boards were a feature of the Water Act of 1956 which 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, 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 (see Section 5.13) 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 54 irrigation districts in the Breede WMA. Of these, 49 were in the catchment of the Breede River upstream of its confluence with the Riviersonderend, 3 were in the Riviersonderend catchment, 1 was in the lower Breede River catchment, and 1 was in the Palmiet River catchment.

In addition to overseeing the allocation of water, irrigation boards were often responsible for the provision and operation of the infrastructure required to deliver irrigation water to landowners in their irrigation districts. In the Breede WMA a considerable amount of infrastructure in the form of diversion weirs, canals, pipelines, pump stations and dams was owned by irrigation boards. This infrastructure is described briefly later in this chapter.

Much of the water that is abstracted and distributed during the winter by means of the infrastructure that was owned by the irrigation boards, and is now owned by water user associations, is stored in farm dams owned by the individual landowners. These dams also store runoff from their own catchments and, in many cases, water that is diverted into them from streams in adjacent catchments. The distribution of registered farm dams in the WMA is shown in Table 4.1.2, where it can be seen that there are 322 of them, with a total storage volume of 114 million m^3. Statistics on additional dams that are too small to require registration are not available.

Most of the towns in the WMA have their own potable water supplies, with the raw water obtained from their own local sources. In 1995 there were 31 potable water supply schemes supplying towns and rural communities. Although accurate information on the capacities of all of these schemes was not obtained during this study, it appears from the information that was obtained that these schemes provided water to about 267 000 people, which was 70% of the total population of the WMA at that time. It is assumed that the remaining 115 000 people obtained their water from private supplies on farms.

The estimated total capacity of the community potable water supply schemes was 52 million m^3/a, while the total water requirements of the population that they supplied were estimated to be 34 million m^3/a. The populations supplied by these schemes, and the availability of water are shown per key area in Table 4.1.3, and per district council area in Table 4.1.4. Information on the individual schemes is shown in Table 4.1.5.

TABLE 4.1.2: FARM DAMS IN THE BREEDE WMA

CATCHMENT						REGISTERED FARM DAMS	
PRIMARY		SECONDARY		QUATERNARY		NO.	CAPACITY (million m^3)
No.	Description	No.	Description	No.	Description		
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast	48	29
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	22	6
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	4	1
		TOTAL IN PALMIET AND OVERBERG				**74**	**36**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	63	21
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	12	4
		H20	Hex	H20A to H	Hex River Valley	25	8
		H30 to H50	Middle Breede	H30A to D H40A to L H50A, B	Breede between Riviersonderend confluence and Brandvlei Dam	93	26
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**193**	**59**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	27	14
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	14	6
		TOTAL RIVIERSONDEREND				**41**	**20**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	14	4
		TOTAL IN BREEDE BASIN				**248**	**83**
TOTAL IN BREEDE WMA						**322**	**119**

The distribution of population supplied and water availability shown in Table 4.1.3 is approximate only because the two Ruensveld rural water supply schemes (see Figure 4.1.1 and Section 4.2.3) extend across the boundaries of several of the key areas and the distribution of the water requirements from the schemes within these areas is not accurately known. In addition, a large proportionof the water provided by the Ruensveld Schemes is for livestock. Nevertheless, the availability of water of between 300 ℓ/c/d and 700 ℓ/c/d suggests that, as far as bulk supplies are concerned, the level of supply throughout the WMA is well above the Reconstruction and Development Programme minimum of 25 ℓ/c/d.

The requirements of several of the schemes were, however, approaching the limits of the raw water supplies in 1995 and needed augmentation in the near future. This was problematic along the coastal strip where surface water supplies are scarce and groundwater supplies are in places unsatisfactory because of poor water quality and/or insufficient quantity.

The potable water supply schemes are discussed in more detail in the remainder of this chapter.

TABLE 4.1.3: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES BY KEY AREA

CATCHMENT						LAND AREA (km^2)	POPULATION	TOWN AND REGIONAL WATER SUPPLY SCHEMES			
PRIMARY		SECONDARY		QUATERNARY				NUMBER OF PEOPLE SUPPLIED	% POPULATION	CAPACITY	
No.	Description	No.	Description	No.	Description					(million m^3/a)	(ℓ/c/d)
G (Part)	Eastern part of Drainage Region G	G40 (Part)	Palmiet	G40C, D G40B	Palmiet Betty's Bay Coast	594	25 050	14 520	58	2,0	377
		G40 (Part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	2 392	51 060	44 500	87	8,0	492
		G50	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	4 128	23 020	20 700	90	2,5	330
		TOTAL IN PALMIET AND OVERBERG				**7 114**	**99 130**	**79 720**	**80**	**12,5**	**430**
H (Part) N P	Breede	H10 (Part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	656	11 940	1 850	15	0,9	486
		H10 (Part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	1 391	48 040	28 300	59	4,6	445
		H20	Hex	H20A to H	Hex River Valley	832	97 880	82 500	84	21,8	724
		H30 to H50	Middle Breede	H30A to D H40A to L H50 A, B	Breede between Riviersonderend confluence and Brandvlei Dam	4 512	73 580	41 350	56	7,2	477
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**7 391**	**231 390**	**154 000**	**67**	**34,5**	**612**
		H60 (Part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	500	9 840	3 300	33	0,7	581
		H60 (Part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	1 741	17 860	13 000	73	1,9	400
		TOTAL RIVIERSONDEREND				2 241	27 700	16 300	59	2,6	437
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	2 922	24 150	17 100	71	2,8	449
		TOTAL IN BREEDE BASIN				**12 554**	**283 240**	**187 400**	**66**	**39,9**	**583**
TOTAL IN BREEDE WMA						**19 668**	**382 370**	**267 120**	**70**	**52,4**	**537**

TABLE 4.1.4: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES IN 1995 PER DISTRICT COUNCIL AREA

PROVINCE	DISTRICT COUNCIL AREA	LAND AREA (km^2)	POPULATION	TOWN AND REGIONAL WATER SUPPLY SCHEMES			
				Number of People Supplied	% of Population	CAPACITY	
						(million m^3/a)	(ℓ/c/d)
Western Cape	Breede River	7 306	231 390	154 000	67	34,5	612
	Cape Metropolitan	31	0	0	0	0	0
	Overberg	11 053	146 680	110 620	75	0,4	365
	Southern Cape	1 072	4 300	3 000	70	17,5	
	Winelands	206	0	0	0	0	0
TOTALS		**19 668**	**382 370**	**267 120**	**70**	**52,4**	**537**

It can be seen from Table 4.1.4 that both the Cape Metropolitan Council area and the Winelands District Council area extend into the Breede WMA. The terrain in both areas is very mountainous and it has been assumed that it is uninhabited.

In the remainder of this chapter the water related infrastructure is described in more detail.

In Section 4.2, the individual regional water supply schemes are described. These are defined as :

- schemes that supply water over large areas that normally include two or more irrigation districts and/or towns, or
- schemes that supply water to farming communities and their livestock, or
- schemes that transfer water across the boundaries of the WMA.

Sections 4.3 to 4.8 describe the water related infrastructure in the individual key areas, except that, for convenience, infrastructure in the Upper Riviersonderend and the Lower Riviersonderend key areas is described under the single heading of the "Riviersonderend Catchment" in Section 4.7. Irrigation related infrastructure is described first in these sections, followed by descriptions of the water supplies to individual towns. This has been done because irrigation is the predominant water user sector in the WMA, and many of the towns obtain their water supplies via infrastructure that has been constructed primarily to provide water to irrigators. Consequently, the town supplies can, in most cases, be more clearly described after the irrigation infrastructure, from which the water is obtained, has been described.

Some of the schemes described in Sections 4.3 to 4.8 fall within the definition of regional water supply schemes, but fit more comfortably into the key area descriptions.

TABLE 4.1.5: POTABLE WATER SUPPLY SCHEMES IN THE BREEDE WMA

DISTRICT COUNCIL AREA	QUATERNARY CATCHMENT	SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED IN 1995	WATER REQUIREMENT IN 1995 (million m^3/a)	SCHEME CAPACITY		
						(million m^3/a)	(ℓ/c/d)	LIMITING FACTOR
Overberg	G40B	Betty's Bay Pringle Bay Rooi Els	Buffels River Dam	220	Not known	Not known	Not known	Treatment capacity
	G40C	Grabouw	Eikenhof Dam	14 300	0,5	2,0	383	Raw water pipelines
	G40G	Kleinmond	Palmiet River	4 500	0,9	1,5	913	Raw water pipelines
	G40E	Botrivier	Boreholes	1 950	0,18	0,19	267	Borehole yield
	G40H	Greater Hermanus	De Bos Dam	20 700	2,93	3,0	397	Yield of De Bos Dam
	G40L	Gansbaai	Springs, Franskraal Dam	5 000	1,2	1,2	240	Raw water source
	H60D, E, F, G, H, J G40F, K G50D, G	Ruensveld West	Riviersonderend, Theewaterskloof Dam	17 000 (1)	1,7	2,4	141	Pipeline capacity
	H60J, K, L H70A, G, H G50D, E, F, G, H, J	Ruensveld East	Riviersonderend Theewaterskloof Dam	6 000 (2)	0,8	0,85	388	Pipeline capacity
	G50E	Bredasdorp	Boreholes, dam	11 000	0,8	1,08	269	Raw water source
	G50D	Napier	Boreholes	2 450	0,25	0,25	280	Borehole yield
	G50B	Elim	Borehole, spring	400	0,05	0,06	410	Raw water source
	G50F	L'Agulhas, Struisbaai Suiderstrand	Boreholes	2 700	0,33	0,8	812	Borehole yield
	H70B	Swellendam	River/small dam	10 800	1,0	2,0	507	Raw water storage
	H70C	Barrydale	River	1 700	0,22	Not known	---	Not known
	H70D	Suurbraak	Stream	1 600	0,13	Not known	---	Not known
	G60C	Villiersdorp	Borehole Elandskloof Dam	3 300	0,4	0,68	565	Raw water source
	H60E	Genadendal	Mountain stream	3 700	0,3	Not known	---	Not known
	H60F	Greyton	Mountain streams	650	0,1	0,6	2 500	Not known
	H60J	Riviersonderend	Mountain stream and Rivier-sonderend	2 650	0,32	Not known	---	Not known
TOTALS FOR OVERBERG DISTRICT COUNCIL AREA				**110 620**	**12,11**	**17,58 (3)**	**435**	**---**
Southern Cape	H70D, E, H, J, K	Duiwenhoks	Duiwenhoks Dam	**3 000 (4)**	**0,4**	**0,4 (5)**	**365**	**Pipeline capacities**
Breede River	H10C	Prince Alfred Hamlet	Borehole, spring	1 850	0,4	0,88	1 300	Raw water source
	H10C	Ceres	Koekedouw Dam	21 300	2,8	3,9 (6)	502	Not known
	H10F	Wolseley	River	5 500	0,6	Not known	---	Not known

Table continued overleaf

TABLE 4.1.5 Continued

DISTRICT COUNCIL AREA	QUATERNARY CATCHMENT	SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED IN 1995	WATER REQUIREMENT IN 1995 (million m^3/a)	SCHEME CAPACITY		
						(million m^3/a)	(ℓ/c/d)	LIMITING FACTOR
	H10L	Rawsonville	Smalblaar River	1 500	0,12	Not known	---	Not known
	H20H	Worcester	Stettynskloof Dam, Fairy Glen Dam	75 700	11,8	21	760	Pipeline capacity
	H20F	De Doorns	Stream Sanddrift Govt Water Scheme	6 800	0,73	Not known	---	Treatment works capacity
	H40J	Robertson	Small dams	17 200	1,98	2,6 (6)	414	Not known
	H40K	McGregor	Houtbaais and Hoeks Rivers	1 850	0,2	Not known	---	Not known
	H30E	Ashton	Breede River	8 450	1,4	1,82	590	Raw water sources
	H30B	Montagu	Mountain streams Breede River	8 800	0,92	1,4	436	Raw water sources
	H50B	Bonnievale	Breede River	5 050	1,0	1,2	651	Raw water sources
TOTALS FOR BREEDE RIVER DISTRICT COUNCIL AREA				**154 000**	**21,95**	**34,45 (3)**	**612**	**---**
TOTALS FOR WHOLE BREEDE WMA				**267 120**	**34,46**	**52,43 (3)**	**537**	**---**

NOTES :

1. This value is a rough estimate made as follows : 370 farms @ 20 people/farm = 7 400 people + 9 400 people in Caledon = 16 800 rounded to 17 000
2. This value is a rough estimate made as follows : 264 farms @ 20 people/farm = 5 280 people + 120 people in Protem = 5 400 rounded to 6 000
3. Where scheme capacities are not known they have been assumed to equal water requirements in 1995 in this total value.
4. This value is a rough estimate made as follows : 145 farms @ 20 people/farm = 2 900 people + 300 people in Witsand = 3 200 rounded to 3 000. The portion of the Overberg District Council area to the east of the Breede River is included.
5. Rough estimate of water requirements.
6. Scheme capacity is not known but has been assumed equal to requirements in 2000.

Finally, even though the Palmiet Pumped Storage Scheme is part of the Palmiet River Government Water Scheme, described in Section 4.2, the power generation component of the scheme is described separately in Section 4.9.

4.2 REGIONAL WATER SUPPLY SCHEMES

4.2.1 The Riviersonderend/Berg River Government Water Scheme

The Riviersonderend/Berg River Government Water Scheme is a large inter-basin water transfer scheme that regulates the flows of the Riviersonderend, the Berg (including its Wolwekloof and Banhoek tributaries) and Eerste Rivers for urban, industrial and irrigation use. It consists, as shown on Figure 4.2.1.1 of the Theewaterskloof Dam on the Riviersonderend, a tunnel through the Franschhoek Mountain Range to the Upper Berg River, and a siphon under that river leading to another tunnel that passes under the Groot Drakenstein Mountains to a balancing dam at Kleinplaas on the Jonkershoek tributary of the Eerste River. A third tunnel leads from the dam to an outlet close to Stellenbosch. Diversion weirs on the Banhoek and Wolwekloof Rivers allow surplus winter flows to be diverted and conveyed through the tunnel system into Theewaterskloof Dam where the water is stored. In summer the stored water can be released back through the tunnel system to outlets on the Berg River, the Eerste River at Kleinplaas Dam, the Stellenbosch Tunnel Outlet, and an outlet from a branch tunnel at Dasbos, for urban and irrigation use in the Berg Water Management Area.

Water for Cape Town is conveyed by pipeline from the Stellenboschberg Tunnel outlet to the Faure and Blackheath Water Treatment Works for treatment and distribution to consumers. Water is also conveyed by pipeline from the same tunnel outlet to treatment works at Stellenbosch, and from the Franschhoekberg Tunnel outlet by pipeline to the City of Cape Town's treatment works at Wemmershoek Dam.

Water for irrigation is released from the Berg River siphon into the Berg River, and from Kleinplaas Dam into the Eerste River. Some irrigation water is also supplied from the Faure pipeline and from the Jonkershoek Tunnel. Water for irrigation is also pumped from Theewaterskloof Dam and released from the dam into the Riviersonderend.

The main raw water source is the Theewaterskloof Dam which has a capacity of 480,2 million m^3 and which regulates the upper reaches of the Riviersonderend. The 1:50 year yield of the dam with the transfers from the Banhoek and Wolwekloof Rivers is 204 million m^3/a (DWAF, 1999d). (The 1:50 year yield of the system comprising Theewaterskloof Dam, Kleinplaas Dam and the Wolwekloof and Banhoek Diversions is 224 million m^3/a. Kleinplaas Dam supplies only to the Berg WMA and its yield is estimated to be 20 million m^3/a. Thus the yield of Theewaterskloof with the Wolwekloof and Banhoek diversions is estimated to be 224 - 20 = 204 million m^3/a). The quantities of water transferred from Theewaterskloof to the Berg WMA vary from year to year, but average about 186 million m^3/a. These transfers take place during the summer months, while smaller transfers from the Banhoek and Wolwekloof diversion weirs in the Berg WMA are made into Theewaterskloof Dam during the winter months. These average approximately 9 million m^3/a and 16 million m^3/a respectively, to give a combined total of 25 million m^3/a. Thus, the net quantity of water exported from Theewaterskloof to the Berg WMA is 161 million m^3/a on average.

The Kleinplaas Dam, in the Berg WMA, has a capacity of 0,376 million m^3, and acts as a balancing reservoir for the tunnel system during the summer months, but it also diverts water from the Jonkershoek tributary of the Eerste River for use in the Berg WMA. It is estimated (Ninham Shand, 2001) that an average quantity of 24 million m^3/a is abstracted from the Jonkershoek River in this way, and that the abstraction at 1:50 year assurance is 20 million m^3/a.

4.2.2 The Palmiet River Government Water Scheme

The Palmiet River Government Water Scheme transfers water from the Palmiet River in the Breede WMA (G40D) to the Berg WMA for use by the City of Cape Town. The scheme is a dual purpose water transfer and hydro-electric pumped storage scheme.

The hydro-electric components comprise the Kogelberg Dam on the Palmiet River, the power station and waterways, and the upper reservoir, known as Rockview Dam. During periods of low demand for electricity, water is pumped from Kogelberg Dam to Rockview Dam using excess power in the electricity grid. During periods of high demand for electricity the water is allowed to flow from Rockview Dam through the turbines and back into Kogelberg, thereby generating electricity.

Rockview Dam (see Figure 4.1.1) is situated on the watershed between the Palmiet and the Steenbras River catchments (which is also the watershed between the Breede and Berg WMAs). Some of the water pumped into Rockview Dam is released into a canal which carries it into the Steenbras Upper Dam, whence it is released through the Steenbras Hydro-electric Power Station to a pipeline that conveys it to Cape Town's Faure Water Treatment Plant.

The hydro-electric components of the scheme were completed in 1988, but the canal between Rockview Dam and the Upper Steenbras Dam was not constructed until 1998, and the first transfers of water to Cape Town occurred in 1999.

The historical firm yield of Kogelberg Dam, before providing for ecological flow requirements, is estimated to be 35 million m^3/a (Ninham Shand, 2001). The scheme was originally intended to increase the water supply to Cape Town by 30 million m^3/a, but the subsequent availability of more detailed information on the ecological flow requirements of the Palmiet River and its estuary resulted in a requirement far higher than originally estimated for ecological releases from Kogelberg Dam. As a result, only surplus winter flow is transferred to Cape Town. Transfers are made only when flow in the Palmiet River below Arieskraal Dam, about 10 km downstream, is adequate to meet the ecological flow requirements, and transfers are, therefore, derived from run-of-river yield. The average quantity that can be transferred in this way is estimated (Ninham Shand, 2001) to be 29 million m^3/a, but the 1:50 year yield falls to 22,5 million m^3/a.

The only other user of water from Kogelberg Dam is Eskom for the pumped storage scheme, but this is a non-consumptive use, apart from evaporation losses from the dams, which are estimated to be about 2 million m^3/a and were allowed for in calculating the above-mentioned yield of Kogelberg Dam.

4.2.3 The Overberg Rural Water Supply Schemes

The Overberg Area extends from Caledon (G40F) in the Breede WMA in an easterly direction to Heidelberg in the Gouritz WMA. The area is served by three rural water supply schemes which provide water for domestic use to about 60% of the rural population as well as drinking water for livestock. The schemes also supplement the supplies from local sources of the towns of Caledon, Witsand (H70K) and Arniston (G50F). The three schemes are :

- the Duiwenhoks Rural Water Supply Scheme, which uses water from Duiwenhoks River Dam in the Gouritz WMA.

- the Ruensveld East Rural Water Supply Scheme, which abstracts water from the Riviersonderend River, and

- the Ruensveld West Rural Water Supply Scheme, which also obtains its water from the Riviersonderend River.

The areas supplied by the schemes are shown on Figure 4.1.1.

The Duiwenhoks Scheme supplies approximately 280 farms to the east of the Breede River in both the Breede and Gouritz WMAs. About 145 of these are in the Breede WMA. It also supplies the town of Witsand in the Breede WMA. Water requirements in 1995 were estimated to have been about 1,1 million m^3/a, of which approximately 0,7 million m^3/a were in the Breede WMA (estimated derived from White Paper N-81).

The two Ruensveld Schemes fall entirely within the Breede WMA. They rely on water released into the channel of the Riviersonderend from Theewaterskloof Dam when there is insufficient natural flow in the river, and pump water to consumers in both the Riviersonderend catchment and the adjoining coastal catchments. Both schemes are operated by the Overberg Water Board.

The Ruensveld East Scheme abstracts water from the Riviersonderend River by means of a pump station situated approximately half-way between the towns of Riviersonderend and Swellendam. Water is purified at a 3,5 Mℓ/day treatment works near the abstraction point and pumped from there to a reservoir on the farm Luipaardsberg. It gravitates from there to the extremities of the scheme. The main feeder pipeline extends from Luipaardsberg in a southerly direction to near Bredasdorp, and further on to near Arniston. Three branch mains supply water to the northern, eastern and western zones of the scheme, which covers an area of some 1 750 km^2 and was designed to supply water to 264 farms (White Paper L-84) and the small rural settlement (20 houses) at Protem railway station, 30 km north of Bredasdorp. The scheme supplies about 65% of the rural population in its supply area, as well as providing drinking water for livestock. Its design capacity is 0,6 million m^3/a (1,64 Mℓ/day), which includes provision for 10% distribution losses. The components of the scheme are designed for a peak factor of 2,0 which allowed 0,73 million m^3/a to be supplied in 1995. Experience has shown the required peak factor to be 1,5, giving the scheme a capacity of 0,85 million m^3/a. It appears from analysis of statistics obtained from the Western Cape Regional Office of DWAF that about 90% of the output of the scheme is used for livestock.

The Ruensveld West Scheme abstracts water from the Riviersonderend about two kilometres downstream of Theewaterskloof Dam. The water is treated in a 9,5 Mℓ/day treatment works adjacent to the abstraction point and pumped from there to the main reservoirs of the scheme on the farm Noordekloof. From there, a gravity main supplies water to the town of Caledon, and farms between Caledon and Riviersonderend. Water is piped from another reservoir near Caledon in a south-westerly direction to farms in the vicinity of Napier. All along the gravity mains, branch lines radiate to the boundaries of the scheme to supply individual farms. Water is provided for domestic use and livestock, and 370 farms (White Paper G-79) in addition to the town of Caledon are supplied. The capacity of the scheme is approximately 2,4 million m^3/a, with approximately 30% of requirements being for livestock. The components are designed for a peak factor of 1,5. The scheme was supplying 1,7 million m^3/a in 1995.

Some of the main characteristics of the schemes are summarised in Table 4.2.3.1.

TABLE 4.2.3.1: THE OVERBERG RURAL WATER SUPPLY SCHEMES

SCHEME	QUATERNARY	CONSUMERS	SCHEME CAPACITY		TREATMENT WORKS		RAW WATER SOURCE	
			million m^3/a	LIMITING FACTOR	CAPACITY (Mℓ/d)	OWNER/ OPERATOR	SOURCE	OWNER/ OPERATOR
Duiwenhoks	H70G, H, J, K (1)	Approx 145 farms Witsand (1)	1,2 (2)	Pumps and pipelines	5,1	DWAF	Duiwenhoks Dam and River	DWAF
Ruensveld East	H60J, K, L H70A, G, H G50D, E, F, G, H, J	264 farms Protem village	0,85	Pipeline capacity	3,5	Overberg Water	Riviersonderend and Theewaters-kloof Dam	DWAF
Ruensveld West	H60D, E, F, G, H, J G40F, K G50D, G	370 farms Caledon	2,4	Pipeline capacity	9,5	Overberg Water	Riviersonderend and Theewaters-kloof Dam	DWAF

(1) Supply within the Breede WMA only
(2) Capacity used for supply to Gouritz and Breede WMAs (i.e. total scheme capacity) (White Paper N-81).

4.2.4 Minor Transfer Schemes

Four small schemes transfer water for irrigation across the boundaries of the WMA. These are :

- The Inverdoorn Canal Scheme in which 2,5 million m^3/a of water for irrigation is diverted by means of weirs on the Spek and Valschgat Rivers (H20C) into the Inverdoorn Canal which carries it into the catchment of the Doring River (E22C) in the Olifants/Doring WMA.
- The Artois Canal Scheme which transfers an estimated 4 million m^3/a (DWAF, 1995) of water from the Breede River (H10D) to the Klein Berg River catchment (G10E) in the Berg WMA for use by the Dwars River Irrigation Board.
- The "Gawie se Water" Scheme, which transfers 5 million m^3/a of water for irrigation from the upper Wit River catchment (H10E) to the Kromme River catchment (G10D) in the Berg WMA (DWAF, 1995).
- The Franschhoek water supply scheme in which 0,6 million m^3/a is transferred from the Du Toits River (H60B) to the town of Franschhoek (G10A) for urban use.

4.3 THE PALMIET RIVER CATCHMENT

The catchment of the Palmiet River comprises quaternary catchments G40C and G40D. The adjoining coastal catchment, G40B, is included under this heading for convenience. The area has a total population of about 25 000 people, of whom 14 300 live in the towns and 10 700 live in rural areas, mainly on farms. Runoff in catchments G40C and G40D is regulated by numerous small farm dams and several larger dams, including Kogelbeg and Rockview Dams which provide the storage for the hydro-power generation component of the Palmiet River Government Water Scheme, described in Section 4.2.2. The other larger dams are all privately owned and were constructed to provide water for irrigation of mainly apple orchards. They are Nuweberg Dam (3,88 million m^3 capacity), Grootvlei Dam (1,65 million m^3 capacity), Eikenhof Dam (25,5 million m^3 capacity), Applethwaite Dam (3,48 million m^3) and Arieskraal Dam (4,46 million m^3). They are all on the Palmiet River and have a combined 1:50 year yield of approximately 43 million m^3/a (DWAF, 1999e). Their approximate individual yields are shown in Table 4.1.1 but it should be noted that the dams comprise an integrated system and individual yields will vary slightly with variations in operating rules. The other registered dams in the catchment of the Palmiet River (G40C, D) total 47 in number and have a combined capacity of 19,2 million m^3. Their combined 1:50 year yield has been estimated to be 10 million m^3/a (DWAF, 1999e). The total storage volume of all the dams except Rockview, which is off-channel, is 75,4 million m^3, which is 30% of the virgin mean annual runoff of the Palmiet catchment of 252,6 million m^3. Thus, the catchment is not severely regulated, but the Palmiet Estuary is of high conservation value and the indications are that its ecological water requirements will severely limit further development.

The only dam in catchment G40D is the Buffelsrivier Dam which has a capacity of 1 million m^3.

Extensive infrastructure for the distribution of irrigation water has been developed in catchments G40C and G40D. Some of the farm dams are filled by natural runoff from their own catchments, but others are filled by means of diversion furrows from streams in adjacent catchments or by pumping from the bigger rivers during winter. In this way, the winter runoff is stored for irrigation use in the dry summer months.

Water from Nuweberg Dam is abstracted by pipeline to supply the Vyeboom Experimental Farm and is also released into the river whence it is abstracted by means of the Wesselsgat Diversion Weir and pipe system for use for irrigation by the members of the Nuweberg Dam Syndicate. This is known as the Drostersness Transfer. Water is also supplied by pipeline from this point to the town of Grabouw.

Eikenhof Dam is owned by the Groenland Irrigation Board and supplies water to 97 landowners in the Groenland Irrigation District. The water is distributed by means of four pumpstations and approximately 60 km of pipelines.

The Groenland Irrigation District, with a scheduled area of land of 5 460 ha, was the only irrigation district in the Palmiet River catchment in 1995.

Water from Eikenhof Dam is also supplied by pipeline to the town of Grabouw, and compensation releases are made into the river for riparian users downstream. Water from Grootvlei Dam, which is situated on a tributary of the Palmiet River, is abstracted by pipeline for use on the Elgin Orchards farms.

Applethwaite Dam also supplies irrigation requirements of Elgin Orchards' Applethwaite Farm by pipeline. In addition, compensation releases are made into the Palmiet River for riparian users downstream.

Kogelberg and Rockview Dams are linked by means of a waterway system for the Palmiet Pumped Storage Scheme comprising a 5,4 m diameter steel lined tunnel connected to a 6,2 m diameter buried steel pipe. The transfer capacity of the canal from Rockveiw Dam to Upper Steenbras Dam is 12 m^3/s, but transfers are limited by the operational constraints of the pumped storage scheme, which limit transfers during winter flow events, and by the ecological flow requirements of the Palmiet River in summer.

The privately owned Arieskraal Dam is used to supply surrounding irrigation users through a network of pipelines using water abstracted direct from the reservoir. Compensation releases for downstream riparian users are made into the Palmiet River.

The small towns in the area obtain their water supplies from local surface water sources as described below.

Grabouw

Grabouw, the biggest town with a population of 14 300 people in 1995, obtains water from the Wesselsgat Weir and Eikenhof Dam. The water is treated at an 8 Mℓ/d treatment works which, assuming a peak factor of 1,5, gives a scheme capacity of 2 million m^3/a. Water requirements in 1995 were 0,5 million m^3/a.

Coastal villages

The small coastal villages of Rooi Els, Pringle Bay and Betty's Bay obtain their water from the Buffels River Dam via a treatment works that serves the three towns. The capacity of the treatment works and current water use are not known.

4.4 OVERBERG WEST

The Overberg West area consists of catchments G40E to G40M and lies between the Riviersonderend Valley and the Indian Ocean. The total population of the area is 50 000 people, of which 85% live in the towns. The Ruensveld West Water Supply Scheme, described in Section 4.2.3, provides water to Caledon and to some of the farms in the northern part of the area. The farms in the southern part rely on their own individual water supplies from local surface or groundwater sources, or from rainwater storage tanks. There are no irrigation districts in the area.

There are 23 registered dams in the area, but they are mainly farm dams with capacities of less than 1 million m^3 each. The only one of significant size is the De Bos Dam (G40H) which supplies Hermanus and has a capacity of 6,3 million m^3. The combined capacity of all the other dams is 6,4 million m^3. The position regarding water supplies to towns is as follows :

Kleinmond

Starting from the western side of the area, the small coastal settlement of Kleinmond (G40G), which had a permanent population of about 4 500 people in 1995, but which accommodates a large number of holiday-makers during December and January of each year, obtains its water supply from the Palmiet River. The water is treated at a plant with a capacity of 6 Mℓ/day before being distributed to consumers. Peak water requirements in 2000 were 5,5 Mℓ/day but consumption dropped to 2 Mℓ/day in winter. The annual requirement in 2000 was 0,9 million m^3. Annual water requirements in 1995 are not recorded.

Botrivier
Botrivier (G40E), which had a population of 1 950 people in 1995, obtains its supply from six boreholes with a combined yield of 0,19 million m^3/a. Requirements in 1995 were 0,18 million m^3/a.

Greater Hermanus
The Greater Hermanus area (G40H), which includes Hermanus, Fisherhaven, Vermont, Onrus River and Sandbaai accommodates large numbers of holidaymakers in December and January, but had a permanent population of 20 700 people in 1995. Water requirements of 2,93 million m^3/a were supplied from De Bos Dam which has a 1:50 year yield of 2,8 million m^3/a (Greater Hermanus Municipality, 1999). Water conservation and demand management measures were introduced in 1996, with the result that water requirements had decreased to 2,43 million m^3/a by 1997. However, since then, water requirements have begun to increase again as a result of ongoing growth in the population of the town. Therefore, it is clear that an additional source of water will be required in the near future. Boreholes with an estimated yield of 1,3 million m^3/a have been identified. The water treatment works has a capacity of 28 $M\ell/d$ (6,8 million m^3/a allowing a peaking factor of 1,35).

Caledon
Caledon (G40F) obtains water from the Ruensveld West Rural Water Supply Scheme, described in Section 4.2.3. Water requirements in 1995 were 1,2 million m^3/a for a population of 9 400 people.

Gansbaai
Gansbaai is a holiday resort which had a permanent population of approximately 5 000 people in 1995 with a water requirement of 1,2 million m^3/a. Water is obtained from springs with a combined yield of 1,1 million m^3/a and Franskraal Dam which has a yield of 0,11 million m^3/a.

Stanford
Details of the water supply to Stanford, with a population of 1 050 people, were not obtained.

4.5 OVERBERG EAST

The Overberg East area consists of catchments G50A to G50K between the Riviersonderend and lower Breede River catchments and the coast. It is a predominantly dryland grain growing and sheep farming area with very little irrigation. There are no major dams in the area, and only four registered farm dams, which have a combined capacity of 1,04 million m^3.

In the northern half of the area the requirements for livestock watering and domestic use on farms that cannot be provided by boreholes and rainwater tanks are supplied by the Ruensveld Rural Water Supply schemes described in Section 4.2.3.

In the southern part, these requirements are met from boreholes, rainwater tanks, and limited surface water sources.

Approximately 76% of the population of 23 000 people lived in the five towns in the area in 1995. Descriptions of the water supplies to these towns follow :

Bredasdorp

Bredasdorp (G50E), with a population in 1995 of 11 000 people, is the biggest of the towns. Water requirements in 1995 were 0,8 million m^3/a (DWAF, 1998a). The water supply is obtained from five boreholes and several springs with a combined yield of 0,64 million m^3/a, and the Klein Sanddrif Dam which has a capacity of 0,455 million m^3 and a 1:50 year yield of 0,44 million m^3/a (DWAF, 1998b). The water is treated to remove iron from the groundwater before it is distributed to consumers, but the capacity of the treatment works is not known. A pipeline to provide a limited amount of water from the Ruensveld East Scheme was installed after 1995.

Napier

The town of Napier (G50D) lies some 25 km to the north-west of Bredasdorp and had a population of 2 450 people in 1995 with an estimated water requirement of 0,25 million m^3/a. Water is obtained from three boreholes and a mountain stream with an estimated total yield of 0,25 million m^3/a (DWAF, 1998a). The water is stabilised and chlorinated before distribution to consumers.

Elim

The village of Elim (G50B) had a population of 400 people in 1995 with water requirements 0,05 million m^3/a (DWAF, 1998a). The water supply consists of chlorinated water provided from a spring and a borehole with an estimated yield of 0,06 million m^3/a (DWAF, 1998a). It appears that average water use in 1995 was about 35 ℓ/c/d. Since then the water reticulation has been improved and additional erven have been developed. It is probable, therefore, that additional raw water sources are required. Investigations carried out in 1997 (DWAF, 1998a) suggested that developing additional boreholes would be the most economic way of increasing the supply.

L'Agulhas, Struisbaai, Suiderstrand

There are three small coastal resorts (L'Agulhas, Struisbaai and Suiderstrand) in catchment G50F, the biggest of which is Struisbaai. They are all situated within 15 km of one another. Their combined permanent populations in 1995 were 2 700 people, but the population increases to about 10 000 people during peak holiday periods.

L'Agulhas obtains water from two boreholes with an estimated yield of 0,3 million m^3/a, which compares with a requirement in 1995 of 0,02 million m^3/a (DWAF, 1998a).

Struisbaai, with a permanent population in 1995 of 2 000 people, required 0,3 million m^3/a of water. Water was supplied from four boreholes with a yield of 0,48 million m^3/a (DWAF, 1998a).

Suiderstrand consisted of fewer than 34 developed erven in 1995 with an estimated water requirement of 0,01 million m^3/a. Water was supplied from a single borehole, the yield of which was not known, but was adequate to meet requirements.

Thus, in 1995, total water requirements in the area were 0,33 million m^3/a and the developed groundwater yield was about 0,8 million m^3/a. By 1997 there were indications of rapid development in the area as erven were developed for holiday and retirement homes (DWAF, 1998a). If this development continues, additional water sources will be required. The indications are that these could be provided from groundwater (DWAF, 1998a).

Arniston

Arniston (Waenhuiskrans) is a coastal village in catchment G50J. The permanent population in 1995 was 750 people, of which about 70% were engaged in the fishing industry. Roughly 60% of the developed erven in the town contained holiday homes which were unoccupied for most of the year. Water requirements in 1995 were approximately 0,86 million m^3/a. About 35% of the water was obtained from Bredasdorp Municipality, and most of the remainder from the Ruensveld East Rural Water Supply Scheme. The town has three boreholes, but the salinity of the water from them is high. Consequently, they are used only to meet peak holiday season demands by blending their output with the surface water supply. The potential for developing boreholes supplying water of acceptable quality is poor (DWAF, 1998a) and the cost of importing additional surface water would be high. This suggests that the future development of Arniston might be inhibited by the high costs of providing an adequate water supply (DWAF, 1998b).

Denel and De Hoop Nature Reserve

There are two other areas, in addition to the towns and farms where water related infrastructure has been developed. These are the Denel armaments testing establishment to the east of Waenhuiskrans (G50J) and the De Hoop Nature Reserve. The water requirements of Denel in 1995 were 0,09 million m^3/a and these were provided from five boreholes with a yield of 0,14 million m^3/a. Water quality is acceptable and the only treatment applied is chlorination (DWAF, 1998a). The De Hoop Nature Reserve has water requirements of less than 0,02 million m^3/a. Water is supplied from several boreholes and supplies are adequate for the foreseeable future (DWAF, 1998a).

4.6 THE BREEDE RIVER CATCHMENT UPSTREAM OF THE RIVIERSONDEREND CATCHMENT

4.6.1 General

This portion of the catchment of the Breede River supported a population of 231 000 people in 1995. Approximately 54% (125 000 people) of the population lived in urban areas, the remainder being on farms and in a few small rural villages.

The 10 towns in the area all have individual water supplies, many of which rely on one of the major dams in the area for their raw water. Infrastructure for irrigation is well developed, and there were 49 irrigation districts in the area in 1995.

In view of the complexity of the water related infrastructure, the area has been sub-divided as follows for purposes of describing it :

- The Warm Bokkeveld (H10A, B, C) which is the area of the catchment upstream of Ceres.
- The upper Breede River Catchment which is the area between Brandvlei Dam and Ceres, but excluding the Hex River valley and Worcester.
- The Hex River valley and Worcester (the Hex key area).
- The middle Breede River Catchment, which is the area between the confluence with the Riviersonderend and Brandvlei Dam.

4.6.2 The Warm Bokkeveld (H10A, B, C)

The Warm Bokkeveld had a total population of 33 200 people in 1995, of whom 23 100 lived in the towns of Ceres and Prince Alfred Hamlet. There are 66 registered dams in the area, with a total capacity of 51,2 million m^3. Most of these are small farm dams with capacities of less than 0,5 million m^3. Only Koekedouw Dam (22,5 million m^3 capacity) is used for municipal water supplies. It was completed in 1998, and also provides water for irrigation. It replaces the old Ceres Dam (0,33 million m^3 capacity) which was demolished.

Two of the dams, Ben Etive (0,15 million m^3 capacity) and Rooikloof (0,5 million m^3 capacity) are diversion structures which are used to divert winter runoff to storage in farm dams. The other farm dams, not supplied from these diversions, are also used to store winter runoff for use for irrigation in the dry summer months.

In 1995, almost the whole of the Warmbokkeveld area (H10A, B, C) comprised a single irrigation district known as the Ceres Irrigation District. Within this district there were four sub-irrigation districts, namely the Koekedouw, Warmbokkeveld, Rooikloof and Titus River irrigation districts. The areas of land scheduled in each of these sub-districts are shown in Table 4.6.2.1. The water supply in the Ceres Irrigation District is derived from several different waterworks and each of the sub-districts is associated with a particular source of water. It appears that in some sub-districts the same piece of land receives water from more than one source (i.e. it is scheduled under more than one sub-irrigation district). In the Koekedouw sub-district some land is scheduled to use only surplus winter water and some to receive summer flow stored in Koekedouw Dam. Again, some of this land may be scheduled for both summer and winter water. As a result, the total area of land shown in Table 4.6.2.1 as scheduled under the sub-districts is, at 2 987 ha, greater than the total of 2 805 ha scheduled in the whole Ceres Irrigation District.

Brief descriptions of the infrastructure in the sub-districts follow.

Koekedouw Irrigation District

Prior to the completion of the new Koekedouw Dam in 1998, surplus winter water was abstracted from the small Ceres Dam on the Koekedouw River just upstream of Ceres and gravitated to farm dams through approximately 12 km of pipeline ranging in diameter from 600 mm to 150 mm. A maximum of 4,26 million m^3/a of water was allowed to be extracted between 1 April and 30 September each year and stored in farm dams for use for irrigation during the summer months. With the completion of the Koekedouw Dam, the area of scheduled land was increased and an additional 5,74 million m^3/a of water is supplied from the dam during the summer months, to bring the total allocation to 10,0 million m^3/a.

Warmbokkeveld Irrigation District

Water from the Valsch River (H10B) which is a tributary of the Titus River, is diverted by Ben Etive Dam through a 5,5 km long 700 mm diameter steel siphon across the Titus River valley into a 45 km long system of canals which delivers water to farm dams in the area in catchment H10C that lies immediately to the east of a line between Ceres and Prince Alfred Hamlet. The capacities of the canals range between 0,7 m^3/s and 0,02 m^3/s. A maximum quantity of 5,1 million m^3 may be diverted from the Valsch River during the winter months each year. The water is used during the summer months to irrigate a scheduled area of 965 ha of crops consisting mainly of deciduous fruit orchards and pastures.

TABLE 4.6.2.1: IRRIGATION DISTRICTS IN THE WARM BOKKEVELD AREA IN 1995

IRRIGATION DISTRICTS						
NAME	CATCHMENT	SCHEDULED AREA (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)	SOURCE OF WATER	REMARKS
Ceres	H10A, B, C	2 805	Varies	19,3 (1)	Various	Includes all the sub-districts listed below.
Koekedouw	H10C	485 (winter) 647 (summer)	8 850 8 870	4,26 5,74	Koekedouw Dam	
Warm Bokkeveld	H10B, H10C	965	5 285	5,1	Valsch River	Water abstracted in winter stored in farm dams for summer use.
Rooikloof	H10A, H10B	435	9 650	4,2	Rooikloof Dam	
Titus River	H10B	455	Not known	Not known	Titus River	Water pumped from Titus River by riparian owners. No other waterworks.

(1) Excluding water used in the Titus River Irrigation District.

Rooikloof Irrigation District
The 8 m high Rooikloof Dam on the Rooikloof River (H10B), which is a tributary of the Titus River diverts surplus winter flow into a 44 km long network of pipelines which supply farm dams in the eastern portion (H10A) of the Ceres Irrigation District. The water is delivered to the farms by gravity between 15 April and 30 September each year, and is used for the irrigation of a scheduled area of 435 ha of land on which deciduous fruit, vegetables and pastures are grown. The maximum quantity of water that may be extracted is 4,2 million m^3/a (DWAF, 2001).

The Titus River Irrigation District
No communal infrastructure has been developed in the Titus River Irrigation District. Individual farmers with riparian rights pump water out of the river into farm dams, but the volume of storage is reported to be inadequate (Ninham Shand, 2001). A scheme to divert surplus winter water from the river into a proposed off-channel storage dam for distribution through a network of pipelines for irrigation during the summer months has been designed. However, the poor financial returns that have been derived from farming activities in the area for the last few years have delayed the implementation of the scheme.

The Riet Valley Irrigation Scheme
This scheme is situated in the Ceres Irrigation District but is not owned by an irrigation board. It provides water pumped from the Titus River between 15 April and 30 September each year to storage in farm dams on eight properties. The maximum permitted abstraction is 1,03 million m^3/a and the water is used to irrigate 150 ha of land (DWAF, 2001).

Private Groundwater Schemes
There are reported to be some 300 boreholes in the Ceres Irrigation District that are used for irrigating an estimated 2 350 ha of land, and that have been estimated (Sarel Bester, 1991) to provide about 37 million m^3/a of water.

There are two urban water supply schemes in the Warm Bokkeveld :

Ceres
The town of Ceres, with a population in 1995 of 21 300 people, had a water requirement of 2,8 million m^3/a (DWAF, 2001), obtained from Koekedouw Dam. Neither the allocation of water from Koekedouw Dam nor the capacity of the water treatment works were ascertained in this study, but both are reported (DWAF, 2001) to exceed the requirement in the year 2000 of 3,9 million m^3/a.

Prince Alfred Hamlet
Prince Alfred Hamlet had a population of 1 850 people in 1995. The town's water requirement was 0,4 million m^3/a (DWAF, 2001). The water supply is obtained from a spring and a borehole with an estimated (DWAF, 2001) combined yield of 0,88 million m^3/a.

4.6.3 The Upper Breede (H10D to H10L)

The Upper Breede key area which, for purposes of this discussion is defined as quaternary catchments H10D to H10L inclusive, had a population of some 27 000 people in 1995. Most of these lived on farms or in small rural settlements, with only 7 000 people, or 26% of the total population living in the two towns that fall within the area, namely Wolseley and Rawsonville.

Water supply related infrastructure in the area is well developed for both irrigation and urban supplies. There are two major dams in the area, the biggest of which is the off-channel Greater Brandvlei Dam (H10L) with a capacity of 342,1 million m^3 (DWAF, 1987) at current operating levels, and Stettynskloof Dam with a capacity of 15,54 million m^3. Greater Brandvlei Dam provides water for irrigation, while Stettynskloof Dam (H10K) supplies most of the requirements of the town of Worcester (H20H). Worcester also obtains water from the small Fairy Glen Dam (H10H), which has a capacity of only 0,5 million m^3. The water supply to Worcester is described in more detail in Section 4.6.4 below. There are, in addition, 12 registered farm dams which have a combined capacity of 3,7 million m^3 and are used for storing surplus winter flow in the rivers for irrigation during the summer months.

The Greater Brandvlei Dam originally comprised two dams, Brandvlei in catchment H10L and Kwaggaskloof in catchment H40B, but the full supply levels of both dams were raised in 1983 to combine them into a single dam. The Greater Brandvlei Dam can be filled by means of water diverted by canal from the Holsloot (H10K) and Smalblaar (H10J) rivers and by pumping from the Breede River. The canal, which has a capacity of 45 m^3/s, enters the dam at level 207,12 masl, and can fill the dam to that level, which corresponds to a storage volume of 342,1 million m^3. The pumping station on the Breede River, which is known as the Papenskuils Pumping station, can deliver 5 m^3/s, but the capacity could be increased to 20 m^3/s by installing additional pumps for which space has been provided in the existing pumping station. The pumps are seldom used at present, but they would have to be used if the dam were to be filled to above its present operating full supply level of 207,12 masl. The maximum full supply level at which it could be operated by pumping water into it is 210,5 masl, which corresponds to a storage capacity of 475,8 million m^3. The dead storage volume is 22,8 million m^3, giving live storage volumes of 319,3 million m^3 and 453,0 million m^3 respectively for the current operating level and the designed maximum operating level. The 1:50 year yield of the dam operated at the present maximum storage level of 207,12 masl has been estimated to be 155 million m^3/a (DWAF, 1987).

Stettynskloof Dam (H10K) has a 1:50 year yield of 25 million m^3/a (Ninham Shand, 1977) and a storage capacity of 15,391 million m^3. It belongs to the Worcester Municipality which is entitled to the full yield of the dam. Water for use in the Holsloot Irrigation District is also stored in the dam at present because the yield of the dam is not fully utilised by Worcester.

The small Fairy Glen Dam (H10H) also belongs to Worcester Municipality. Even though the dam has a capacity of only 0,516 million m^3, the Municipality extracts between 1 million m^3/a and 1,5 million m^3/a from it. The Municipality has rights to 2,7 million m^3/a from the dam.

In 1995, there were nine irrigation districts in the Upper Breede key area. These are listed in Table 4.6.3.1, together with their scheduled areas and information on their water allocations. In most cases the allocations were made in the early 1900s and are in terms of fractions of the flow in the rivers. As there are generally no measuring devices on the diversion structures, the quantity of water used each year is not known.

In addition, 4 million m^3/a of water is exported from catchment H10F to the Dwars River Irrigation District in the Berg WMA. The water is diverted from the Dwars River tributary of the Breede River at Witbrug in Michell's Pass and conveyed by means of the Artois Canal with a capacity of 1,13 m^3/s.

Brief descriptions follow of the infrastructure that has been developed in the nine irrigation districts to use the water.

The Darling Bridge Irrigation District

The irrigation district lies to the south of the town of Wolseley in catchment H10F. The scheduled area of land is 288,4 ha, under wine grapes (70%) and deciduous fruit (30%). Water is abstracted from a division box on the Waboom's River and distributed by means of a pipeline.

The irrigation district is entitled to three fifths of the flow in the river but the quantity of water abstracted is not known. Water is also obtained from boreholes.

The Wagenbooms River Irrigation District

This irrigation district is situated in catchment H10G and shares the division box in the Waboom's River with the Darling Bridge Irrigation District. The Wagenboom's River Irrigation District is entitled to two fifths of the flow in the river. Water is distributed to the 216,4 ha of land scheduled by means of a 300 mm x 300 mm concrete lined open channel, but it is not known how much water is abstracted. The crops irrigated are wine grapes (80%) and peaches (20%).

According to officials of the DWAF Western Cape Regional Office, water is also obtained from the Muishond River (6 900 m^3/a), a spring in Varkenskloof (116 000 m^3/a) and about 258 000 m^3/a of groundwater is abstracted by means of boreholes.

The Waaihoek Irrigation District

The Waaihoek Irrigation Board has exclusive rights to water in the Waaihoek River, a tributary of the Jan du Toits River, and a right to one third of the flow in the Jan du Toits River (H10F). Water is diverted by means of a concrete weir on the Jan du Toits River into a pipeline with a capacity of 0,18 m^3/s. If the flow exceeds the capacity of the pipeline, the additional water is conveyed by a canal with a capacity of 0,34 m^3/s, which was the original conveyance structure. The pipeline was constructed in 1997 to avoid the high (50%) losses that occur in the canal. The flow obtained in summer is reported to be about 0,09 m^3/s (DWAF, 2001).

The area of land scheduled in the Waaihoek Irrigation District is 144,3 ha. Crops grown are wine grapes (95%) citrus, peaches and pears (5%).

TABLE 4.6.3.1: IRRIGATION DISTRICTS IN THE UPPER BREEDE AREA (H10D TO H10L)

IRRIGATION DISTRICTS						
NAME	**CATCHMENT**	**SCHEDULED AREA (ha)**	**QUOTA (m^3/ha/a)**	**ALLOCATION**	**SOURCE OF WATER**	**REMARKS**
Darling Bridge	H10G	288,4	Not known	$^3/_5$ of flow	Wabooms River	Average annual quantity used is not known.
Wagenbooms River	H10G	216,4	Not known	$^2/_5$ of flow	Wabooms River	Average annual quantity used not known.
Waaihoek	H10F	144,3	Not known	Full flow in Waaihoek $^1/_3$ of flow in Jan du Toits	Waaihoeks River Jan du Toits River	Maximum diversion capacity 0,52 m^3/s but average annual abstraction not known.
Jan du Toits	H10G	144,0	Not known	$^1/_3$ of flow	Jan du Toits River	Maximum diversion capacity of 0,11 m^3/s, but average annual abstraction not known.
Olifantsberg	H10H	286,0	Not known	$^1/_3$ of flow	Jan du Toits River	Maximum diversion capacity 0,6 m^3/s, but average annual abstraction not known.
Brandwag	H10H	322,0	Not known	1,7 million m^3/a	Hartebees River	Water stored in Fairy Glen Dam
Groot Eiland – Klipdrif	H10G	432,0	Not known	Not known	Molenaars River	Maximum diversion capacity 0,4 m^3/s but average annual abstraction not known.
Smalblaar	H10G, H10L	312,6	Not known	$^2/_3$ of flow	Smalblaar River	Maximum diversion capacity 0,113 m^3/s, but average annual abstraction not known.
Holsloot	H10K	944,0	Not known	0,86 m^3/s	Holsloot River	Water is stored in Stettynskloof Dam, but the quantity used is not known.

The Jan du Toits Irrigation District

The Jan du Toits Irrigation District is situated in catchment H10G and, like the Waaihoek Irrigation District, is entitled to one third of the flow in the Jan du Toits River. The scheduled area of land is 144 ha on which wine grapes (90%), deciduous fruit (5%) and citrus (5%) are grown. Water is diverted by means of a concrete weir into a canal with a capacity of 0,11 m^3/s. The quantity of water diverted each year is not known.

The Olifantsberg Irrigation District

Like the Waaihoek and Jan du Toits Irrigation Disticts, the Olifantsberg Irrigation District is also entitled to one third of the flow in the Jan du Toits River. The scheduled area of land is 286 ha and wine grapes (85%), apricots (5%), plums (5%) and pears (5%) are grown.

The water is diverted by means of a concrete weir into a concrete canal with a capacity of 0,6 m^3/s. This canal is 4,5 km long and splits into two earth canals of equal size. The total quantity of water abstracted is not known, but summer flow in the main canal is reported (DWAF, 2001) to be about 0,04 m^3/s.

The Brandwag Irrigation District

This irrigation district is situated in catchment H10H immediately to the west of Worcester in the valley of the Hartebees River. An area of 322 ha of land is scheduled, but only 250 ha are actually irrigated (DWAF, 2001). The land is under wine grapes (80%) and pasture (20%), and the allocation from the Hartebees River is 1,7 million m^3/a. The full flow of a small, unnamed river to the east of the Hartebees River may also be used, but the quantity of water obtained from this source is not known.

The Brandwag Irrigation Board has an agreement with Worcester Municipality for its allocation from the Hartebees River to be stored in Fairy Glen Dam. The water is distributed by means of a pipeline with a capacity of 0,07 m^3/s that is shared with Worcester Municipality. When the dam is overflowing, additional water is diverted from the river downstream of the dam into a canal system.

The Groot Eiland-Klipdrif Irrigation District

The Groot Eiland-Klipdrif Irrigation District lies to the west of the town of Rawsonville in catchment H10G, and obtains water from the Molenaars River. The scheduled area is 432 ha, but it is estimated (DWAF, 2001) that the actual area irrigated is almost double the scheduled area. Crops grown are wine grapes (95%) and citrus (5%). Water is diverted by a weir on the Molenaars River into a pipeline with a capacity of 0,4 m^3/s. It is not known what quantity of water is abstracted.

The Smalblaar Irrigation District

This district surrounds the town of Rawsonville and lies in catchments H10G and H10L. The scheduled area of land is 312,6 ha, but the actual area irrigated is estimated (DWAF, 2001) to be double this. Crops grown are wine grapes (95%) and citrus and peaches (5%). Water is diverted by a weir on the Smalblaar River into a 500 m long earth canal. At the end of the canal, the water is divided between the Smalblaar Irrigation District ($^2/_3$ of the flow) and Rawsonville Municipality ($^1/_3$ of the flow). The irrigation water is conveyed to farms by pipeline from the division point. The capacity of the pipeline at the division box is estimated to be 0,113 m^3/s. The average annual quantity of water diverted is not known. It is reported (DWAF, 2001) that the supply often fails during the summer months.

The Holsloot Irrigation District

This irrigation district is located to the south of Rawsonville in catchment H10K. The scheduled area of land is 944 ha and water is obtained from the Holsloot River via three masonry diversion weirs that divert flow into furrows. By agreement with Worcester Municipality, water is stored in Stettynskloof Dam and released into the river during the summer months when required. The irrigation district is entitled to 0,86 m^3/s from the Holsloot River, but the quantity actually used is not known.

As mentioned earlier, the two towns of Wolseley and Rawsonville are situated in the area. Wolseley, with a population in 1995 of 5 500 people, and an estimated water requirement of 0,6 million m^3/a, is entitled to 35,38 ℓ/s from the Tierhokkloof catchment in the Witzenberg Mountains. The water is conveyed to the town by pipeline and distributed untreated, except after pipe breaks, when it is chlorinated. The capacity of the pipeline is not known. Rawsonville, with a population in 1995 of 1 500 people, and a water requirement of 0,12 million m^3/a, obtains its water from the Smalblaar River. The water is filtered and chlorinated before distribution. The capacity of the scheme is not known.

4.6.4 The Hex River Valley (H20A to H20H)

Land in the Hex River valley is used predominantly for growing table grapes under irrigation. Consequently, the water related infrastructure in the area has been developed mainly for the provision of water for irrigation. Worcester (H20H), which is the biggest town in the Breede WMA, is situated on the wide floor of the Breede River valley close to the mouth of the valley of the Hex River. Even though it is in the Hex River area, Worcester obtains its water from sources in the Upper Breede area. The only other town in the Hex River area is De Doorns (H20B) which obtains its water partially from local sources and partially from the Sanddrift Government Water Scheme, which is described later in this section.

The only two major dams in the area are both components of the Sanddrift Scheme. They are Lakenvallei Dam, with a capacity of 10,341 million m^3, and Roode Elsberg Dam with a capacity of 7,735 million m^3. In addition, there are 25 registered farm dams with a combined capacity of 8 million m^3. These are mainly in the upper reaches of the catchment (H20A, B, C) and are generally filled during the winter months by direct runoff, diversion furrows, or pumping. The water stored during the winter is used for irrigation in summer.

There are five irrigation districts that fall entirely within the Hex River valley area. These are listed in Table 4.6.4.1 where their scheduled areas of land, quotas and allocations are shown.

The Hexvallei Irrigation District extends over most of the floor of the valley of the Hex River itself (H20A, H20B, H20F, H20G) and obtains water from the Sanddrift Government Water Scheme. The Bovenstewater, Groothoek and Matroosberg Irrigation Districts fall within the Hexvallei Irrigation District, and in addition to obtaining water from the Sanddrift Scheme, two of them have land that is scheduled for water from local streams, as shown in Table 4.6.4.1. The infrastructure for distributing this water consists of small diversion weirs, furrows or pipelines, and off-channel storage dams. The Drie Riviere Irrigation District (H20H) lies outside the Hexvallei Irrigation District at the lower end of the Hex River valley, but obtains water from the Sanddrift Scheme by way of compensation releases from Roode Elsberg Dam into the Sanddrift River in summer. The water is diverted by means of a weir on the river into a gravity pipeline which distributes it to the farms. This system is also used to store winter flow in farm dams.

A description of the Sanddrift Scheme follows.

TABLE 4.6.4.1: IRRIGATION DISTRICTS IN THE HEX RIVER VALLEY AREA (H20A TO H20H)

IRRIGATION DISTRICTS						
NAME	**CATCHMENT**	**SCHEDULED AREA (ha)**	**QUOTA (m^3/ha/a)**	**ALLOCATION (million m^3/a)**	**SOURCE OF WATER**	**REMARKS**
Hexvallei	H20A, H20B, H20F, H20G	2 744,1 682	1 500 6 500	4,12 4,43 8,55	Sanddrift Scheme	Some of the land is also scheduled in other irrigation districts (see Note 1).
Bovenstewater [(1)]		116,6	Not known	Not known	Sanddrift Scheme	Falls entirely within Hex-vallei Irrigation District.
Groothoek [(1)]	H20B	982,8	4 100	4,02	Sanddrift Scheme Two small dams Groothoek River	144 ha are scheduled in the Hexvallei Irrigation District. Only 420 ha were irrigated in 1995.
Matroosberg [(1)]	H20B	168	9 400	2,31	Mountain streams and Hex River	2,14 million m^3/a from three streams and 0,17 million m^3/a from the Hex River. 228 ha actually irrigated.
Drie Riviere	H20G	786,3	7 500	5,9	Sanddrift Scheme	Water from boreholes also used. Winter water obtained from the Sanddrift River and compensation water in summer (2,5 million m^3/a) from Roode Elsberg Dam.

(1) Some or all of the land scheduled in these irrigation districts is also scheduled in the Hexvallei Irrigation District.

The Sanddrift River Government Water Scheme

The Sanddrift River Government Water Scheme comprises the two storage dams, Lakenvallei and Roode Elsberg (with a combined storage capacity of 18,1 million m^3 and a 1:50 year yield of 9 million m^3/a), a pressure tunnel, and a pipe distribution system. The pressure tunnel and pipe distribution system supply water to land in the Hex River valley scheduled in the Hexvallei Irrigation District. In addition, water is released into the Sanddrift River for abstraction by users further downsteam.

The Sanddrift River is one of the two major tributaries of the Hex River, the other being the Amandel River. The Sanddrift River rises in a valley to the west of, and parallel to, the Hex River valley, and its runoff at its confluence with the Hex River is about 50% greater than the runoff of the Hex River itself. Water is carried by the pressure tunnel from Roode Elsberg Dam under the Hex River Mountains into the Hex River valley.
Allocations from the scheme total 12,5 million m^3/a as shown in Table 4.6.4.2.

TABLE 4.6.4.2: ALLOCATIONS OF WATER FROM THE SANDDRIFT GOVERNMENT WATER SCHEME

WATER USER	CONVEYANCE ROUTE	ALLOCATION (million m^3/a)
Hex Vallei Irrigation Board	Tunnel	8,92 (1)
Drie Riviere Irrigation Board (compensation flow)	River	2,50
De Doorns Municipality	River	0,66
Other irrigation through Water Court Orders	River	0,42
TOTAL OF ALLOCATIONS		12,50

(1) The reason for the difference between this value and the value in Table 4.6.4.1 is not known.

The Sanddrift and Amandel Rivers join the Hex River just upstream of the narrow gorge through which the river flows before entering the Breede River valley. The distance from the downstream end of this gorge to the confluence with the Breede River is about 15 km and there are three points within this reach of the river where water is diverted for use by irrigators. Descriptions of these diversions follow.

The Sesbek Diversion

This is a diversion weir at the lower end of catchment H20G which is also known as the Glen Heatlie weir. It is the weir used for streamflow gauging station H2H001. Water is apportioned at the weir for use by Worcester Municipality and the Worcester East Irrigation District which is partially in catchment H20H and extends into catchments H40C and H40H. In addition, a portion of high flows in the river is diverted to the Nuy River catchment (H40C) by means of a 20 km long unlined earth canal known as the Overhex Surplus Canal. This water is stored in farm dams. Water for the De Wet-Heatlie Irrigation Sub-district is also diverted from the Hex River at the Sesbek Weir by means of the Glen-Heatlie and De Wet Canals.

One third of the "normal" flows apportioned at the Sesbek Weir are diverted into the Glen Heatlie and De Wet canals, while the remaining two thirds flow past the weir and continue down the Hex River for 4,8 km to the De Wet Weir.

The De Wet Diversion Weir

This weir diverts water into the Worcester Canal which carries water to farms on the west bank of the Hex River as well as "leiwater" for Worcester. The third diversion structure, the Hammond Weir is located 2 km further downstream.

The Hammond Weir

Water is diverted by this weir into a pipeline which leads to two canals, each with an initial capacity of 1,2 m^3/s, which carry the water into the Aan de Doorns and Nooitgedacht areas in catchment H40C. The one canal is 12 km long and the other has a length of 8 km.

It is apparent from the above description that a significant quantity of water is transferred out of the Hex River catchment to catchments lower down along the Breede River. This water, if not diverted, would flow naturally to the downstream catchments along the Breede River. The advantage of the diversions is that the water can be supplied by gravity to irrigators in the downstream catchments, whereas it would need to be pumped from the Breede River. The Worcester East Irrigation District, in which the water is used, is discussed in more detail in Section 5.6.5.

Water is also exported from the catchment of the Sanddrift River into the Olifants/Doring WMA, as described below.

The Inverdoorn Canal

The Inverdoon Canal was constructed in about 1913. It transfers water from the Spek and Valschgat Rivers (H20C) to the headwaters of the Doring River (E22C) for irrigation use. Analysis of records of flow in the canal has shown the transfer to be about 2,5 million m^3/a (Ninham Shand, 2001).

The only other water related infrastructure that merits description is that for the supplies to the urban centres of Worcester and De Doorns.

Worcester Urban Supply

Worcester, which is the biggest town in the Breede WMA, had a population in 1995 of 75 700 people, and water requirements are estimated to have been 11,8 million m^3/a (DWAF, 2001). Water is obtained from Stettynskloof Dam (H10K) which has a 1:50 year yield of 25 million m^3/a and which is owned by Worcester Municipality. The water is stabilised by treatment at the dam site with lime and carbon dioxide before it is conveyed by means of a 32 km long pipeline to the main service reservoir of the town, where it is chlorinated before distribution to consumers. The pipeline has a capacity of 54 Mℓ/d (19,7 million m^3/a). Worcester also owns the small Fairy Glen Dam (H10H), with a capacity of 0,516 million m^3. It is used for meeting short duration peak demands and supplies between 1 million m^3/a and 1,5 million m^3/a through a pipeline with a capacity of 18 Mℓ/d (6,5 million m^3/a). In 1995, Worcester also had rights to water from the Hex River which originally belonged to some of the land upon which the town has been built. The water is not used for potable supplies but is supplied as "leiwater" for watering gardens and smallholdings. Data on the quantity of water obtained from this source is not readily available and could not be obtained in this study.

De Doorns Urban Supply

De Doorns had a population in 1995 of 6 800 people, and a water requirement of 0,73 million m^3/a. It obtains raw water from a mountain stream, which provides about 0,27 million m^3/a, and the Sanddrift Scheme which provides the rest of its requirements. The water is filtered and chlorinated before distribution. The capacity of the treatment works was not ascertained.

4.6.5 The Middle Breede Key Area (H30A to H30E, H40A to H40L, H50A, B)

The Middle Breede area is, for purposes of this discussion, considered to extend from immediately downstream of Brandvlei Dam and the confluence of the Hex River with the Breede River to the confluence of the Breede with the Riviersonderend. The total population of the area in 1995 was approximately 74 000 people, of whom 41 000, or 55%, lived in the five towns that are located there. The towns all have their own well developed water supplies and, because the economy of the area is founded predominantly on irrigated agriculture, the infrastructure needed to provide irrigation water is also well developed.

There are three State owned dams, namely Klipberg Dam (H40K) with a capacity of 1,97 million m^3, Pietersfontein Dam (H30C) with a capacity of 2,099 million m^3, and Poortjieskloof Dam (H30A) with a capacity of 9,85 million m^3. They all provide water for irrigation. Several dams of significant size are owned by Irrigation Boards : Keerom Dam (H40B), with a capacity of 7,407 million m^3, is owned by the Nuy Irrigation Board, Knipes Hope Dam (H30B), with a capacity of 3,1 million m^3, and Sarah's Dam (H30E) with a capacity of 1,037 million m^3 are owned by the Cogmanskloof Irrigation Board, while Draaivlei Dam (H40E) is owned by the Moordkuil Irrigation Board and has a capacity of 1,607 million m^3. The other 93 registered dams in the area are mainly small farm dams that are used for irrigation and have a combined capacity of approximately 23 million m^3.

In 1995 there were 35 irrigation districts in the area, and some statistics on these are shown in Table 4.6.5.1. Approximately 29 000 ha of land was scheduled in the irrigation districts but, because of the complexity of the water allocations in the area, in many cases the same piece of land was scheduled under two or more irrigation districts. Therefore, the total scheduled area is not a true reflection of the extent of irrigated land.

Infrastructure has been developed to abstract and distribute water for irrigation from the various sources as follows :

- water from the Sanddrift Government Water Scheme (described in Section 4.6.4) and the Hex River by means of canals;
- water stored in Greater Brandvlei Dam during the winter months and distributed during the summer by means of canals or release into the Breede River and abstraction further downstream by pumping or diversion into canals;
- winter flow in the Breede River abstracted by pumping or diversion into canals and stored in farm dams and a few bigger dams;
- water from the tributaries of the Breede River diverted into canal and pipeline distribution systems and stored in farm dams during winter or conveyed straight to the lands during summer.

In most of the irrigation districts some water is obtained from tributaries of the Breede River by means of diversion weirs and canal or pipeline distribution systems, but only the bigger of these schemes are described in this report. Similarly, as there are more than 35 pumps on the Breede River between the greater Brandvlei Dam and the Riviersonderend confluence (DWAF, 2001), only the bigger pumping schemes are described.

TABLE 4.6.5.1: IRRIGATION DISTRICTS IN THE MIDDLE BREEDE AREA (H30A to E, H40A to L, H50A, B) (1)

IRRIGATION DISTRICTS						
NAME	**CATCHMENT**	**SCHEDULED AREA (ha)**	**QUOTA (m^3/ha/a)**	**ALLOCATION (million m^3/a)**	**SOURCE OF WATER**	**REMARKS**
Worcester East	H20H, H40C, H20H	1 701,2	7 450	12,7 Not known	Brandvlei Dam Hex River	The districts marked (2) below fall within the Worcester East District and receive water from Brandvlei Dam, the Hex River and local sources.
De Wet (2)	H20H	Not known	Not known	Not known	Hex River	
Nonna (2)	H40C	428 274,3	1 500	0,64	Sanddrift Scheme Nonna river	
Nooitgedacht (2)	H40C	365,7	Not known	Not known	Brandvlei Dam Nonna River Hex River	
Aan de Doorns (2)	H40C	366,6	Not known	Not known	Hex River	
Nuy (2)	H40C	1 379,9	Not known	Not known	Keerom Dam Brandvlei Dam	
Overhex (2)	H40C	1 285,3	Not known	Not known	Hex River Brandvlei Dam	
Bossieveld	H40E, D	1 371	7 450	10,22	Brandvlei Dam	The districts marked (3) below fall within the Bossieveld District.
Doornrivier (3)	H40D	790,75	7 450	5,89	Brandvlei Dam	
Bo-Doornrivier (3)	H40D	216	Not known	Not known	Doorn River Brandvlei Dam	
Stettyn (3)	H40E	81	Not known	Not known	Hoeks River Brandvlei Dam	
Moddergat (3)	H40E	283	7 450	2,11	Brandvlei Dam	
Agterkliphoogte	H40G	339,2 156	Not known Not known	1,02 1,36	Poesjenels River Brandvlei Dam/ Breede River	0,783 million m^3/a in summer from Brandvlei. Balance is winter flow in the Breede River.
Breede River Conservation District	H40G, J, L H50A, B	12 200	7 450	90,9	Brandvlei Dam/ Breede River	Irrigation districts marked (4) below fall within this district.
Angora (4)	H50A, B	1 751,8	7 450	20,4	Brandvlei Dam/ Breede River	Allocation does not include losses. 13,04 million m^3/a from Brandvlei. 7,4 million m^3/a winter water from Breede River.
Breede River (4) (Robertson)	H40G, J, L	2 748,9	Not known	31,9	Brandvlei Dam/ Breede River	Allocation does not include losses. 20,4 million m^3/a from Brandvlei. 11,5 million m^3/a winter water from Breede River.
Le Chasseur (4) and Goree	H40J	4 195,8	Not known	59,4	Brandvlei Dam/ Breede River	Conveyance losses not included in allocation. 36,3 million m^3/a from Brandvlie. 23,1 million m^3/a winter water from Breede River.
Zanddrift (4)	H50B	3 283,5	Not known	51,9	Brandvlei Dam Breede River	Conveyance losses not included in allocation. 32,6 million m^3/a from Brandvlei. 19,3 million m^3/a winter water from Breede River.
Vink River	H40H	60,0	Not known	Not known	Vink River	Diversion weir and pipe. No records of quantities used.
Noree	H40H, J	270,2 160	Not known 7 450	Not known 1,192	Noree River Brandvlei Dam	Quantity diverted from Noree River is not known. Summer water from Brandvlei
Willemnels River	H40J	358,9	Not known	Not known	Willem Nels River	Diversion weir and canal system. Quantity diverted not known.
Keurkloof	H40J	107,8	6 000	0,65	Keurkloof Stream	Diversion weir and pipeline and canal system. 90 ha actually irrigated. The quantity of water used is not known.
Hoops River	H40J, K	345,6	Not known	0,66	Two mountain streams	Diversion weirs and pipe and furrow distribution system. Robertson Municipality receives about 0,2 million m^3/a.
Konings River	H40K	367,8	1 000	0,37	Konings River	Klipberg Dam of 2,0 million m^3 capacity improves security of supply. Water is distributed by canal.
McGregor	H40K	720,9	Varies	2,52	Two mountain streams	Diversion weirs with canal and pipeline distribution system. McGregor Municipality obtains

IRRIGATION DISTRICTS						
NAME	**CATCHMENT**	**SCHEDULED AREA (ha)**	**QUOTA (m^3/ha/a)**	**ALLOCATION (million m^3/a)**	**SOURCE OF WATER**	**REMARKS**
						1,2 million m^3/a. Only 173 ha of farm land is under irrigation.
Vrolikheid	H40K	221,4	Varies	1,72	Two mountain streams	Shares sources with McGregor Irrigation District. Diversion weirs with canal distribution system.
Uitnood	H40K	150	8 900	1,33	Brandvlei Dam/ Breede River	Some of the land is also scheduled under the Vrolikheid and Konings River Irrigation Districts. Water is pumped from the Breede River into a pipe distribution system.
Klaasvoogds	H40L, H30E	800,3	Not known	4,4	Brandvlei/Breede River Groot Klaasvoogds River Klein Klaasvoogds River Mountain streams	Water is pumped from the Breede River into a pipe network. 3,31 million m^3/a summer water from Brandvlei. 1,1 million m^3/a winter water from the Breede River. The quantity of water obtained from the Klaasvoogds Rivers and other mountain streams is not known.
Cogmanskloof	H30A to H30E	2 836	Varies	20,4	Brandvlei/Breede River	Water is pumped from the Breede River via 9 pumpstations and 125 km of pipeline. The division between summer water and winter water is not known.
Dwariga	H30A	171,2	Not known	Not known	Dwariga River	Water is diverted into a 310 mm diameter pipeline. The quantity used is not known.
Kingna	H30B	574,9	Not known	1,32	Kingna River	Diversion weir and canal system. Average quantity of water supplied is about 0,8 million m^3/a.
Baden	H30A	287,9	4 500	1,3	Pietersfontein Spring	Relies on groundwater. the land is also scheduled in the Cogmans-kloof Irrigation District.
Martinusvlei	H30E	144,6	Not known	Not known	Martinusvlei River	Diversion weir and pipeline and canal system. About 40% of the water is used by the Ashton Canning Factory, 35% by Ashton Municipality, and 25% for irrigation. Quantities are not known.
Boesmansrivier	H50A	504	Not known	Not known	Boesmans River	Two diversion weirs and a canal and pipeline distribution system. The quantity of water used is not known.
Langeberg	H50B	235	Not known	Not known	One mountain stream	A diversion weir and distribution pipeline. It is reported that only about half of the scheduled area can be effectively irrigated from the quantity of water available.

(1) The information in this table has been extracted from a draft report prepared for the Breede River Basin Study (DWAF, 2001) or from DWAF files.
(2) Sub-irrigation district falling within the Worcester East Irrigation District and included in the area scheduled under it.
(3) Sub-irrigation district falling within the Bossieveld Irrigation District and included in the area scheduled under it.
(4) Sub-irrigation district falling within the Breede River Conservation District and included in the area scheduled under it.

The main features of the infrastructure developed for the bulk delivery of water for irrigation may be summarised as follows :

- In the Worcester East Irrigation District (H20H, H40C, H40H), the canals described in Section 4.6.4 convey water from the Hex River to the irrigation district which extends for some 18 km from the Hex River in an easterly direction along the floor of the Breede River valley on the northern side of the R60 road. Water is also obtained from the Worcester East pumping scheme which is designed to abstract 12,8 million m^3/a from the Breede River opposite Brandvlei Dam. The water is pumped during the summer for four months at 981 ℓ/s and for two months at 512 ℓ/s through a network of 54 km of pipeline and by four booster pumpstations. The water is stored in farm dams before being used for irrigation. If there is insufficient natural flow in the Breede River, water is released from Brandvlei Dam.

The De Wet, Nonna, Nooitgedacht, Aan de Doorns, Nuy and Overhex Irrigation Districts all fall within the Worcester East District and receive water from the Worcester East pumping scheme. Before the pumping scheme was constructed, the Overhex, De Wet and Aan de Doorns districts received water from the Sanddrift scheme or the Hex River only. The Nooitgedacht and Nonna Districts received water from the Hex River and diversions on the Nonna River, and the Nuy District received water from Keerom Dam. These supplies are still in place and the water from the pumping scheme is supplementary, or is provided for land that was not previously scheduled.

Keerom Dam has a capacity of 10,4 million m^3 and belongs to the Nuy Irrigation Board. The 1:20 year yield of the dam has been estimated to be 4,17 million m^3/a (Ninham Shand, 1990) which equates to approximately 3,8 million m^3/a at 1:50 year assurance.

- In the Le Chasseur and Goree Irrigation District (H40E, F, J, L) water from the Breede River and Brandvlei Dam is distributed by means of the 104 km long Le Chasseur and Goree Canal System. Water from the Breede River opposite Brandvlei Dam, and water released into the canal from the Kwaggaskloof outlet of Brandvlei Dam, is conveyed in the Le Chasseur Canal along the right bank of the Breede River to beyond Robertson. An inverted siphon some 20 km upstream of Robertson carries water from the Le Chasseur Canal under the Breede River into the Goree Canal. The latter supplies water to irrigators along the left bank from the crossing point downstream as far as Robertson.

  The summer flow at the upper end of the canal system is 2,3 m^3/s, with roughly 40% of the flow coming from the Breede River and 60% from Brandvlei Dam. During the winter months (1 May to 15 October), flow up to a maximum of 1,5 m^3/s is diverted into the canal from the Breede River only.

- Water for the Bossieveld Irrigation District (H40E, D) is abstracted from Brandvlei Dam by means of a pipe under the Kwaggaskloof main embankment and distributed through a 55 km long system of pipelines ranging in diameter from 800 mm to 75 mm. The main pumpstation can deliver 0,607 m^3/s, and there are seven smaller booster pumpstations.

  The irrigation districts of Doornrivier, Bo-Doornrivier, Stettyn, Moordkuil and Moddergat fall within the Bossieveld Irrigation District. The water from the pumping scheme supplements supplies that are obtained from local sources which include the 1,067 million m^3 capacity Draaivlei Dam which belongs to the Moordkuil Irrigation Board. The allocation from the dam is 2,6 million m^3/a, but the assurance at which this can be provided is not known.

- The Agterkliphoogte Irrigation District (H40G) abstracts water from the Breede River using the Le Chasseur canal. In summer, water released from Brandvlei Dam is pumped into the canal by a 0,057 m^3/s pumpstation situated 24 km downstream of Brandvlei Dam because the upper section of the canal has no spare capacity during the summer months. The water is conveyed by the canal for 8 km to a balancing dam whence it is pumped to farm dams in the Agterkliphoogte Irrigation District. In winter there is sufficient spare capacity for the water to be conveyed from the Breede River intake of the canal and the river pumpstation is not used.

- The Breede River (Robertson) Irrigation District (H40G, J, L) obtains water by means of a 40 km long canal that draws water from the Breede River at the Goree diversion weir some 20 km upstream of Robertson and distributes it to irrigators along the left bank of the Breede River between the Vink River and the Cogmanskloof River near Ashton. The canal carries a maximum flow of 1,7 m^3/s in summer (1 November to 30 April) and a maximum of 1,13 m^3/s for the rest of the year. It also supplies water to the municipalities of Robertson and Ashton.

- The Angora Irrigation District (H50A, B) receives water abstracted from the Breede River on its right bank about 12 km downstream of Robertson and distributes it to irrigators by means of a 26 km long canal which ends at Angora opposite Bonnievale. Flow at the start of the canal is a maximum of 0,78 m^3/s in summer and a maximum of 0,35 m^3/s in winter. Additional water is pumped into the canal at the Zanddrift Weir, some 5 km downstream of the canal intake, by a pumpstation with a maximum capacity of 0,23 m^3/s. The maximum rate of pumping is limited to 0,14 m^3/s.

- The Zanddrift Irrigation District uses water abstracted at the Zanddrift weir, which is about 17 km downstream of Robertson. The water is conveyed along the left bank of the Breede River and distributed to irrigators as far as Drew, some 15 km downstream of Bonnievale. An inverted siphon under the Breede River opposite Bonnievale carries water from the left bank canal to a canal on the right bank which supplies irrigators between Bonnievale and Drew. The total canal length is 69 km. The canal carries maximum flows of 1,84 m^3/s in summer and 1,38 m^3/s in winter. The canal also provides water to the town of Bonnievale.

- The Cogmanskloof Irrigation District (H30A to H30E) extends from the Breede River in the vicinity of Ashton (H30E) over the Langeberg Mountains into the valleys of the Kingna (H30A, B), Keisie (H30D) and Pietersfontein (H30C) Rivers in the vicinity of Montagu. Water is pumped through a 125 km long network of pipelines, ranging in diameter from 700 mm to 75 mm, by nine pumpstations. The main pumpstation is situated on the left bank of the Breede River some 71 km downstream of Brandvlei Dam. The pumpstation has a capacity of 0,667 m^3/s. The scheme abstracts up to 15,35 million m^3/a from the Breede River, of which 0,2 million m^3/a is supplied to Montagu and 0,27 million m^3/a to Ashton for urban supplies. The water is stored in a number of farm dams and in three bigger dams, namely Knipes Hope (3,1 million m^3 capacity) at Montagu, Sarahs Dam (1,04 million m^3 capacity) near Ashton, and Goedemoed Dam (0,38 million m^3 capacity) in the Keisies River valley. There are also two balancing dams, each with a capacity of 0,011 million m^3.

- Water for the Noree Irrigation District (H40H, J) is abstracted from the Breede River by a pumpstation on its left bank some 45 km downstream of Greater Brandvlei Dam. The pumpstation has a capacity of 0,08 m^3/s. Water is also obtained from a diversion weir on the Noree River.

- The Rietvallei private pumping scheme abstracts water from the Breede River by means of a pumpstation with a capacity of 0,063 m^3/s which is situated 61 km downstream of Greater Brandvlei Dam. The scheme provides water for the irrigation of 263,3 ha of land at a quota of 7 450 $m^3/ha/a$. A maximum of 1,962 million m^3/a may be abstracted from the river.

- The Kingna Irrigation District obtains water from a diversion weir on the Kingna River. In addition, water that is stored in winter in the Poortjieskloof Dam (H30A), on the Groot River tributary of the Kingna River is conveyed by canal for use in the irrigation district during the summer. Poortjieskloof Dam has a capacity of 9,85 million m^3, and the 1:50 year yield is estimated to be approximately 2,0 million m^3/a (Ninham Shand, 2001). The dam is owned by DWAF but operated by the Kingna Irrigation Board.

- The Pietersfontein Dam (H30C) with a capacity of 2,097 million m^3, is owned and operated by DWAF. It is situated just upstream of the Cogmanskloof Irrigation District and supplies water to farms in the district through a 32 km long (White Paper CC-68) network of pipelines. The 1:50 year yield of the dam is estimated to be 0,7 million m^3/a (Ninham Shand, 2001).

It is apparent from the above description of infrastructure that several of the towns in the area obtain at least some of the raw water supplied via infrastructure that has been developed mainly for the provision of irrigation water. Brief descriptions of the water supplies of the towns follow.

Robertson

Robertson (H40J) had a population in 1995 of 17 200 people and a water requirement of 1,98 million m^3/a. It obtains water from two dams on mountain streams, namely Dassieshoek Dam with a capacity of 0,835 million m^3, and Koos Kok Dam with a capacity of 0,11 million m^3. The yields of these dams are not known, but were sufficient to meet the water requirements in 1998 of 2,55 million m^3/a. A new treatment works has recently been constructed, but its capacity was not ascertained in this study.

The municipality also obtains about 1,5 million m^3/a of irrigation water from the Robertson Irrigation Board. This is provided to residents as "leiwater" at present.

McGregor

McGregor (H40K) had a population of 1 850 people in 1995 and its water requirements were 0,2 million m^3/a. Water is obtained from the Houtbaais and Hoeks Rivers from which the municipal area has rights to 7,17 million m^3/a. This needs to provide for domestic use, leiwater, and irrigation of smallholdings, and it has been estimated that it will meet requirements to beyond 2018 (McGregor Water Conservation Programme Newsletter, May 1998).

Ashton

Ashton (H30E) had a population in 1995 of 8 450 people. There are two canning factories in the town and these use significant quantities of water. The water requirements of the town in 1995 were 1,4 million m^3/a, of which the canning factories required approximately 1 million m^3. The main source of water is the Breede River (Robertson) Irrigation Board's canal, from which 0,83 million m^3/a is obtained. The town also has a permanent allocation of 0,27 million m^3/a from the Cogmanskloof Irrigation Board's pumping scheme, and a temporary allocation from the same scheme of 0,35 million m^3/a. Thus, raw water available from these sources totals 1,45 million m^3/a. Some additional water is obtained from mountain streams, but the quantity is not known. It appears that these sources made up the difference between the 1,45 million m^3 available from the main sources, and the reported (DWAF, 2001) water requirement of 1,82 million m^3 in 1998. It appears from the above statistics that Ashton is in urgent need of additional raw water supplies.

The water treatment works has a capacity of 11,5 Mℓ/day, or approximately 2,8 million m^3/a (for a peaking factor of 1,5).

Montagu
Montagu, in catchment H30B, had a water requirement in 1995 of 0,92 million m^3/a. Industrial use accounted for 0,16 million m^3/a and the balance represented the requirements of the population of 8 800 people. The total quantity of water available from the town's raw water sources is 1,4 million m^3/a, of which 0,8 million m^3/a is available from mountain streams and 0,6 million m^3/a is available from the Cogmanskloof Irrigation Board. The only treatment applied to the water before it is distributed to consumers is chlorination, which takes place at the service reservoirs.

Bonnievale
The water requirements of Bonnievale (H50B) were approximately 1 million m^3/a in 1995 for a population of 5 050 people. The raw water supply is from the Zanddrift Irrigation Board's canal, from which Bonnievale has an allocation of 1,2 million m^3/a. As water requirements in 1998 reached this level, an additional raw water source is needed.

All water is flocculated, filtered and chlorinated before distribution to consumers. The capacity of the treatment works was not ascertained in this study.

4.7 THE RIVIERSONDEREND CATCHMENT (H60)

The catchment of the Riviersonderend River, which is the major tributary of the Breede River, had a population in 1995 of 27 700 people. The four towns in the catchment are small and accommodate only 10 300 people, or 37% of the population of the catchment. Thus the majority of the population lives on farms.

The major components of water related infrastructure in the area are Theewaterskloof Dam and the tunnel that leads from it to the Berg River catchment. These are components of the Riviersonderend-Berg River Government Water Scheme that is described in Section 4.2.1, above. The only other dam of significant size in the catchment is Elandskloof Dam (H60C) which has a capacity of 11,415 million m^3 and is owned by DWAF and operated by the Elandskloof Irrigation Board. There are 41 registered small dams in the area, with a combined capacity of approximately 20 million m^3. These are mainly farm dams used for storing winter runoff for use for irrigation in the summer months.

In 1995 there were only three irrigation districts in the area. Some statistics on these are shown in Table 4.7.1 and a brief description of each of them follows.

TABLE 4.7.1: IRRIGATION DISTRICTS IN THE RIVIERSONDEREND CATCHMENT

IRRIGATION DISTRICTS						
NAME	**CATCHMENT**	**SCHEDULED AREA (ha)**	**QUOTA (m^3/ha/a)**	**ALLOCATION (million m^3/a)**	**SOURCE OF WATER**	**REMARKS**
Vyeboom	H60A, B	1 852,4	7 100	13,15	Theewaterskloof Dam	Summer pumping scheme. 81% of the scheduled area is under irrigation. A maximum of 12,58 million m^3/a is abstracted from the dam.
Elandskloof	H60B, C	1 880,5	6 860	13,60	Elandskloof Dam	12,9 million m^3/a allocated to irrigation. 0,36 million m^3/a allocated to Villiersdorp 0,33 million m^3/a allocated to Villiersdorp Co-operative.
Zonderend	H60C to H60L	6 017,5 (summer) 1 389,1 (winter)	6 000 8 000	36,10 11,10 47,20	Theewaterskloof Dam	Water is released into the Riviersonderend River and individual farmers provide their own infrastructure for abstracting it.

- **The Vyeboom Irrigation District (H60A, B)**
  The Vyeboom Irrigation District lies on the west bank of Theewaterskloof Dam at the foot of the Franschhoek Mountains. Water is pumped during the summer months from Theewaterskloof Dam into a 29 km long network of pipelines that distributes it to farms throughout the district. Pipeline diameters range from 900 mm to 150 mm diameter and the main pumpstation has a maximum capacity of 1,2 m^3/s. There are, in addition, three booster pumpstations at different points in the network. The scheduled area of land is 1 852,4 and the quota is 7 100 m^3/ha/a, giving an allocation of 13,15 million m^3/a. However, only 2,6 million m^3/a is abstracted from Theewaterskloof Dam because some of the irrigation requirements are provided for from water rights from local streams as well.

- **The Elandskloof Irrigation District (H60B, C)**
  The Elandskloof Irrigation District is situated in the vicinity of Villiersdorp and obtains its water from Elandskloof Dam. At the time of construction, the assured yield of the dam (approximate 1:50 year yield) was estimated to be 12,0 million m^3/a (White Paper H-72). The scheduled area of land in 1995 was 1 880,5 ha, which at the applicable quota of 6 860 m^3/ha/a, gives a water requirement of 12,9 million m^3/a. In addition, Villiersdorp Municipality was entitled to 0,37 million m^3/a, and Villiersdorp Co-operative to 0,33 million m^3/a. Thus the total requirement was 13,6 million m^3/a. The total volume supplied in the year 2000 was 11 million m^3 (DWAF, 2001). In 2001 it became necessary to apply water restrictions because of the low volume of water in storage in the dam.

  Water is released from Elandskloof Dam into the Elands River and flows about 5 km to a weir where it is diverted into a system of two concrete lined canals, one on each side of the valley, that distribute the water to irrigators.

- **The Zonderend Irrigation District (H60C to H60L)**
  The Zonderend Irrigation District extends from immediately downstream of Theewaterskloof Dam to the confluence of the Riviersonderend with the Breede River. Water is supplied from Theewaterskloof Dam and the natural runoff in the Riviersonderend for scheduled areas of land of 6 017,5 ha at a quota of 6 000 m^3/ha for summer water, and 1 389,1 ha at a quota of 8 000 m^3/ha for winter water. Thus the summer and winter requirements are 36,1 million m^3/a and 11,1 million m^3/a respectively, giving a total requirement of 47,2 million m^3/a. The allocation from Theewaterskloof Dam is 31,5 million m^3/a. The Zonderend Irrigation Board does not own any water distribution infrastructure : individual farmers make their own arrangements for abstracting water from the Riviersonderend.

With the exception of Villiersdorp, which obtains its water from the Elandskloof Irrigation Board, all the towns in the catchment have their own local sources of water supply. The individual supplies are described briefly below.

Villiersdorp
Villiersdorp (H60C) had a population in 1995 of 3 300 people and a water requirement of 0,4 million m^3/a. By 1998, the water requirement had increased to 0,7 million m^3/a (DWAF, 2001). The town obtains 0,3 million m^3/a of water from a borehole and 0,37 million m^3/a from Elandskloof Dam. It also has rights to water from a mountain stream that generally flows only during the winter months. The water is filtered and chlorinated before distribution.

Genadendal
Genadendal (H60E) has one of the smaller commercial centres of the towns in the area. It had a population in 1995 of 3 700 people and an estimated water requirement 0,3 million m^3/a. As water use is not metered, the actual usage is not known. Water is obtained from a mountain stream and the only treatment it receives before distribution is chlorination.

Greyton
Greyton (H60F), with a population in 1995 of 650 people, is the smallest town in the area. Water requirements were estimated to be 0,1 million m^3/a in 1995. Water is obtained from several mountain streams and is filtered and chlorinated before distribution to consumers. The yield of the sources is estimated to be about 0,6 million m^3/a (DWAF, 2001).

Riviersonderend
Riviersonderend (H60J) had a water requirement in 1995 that is estimated to have been 0,32 million m^3/a, and its population was 2 650 people. The water requirement had grown to 0,5 million m^3/a by the year 2000 (DWAF, 2001). Water is obtained from a tributary of the Riviersonderend River through a 7,9 km long 150 mm diameter pipeline. When this supply is inadequate, additional water is pumped from the Riviersonderend River itself, using a mobile pump.

4.8 THE LOWER BREEDE AREA (H70A TO K)

The Lower Breede Area is, for the purposes of this report, defined as the catchment of the Breede River between its confluence with the Riviersonderend and the sea. Of the total population in 1995 of 24 000 people, 65% lived in urban areas, the majority in the two main towns of Swellendam and Barrydale. These towns have their own independent water supplies, as does the village of Suurbraak (H70F). The small coastal town of Witsand receives water from the Duiwenhoks Rural Water Supply Scheme described in Section 4.2.3.

Agriculture in the southern part of the area is predominantly concerned with dryland grain and sheep production on pasture, and most of the irrigated land is in the northern part in the vicinity of Swellendam and Barrydale. The only major dam in the area is Buffelsjags (H70E) with a capacity of 5,7 million m^3. The 14 other registered dams are all small, with a combined capacity of 3,9 million m^3.

The Buffelsjags Dam supplies water to the Buffelsjags River Irrigation District, which is the only irrigation district in the area. The irrigation district (H70F, H70B) lies to the east of the town of Swellendam at the foot of the Langeberg Mountain range. An area of 1 450,4 ha of land is scheduled in the district. Crops grown are citrus (20%), wine grapes (10%), pasture (25%), deciduous fruit (30%), vegetables (10%) and olives (5%). The water quota is 6 100 m^3/ha/a, giving an allocation of 8,8 million m^3/a. The 1:50 year yield of the dam has been estimated to be 11 million m^3/a (DWAF, 2001).

The dam belongs to DWAF, but is operated by the irrigation board. Water is conveyed to the 49 landowners supplied from the dam by two concrete lined canals, each approximately 10 km long. The capacities of the canals range from a maximum of 1,27 m^3/s to a minimum of 0,08 m^3/s.

Some details of the water supplies of the towns are given below.

Swellendam
The population of Swellendam (H70B) in 1995 was 10 800 people and the water requirement was 1,0 million m^3/a. Raw water is obtained from a weir on the Klip River in the Langeberg Mountains adjacent to the town and conveyed by canal and pipeline to three storage dams at the edge of the town with a combined capacity of 0,7 million m^3. It is pumped from the dams to the water treatment works which has a capacity of 5,5 Mℓ/d or 1,3 million m^3/a at a peaking factor of 1,5.

Barrydale
Barrydale (H70C), with a population of 1 700 people in 1995, had a water requirement of 0,22 million m^3/a. The water is diverted from the Huis River, which passes through the town, and chlorinated before distribution to consumers.

Suurbraak
Suurbraak had a population of 1 600 people in 1995, and the water requirement of the town was 0,13 million m^3/a. Water is obtained from a local mountain stream and is stabilised with lime and chlorinated before use.

Witsand
Witsand, with a population of about 300 people, obtains its water from the Duiwenhoks Rural Water Supply Scheme. During holiday periods, visitors increase the population to about 1 200 people. The pipeline from the Duiwenhoks Scheme can only deliver 1,7 ℓ/s, (0,05 million m^3/a), which is adequate for the off-season but inadequate for peak holiday season requirements. Therefore, the supply is augmented during the holiday season from a borehole with a yield of 3,8 ℓ/s.

4.9 HYDRO-POWER AND PUMPED STORAGE

The only hydro-powerstation in the WMA is the Palmiet Pumped Storage Scheme, the power generating component of which is owned by Eskom and is a component of the Palmiet River Government Water Scheme (see Section 4.2.2).

Kogelberg Dam (G40C) on the Palmiet River is the main storage reservoir for the scheme, and water is pumped to Rockview Dam (G40A, D) during periods of low electric power demand. It is released back through the turbines into Kogelberg Dam during periods of high demand for electricity. Some of the water is released to Steenbras Dam via the canal between the Rockveiw and Steenbras Dams and is used for the water supply to Cape Town.

The station operates at an annual load factor of about 20%. Some of the principal statistics are given in Table 4.9.1.

TABLE 4.9.1: PALMIET PUMPED STORAGE SCHEME

Locality	Latitude Longitude	34° 11' 54" S 18° 58' 30" E
Rated capacity		400 MW
Peak capacity (generated limitation)		430 MW
Rated head		260 m
Load factor		20%

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

Water requirements in the WMA totalled an estimated 2 019 million m³/a in 1995, distributed amongst user groups and the ecological Reserve as shown in Table 5.1.1 and discussed in the subsequent sections of this chapter. The biggest water requirement, although not a use, is that of the riverine ecosystem, which requires an estimated 895 million m³/a on average to sustain it. The major water user is the agricultural sector which, at 683 million m³/a accounts for 60% of total consumptive water requirements (i.e. excluding the requirements of the ecological Reserve). Water transfers out of the WMA totalled 173 million m^3, and alien vegetation used an estimated 186 million m^3/a. Urban and rural household requirements were relatively small at 46 million m^3/a, or 2% of total water requirements.

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.

The agricultural water requirements shown in Table 5.1.1 represents both irrigation and livestock watering requirements, but livestock accounts for only 4,1 million m³/a.

The requirements at 1:50 year assurance for the domestic, bulk water use 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 equivalent 1:50 year requirement was calculated for each quaternary catchment by the Water Situation Assessment Model on the basis of the crop mix and typical yield/assurance relationships for dams in the area.

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 based on the requirements of the rivers. The requirement at 1:50 year assurance is the impact of the reserve requirement on the 1:50 year yield of the water resources as developed in 1995, which is far less than the average annual volume of water required for reasons given in Section 5.2.5.

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 yield in 1995.

The distribution of total equivalent water requirements at 1:50 year assurance is shown on Figure 5.1.1. Where water is transferred from one quaternary catchment to another, the quantity exported is shown as a water requirement in both the source catchment and the receiving catchment.

Water requirements per user group are shown on Figure 5.1.2.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP IN 1995

USER GROUP	ESTIMATED WATER REQUIREMENT (million m^3/a)	REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m^3/a)
Ecological Reserve	892	67 (5)
Domestic (1)	45	45
Bulk water use (4)	1	1
Neighbouring States	0	0
Agriculture (2)	684	582
Afforestation	13	6
Alien vegetation	186	57
Water transfers (3)	173	173
River freshening releases	20	20
Hydropower	2	2
TOTALS (6)	2 016	953

(1) Includes urban and rural domestic requirements and commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, dry land sugar cane, livestock and game.
(3) Net transfers out of the WMA (198,1 million m^3/a exported less 25,4 million m^3/a imported = 172,7 million m^3/a).
(4) Agricultural produce processing industries not supplied by municipalities.
(5) The Reserve requirement shown at 1:50 year assurance represents the impact on the system yield as developed in 1995 of the Reserve requirement. The determination of the value was at a low level of confidence and the true value may be significantly higher.
(6) Evaporation losses only as water used for power generation remains in the system.

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. Likewise 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 Breede WMA fall within the so-called Western Cape Wet and Dry, Southern Cape Wet and Dry, Western Karoo, and Eastern Karoo 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 members of the specialist team that carried out the classification of the rivers expressed their opinions on the strengths and weaknesses of the processes. These opinions are summarised below :

- Accuracy of assessments was facilitated by the diverse number of specialists involved in the process. However, some considered the fact that, in most cases, only one specialist in each field was present made it difficult to verify the results obtained.
- The upgrading of rivers to a higher class is decided by possible improvements through flow modification. This leaves uncertainty as to how other factors should be addressed. It was felt, for instance, that in some instances catchment management options such as removing invasive alien vegetation and reducing bulldozing of river beds would improve conditions, yet these options were not addressed. Very few rivers have the potential to be upgraded over a short period and the majority require upgrading over ten years or more.
- Groupings of various catchments are rather big, leading to very broad based assessments which could result in inaccuracies. A number of quaternary catchments were linked together, but only the main stem river was taken into account. The tributaries could be ecologically more important than the main stem, in which case the class determined for the main stem might not be accurate for the quaternary catchment overall.
- Confidence levels need to be attached to all the classes determined.
- Ideally, rivers should be grouped according to ecotones rather than quaternary catchments, as the latter are ecologically inappropriate, but it is acknowledged that this would not meet the resolution requirements of the water balance component of the study.

Subsequent to the classification of the rivers as described above, more detailed investigations of environmental flow requirements have been carried out for some river reaches as part of the Breede River Basin Study. The results of these investigations have indicated ecological flow requirements to maintain the rivers in their present ecological states that are two to three times the quantity of those derived by the methodology described above. It was agreed in discussions with officials of the DWAF Western Cape Regional Office that the values used for this situation assessment should be in line with those determined in the Basin Study investigations. Consequently, the requirements shown in Table 5.2.4.1 are the initially determined requirements multiplied by factors of between two and three.

5.2.4 Presentation of Results

In Table 5.2.4.1, the requirements of the ecological component of the Reserve are shown 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 catchments and are points of particular interest from the water resources point of view. They are described in more detail in Section 1.1.

The long term average total ecological flow requirement for the whole WMA is 895 million m^3/a, or 36% of the total virgin 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 Palmiet River where 46,9% is required, because fo the high conservation value of its lower reaches. The lowest requirements of 19,5% and 21,9% are, respectively at the mouth of the Hex River and in the Breede River at its confluence with the Riviersonderend, where the rivers have been modified by farming and other human activities. The estimates of the impacts of the ecological component of the Reserve on 1:50 year yields appear low in comparison to the long-term average requirements. This is discussed below.

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 (3)	LONG-TERM AVERAGE REQUIREMENT (million m^3/a)	IMPACT ON 1:50 YEAR YIELD (4) (million m^3/a)
Palmiet, Betty's Bay coast	G40D, G40B	C	46,9	141,6	12,5
Bot, Onrus, Klein, Uilkraals (Overberg West)	G40G, H, L, M	C, D	28,3	47,9	2,0
Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei (Overberg East)	G50F, J, K	C, D	40,0	43,8	0,5
Catchment above Ceres	H10B	D	20,7	32,1	2,5
Catchment above Brandvlei Dam	H10L	C	36,4	257,0	12,5
Hex River Valley	H20H	D	19,5	20,4	1,0
Breede at Riviersonderend confluence	H50B	C	21,9	265	2,0
Theewaterskloof Dam catchment	H60C	C	31,2	90,7	30,0
Riviersonderend at Breede confluence	H60L	D	28,0	128,5	0,0
Breede at its estuary	H70K	C	35,0	658,7	4,0
TOTAL FOR BREEDE WMA			**32,8**	**892,0 (2)**	**67,0**

(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, (Palmiet and Overberg areas), more than one class is applicable as a common outlet does not physically occur.
(2) The sum of requirements at the Breede estuary, the Palmiet, Betty's Bay area, the Western and Eastern Overberg areas.
(3) These values are two to three times the values obtained using the desktop method and were determined by means of more detailed studies.
(4) The determination of these values is at a low level of confidence and the true values may be significantly higher.

5.2.5 Discussion and Conclusions

The determination of the impact of the ecological flow requirements on the 1:50 year yield in the Breede WMA is complex because there are numerous dams of significant size on both the main stem rivers and tributaries, and there is also considerable use of run-of-river yield. The estimated impact on the total 1:50 year yield of the WMA is 67 million m^3/a, made up as shown in Table 5.2.4.1. With the exception of that for the Palmiet River, these estimates are at a low level of confidence and it is possible that the true impact is considerably higher than estimated. The Palmiet estimate is derived from detailed studies (DWAF, 1999f) carried out as part of the Western Cape System Analysis. The effect of the ecological flow requirements on the yield available for other requirements in the Breede catchment is being investigated in more detail in the current Breede River Basin Study.

The estimated impacts on 1:50 year yield shown in Table 5.2.4.1 are the impacts on the yields of dams in the Palmiet catchment, the Hex River valley and the Theewaterskloof Dam catchment. The impacts on the yields of dams were calculated as described in Section 7.1.3 using the Water Situation Assessment Model.

The impact of 4,0 million m^3/a shown for the Breede River at its estuary consists of an impact of 2,5 million m^3/a on the yield of Buffelsjags Dam, and 1,5 million m^3/a run-of-river impact along the lower Breede River. The theoretical impact on run-of-river yield along the lower Breede River is 19 million m^3/a, but the developed run-of-river yield is only 1,5 million m^3/a, and the impact cannot exceed the developed yield.

The values shown for other key points are the estimated impacts on run-of-river yield, determined as described in Section 5.2.2. It has been assumed that the 20 million m^3/a of water that are released from Brandvlei Dam for freshening purposes during summer provide the ecological flow requirements of the Breede River between Brandvlei Dam and the Riviersonderend confluence. Consequently, there is no impact on run-of-river yield. A similar assumption has been made regarding the Riviersonderend River and the compensation releases from Theewaterskloof.

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 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, as well as the comments regarding each quaternary catchment that are presented in Appendix F, 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 ecolgocial Reserve at the Rapid, Intermediate, or Comprehensive levels should be applied.

5.3 URBAN AND RURAL

5.3.1 Introduction

Urban and rural water requirements in 1995 are summarised per key area in Table 5.3.1.1 and their distribution per quaternary catchment is shown on Figure 5.3.1.1. Urban requirements include direct and indirect requirements, unaccounted for water and conveyance and distribution losses, all of which are discussed in more detail in Section 5.3.2. Rural requirements include household use, small scale irrigation, livestock water requirements, and conveyance and distribution losses. These components of the requirements are discussed in Section 5.3.3.

Some of the towns did not use all the water allocated to them in 1995 for potable supplies, but provided some of it to residents as untreated "leiwater" that could be used for watering gardens. Information on the quantity of "leiwater" supplied is not readily available and was not found in this study. Consequently, some of the urban requirements may be under-estimated.

It can be seen from Table 5.3.1.1 that the combined urban and rural domestic requirements in 1995 amounted to approximately 50 million m^3/a. Urban requirements, at some 36 million m^3/a accounted for 72% of the total. The rural domestic requirements of approximately 14 million m^3/a include 5 million m^3/a for livestock.

Table 5.3.1.1 also shows the estimated equivalent requirement at 1:50 year assurance. As both urban and rural domestic supplies have been assumed to be required under normal conditions at 1:50 year assurance, there is no difference between the total requirements and the equivalent 1:50 year requirements.

The table also shows the Human Reserve requirement, calculated on the basis of 25 ℓ/person/day for the whole population, and totalling 3,48 million m^3/a for the WMA. This requirement is included in the 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.

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.

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 ASSURANCE (million m^3/a)	HUMAN RESERVE (million m^3/a)
PRIMARY		SECONDARY		TERTIARY						
No.	Description	No.	Description	No.	Description					
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	1,31	1,0	2,31	2,31	0,22
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	5,98	1,4	7,38	7,38	0,47
		G5	Eastern Overberg	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	1,93	1,9	3,86	3,86	0,21
		TOTAL IN PALMIET AND OVERBERG				**9,22**	**4,4**	**13,64**	**13,64**	**0,90**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0,22	0,6	0,82	0,82	0,11
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	4,77	1,4	6,17	6,17	0,44
		H20	Hex	H20A to H	Hex River Valley	13,88	1,0	14,88	14,88	0,89
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	4,98	2,4	7,38	7,38	0,67
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**23,84**	**5,5**	**29,24**	**29,24**	**2,11**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam catchment	0,40	0,7	1,10	1,10	0,09
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend valley)	0,69	1,4	2,09	2,09	0,16
		TOTAL RIVIERSONDEREND				**1,09**	**2,1**	**3,19**	**3,19**	**0,25**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	1,65	1,8	3,45	3,45	0,22
		TOTAL IN BREEDE BASIN				**26,58**	**9,2**	**35,78**	**35,78**	**2,58**
TOTAL IN BREEDE WMA						**35,80**	**13,6**	**49,40**	**49,40**	**3,48**

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 Breede WMA. Therefore, the appropriate ratios of those shown in the above tables were used to estimate the split between direct and indirect water use.

It can be seen from Table 5.3.2.4 that 13,9 million m^3/a, or 39% of the total estimated urban water requirement of 35,87 million m^3/a occurred in the Hex River valley area. This was mainly the requirement of Worcester, which is the biggest town in the Breede WMA. The remaining urban water requirements are distributed throughout the WMA.

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.

It can be deduced from the figures shown in the table that the allowances for conveyance and distribution losses account for approximately 25% of the estimated total urban requirements in the WMA. The reasons for this are discussed below.

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 the water treatment works.

Further losses occur between the bulk treated water storage reservoirs and consumers, mainly as a result of leaking of 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, as shown in Table 5.3.2.4, were 5% for bulk conveyance losses and 20% for distribution losses.

In the context of the overall water resources of the WMA, some of the water used by urban consumers is returned to the rivers as treated effluent, and can contribute to ecological flow requirements or be abstracted and re-used further downstream, except in the coastal towns where the treated effluent generally runs into the sea, without re-use.

TABLE 5.3.2.4: URBAN WATER REQUIREMENTS IN 1995

CATCHMENT						URBAN WATER REQUIRMENTS (10^6 m^3/a)							TOTAL AT 1:50 YEAR ASSURANCE	RETURN FLOWS			
PRIMARY		SECONDARY		QUATERNARY		DIRECT (million m^3/a)	INDIRECT (million m^3/a)	BULK CONVEYANCE LOSSES		DISTRIBUTION LOSSES		TOTAL		EFFLUENT	IMPERVIOUS URBAN AREA	TOTAL RETURN FLOW	RETURN FLOW AT 1:50 YEAR ASSURANCE
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)	(million m^3/a)	(million m^3/a)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay coast	0,69	0,29	0,07	5	0,26	20	1,31	1,31	0,63	0,40	1,04	1,04
		G40 (part)	Overberg West	G40E to M	Bot. Onrus, Klein, Uitkraals	2,91	1,58	0,30	5	1,19	20	5,98	5,98	3,08	1,17	4,25	4,25
		G5	Eastern Overberg	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	1,00	0,44	0,10	5	0,39	20	1,93	1,93	0,91	0,39	1,31	1,31
	TOTAL IN PALMIET AND OVERBERG					**4,60**	**2,31**	**0,47**	**5**	**1,84**	**20**	**9,22**	**9,22**	**4,62**	**1,97**	**6,59**	**6,59**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0,12	0,04	0,01	5	0,04	20	0,21	0,22	0,10	0,28	0,39	0,39
		H10 (part)	Upper Breede	J25	Catchment above Brandvlei Dam	2,20	1,37	0,24	5	0,96	20	4,77	4,77	2,21	0,19	2,40	2,40
		H20	Hex	H20A to H	Hex River Valley	6,14	4,26	0,70	5	2,78	20	13,88	13,88	6,83	0,44	7,26	7,26
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	2,53	1,20	0,25	5	1,00	20	4,98	4,98	2,26	0,40	2,66	2,66
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**10,99**	**6,87**	**1,20**	**5**	**4,78**	**20**	**23,84**	**23,84**	**11,39**	**1,31**	**12,71**	**12,71**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam catchment	0,22	0,08	0,02	5	0,08	20	0,40	0,40	0,19	0,10	0,28	0,28
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	0,38	0,14	0,03	5	0,14	20	0,69	0,69	0,27	0,17	0,45	0,45
		TOTAL RIVIERSONDEREND				**0,60**	**0,22**	**0,05**	**5**	**0,22**	**20**	**1,09**	**1,09**	**0,46**	**0,27**	**0,73**	**0,73**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	0,90	0,34	0,08	5	0,33	20	1,65	1,65	0,71	0,19	0,90	0,90
		TOTAL IN BREEDE BASIN				**12,49**	**7,43**	**1,33**	**5**	**5,33**	**20**	**26,58**	**26,58**	**12,56**	**1,77**	**14,33**	**14,33**
TOTAL IN BREEDE WMA						**17,09**	**9,74**	**1,80**	**5**	**7,17**	**20**	**35,80**	**35,80**	**17,18**	**3,74**	**20,92**	**20,92**

Return Flows

Reliable information on return flows was available for most of the towns in the WMA. The return flows are shown in Table 5.3.2.4 and are generally between 60% and 68% of the sum of the direct and indirect water requirements.

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, and is shown in Table 5.3.2.4.

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 Breede WMA constitutes 34% of the total and consequently, the rural water use is significant 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	75	19	20	94
Developing urban	150	38	20	188
Commercial farming	175	44	20	219

Rural water requirements were calculated from the estimated number of people in each user category in each quaternary catchment. In the Breede WMA, most of the rural population was assumed to fall into the "commercial farming" category. 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 13,6 million m^3/a in 1995, including distribution losses.

TABLE 5.3.3.2: RURAL DOMESTIC WATER REQUIREMENTS IN 1995

CATCHMENT						RURAL WATER REQUIRMENTS (10^6 m^3/a)								RETURN FLOWS	
PRIMARY		SECONDARY		QUATERNARY		DOMESTIC (million m^3/a)	SMALL SCALE IRRIGATION (million m^3/a)	LIVESTOCK AND GAME	LOSSES		TOTAL	TOTAL AT 1:50 YR ASSURANCE		NORMAL	TOTAL AT 1:50 YR ASSURANCE
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)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D. G40B	Palmiet, Betty's Bay Coast	0,7	0,0	0,2	0,2	20	1,0	1,0		0,0	0,0
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	0,5	0,0	0,7	0,2	20	1,4	1,4		0,0	0,0
		G5	Eastern Overberg	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0,6	0,0	1,0	0,3	20	1,9	1,9		0,0	0,0
	TOTAL IN PALMIET AND OVERBERG					**1,8**	**0,0**	**1,9**	**0,7**	**20**	**4,4**	**4,4**		**0,0**	**0,0**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0,5	0,0	0,0	0,1	20	0,6	0,6		0,0	0,0
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	1,0	0,0	0,2	0,2	20	1,4	1,4		0,0	0,0
		H20	Hex	H20A to H	Hex River valley	0,8	0,0	0,1	0,2	20	1,0	1,0		0,0	0,0
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	1,6	0,0	0,4	0,4	20	2,4	2,4		0,0	0,0
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**3,8**	**0,0**	**0,7**	**0,9**	**20**	**5,5**	**5,4**		**0,0**	**0,0**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	0,4	0,0	0,2	0,1	20	0,7	0,7		0,0	0,0
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	0,6	0,0	0,5	0,2	20	1,4	1,4		0,0	0,0
		TOTAL RIVIERSONDEREND				**1,0**	**0,0**	**0,7**	**0,3**	**20**	**2,1**	**2,1**		**0,0**	**0,0**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	0,7	0,0	0,8	0,3	20	1,8	1,8		0,0	0,0
		TOTAL IN BREEDE BASIN				**5,5**	**0,0**	**2,2**	**1,5**	**20**	**9,2**	**9,2**		**0,0**	**0,0**
TOTAL IN BREEDE WMA						**7,3**	**0,0**	**4,1**	**2,3**	**20**	**13,6**	**13,6**		**0,0**	**0,0**

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

Return flows from rural users are assumed to be negligible.

Rural water requirements include small scale irrigation. Table 5.3.3.2 indicates that no water use of this type occurs in the WMA as no details of the quantity of water used for this purpose were found.

5.4 BULK WATER USE

This section deals with industries, mines and thermal powerstations having individual bulk water supplies or direct supplies from DWAF. Only small bulk water users of this type were identified in the Breede WMA : in the Upper Riviersonderend area (H60A, B, C), a combined total of 0,4 million m^3/a is supplied from Theewaterskloof and Elandskloof Dams to fruit processing plants, and in the Middle Breede area (H20 to H30) 0,25 million m^3/a is supplied to wine cellars and fruit processing plants.

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 estimated irrigated areas are shown in Table 3.5.2.1, and the sources from which information was obtained are 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 Western 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 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.

TABLE 5.6.2.1: IRRIGATION WATER REQUIREMENTS IN 1995

CATCHMENT						FIELD EDGE WATER REQUIREMENT (million m^3/a)	CONVEYANCE LOSS		TOTAL WATER REQUIREMENT (million m^3/a)	TOTAL WATER REQUIREMENT AT 1:50 YR ASSURANCE (million m^3/a)	RETURN FLOWS				
PRIMARY		SECONDARY		QUATERNARY			(million m^3/a)	%			LEACHING BEYOND THE ROOT ZONE (million m^3/a)	ADDITIONAL RETURN FLOW FROM LANDS (milion m^3/a)	FROM CONVEYANCE LOSSES (million m^3/a)	TOTAL RETURN FLOW (million m^3/a)	
No.	Description	No.	Description	No.	Description									NORMAL	AT 1:50 YR ASSURANCE
G (part)	Eastern part of Drainage Regon G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	53,4	2,7	4,8	56,1	43,2	0,0	4,3	0,0	4,3	3,3
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	25,7	1,3	4,8	27,0	20,8	0,0	2,1	0,0	2,1	1,6
		G5	Eastern Overberg	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0,3	0,0	0,0	0,3	0,2	0,0	0,0	0,0	0,0	0,0
	TOTAL IN PALMIET AND OVERBERG					**79,4**	**4,0**	**4,7**	**83,4**	**64,2**	**0,0**	**6,4**	**0,0**	**6,4**	**4,9**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	48,8	9,8	16,7	58,6	50,4	0,0	4,9	0,0	4,9	4,3
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	99,3	19,9	16,7	119,2	102,5	0,0	9,9	0,0	9,9	8,8
		H20	Hex	H20A to H	Hex River Valley	36,3	7,2	16,7	43,5	37,4	0,0	3,6	0,0	3,6	3,2
		H30 to H50	Middle Breede	H30 to H50	Between Riviersonderend confluence and Brandvlei Dam	237,6	47,5	16,7	285,1	245,3	0,0	23,8	0,0	23,8	21,1
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**422,0**	**84,4**	**16,7**	**506,4**	**435,5**	**0,0**	**42,2**	**0,0**	**42,2**	**37,4**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	31,2	0,9	2,9	32,1	27,9	0,0	1,6	0,0	1,6	1,2
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend valley	23,3	0,7	2,9	24,0	20,9	0,0	1,2	0,0	1,2	0,9
		TOTAL RIVIERSONDEREND				**54,5**	**1,6**	**2,9**	**56,1**	**48,8**	**0,0**	**2,8**	**0,0**	**2,8**	**2,1**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	31,9	1,6	4,8	33,5	28,5	0,0	1,6	0,0	1,6	1,2
		TOTAL IN BREEDE BASIN				**508,4**	**87,6**	**14,6**	**596,0**	**512,8**	**0,0**	**46,1**	**0,0**	**46,1**	**40,7**
TOTAL IN BREEDE WMA						**587,8**	**91,6**	**13,5**	**679,4**	**577,0**	**0,0**	**53,0**	**0,0**	**53,0**	**45,6**

Total irrigation water requirements in 1995 are estimated to have been 679 million m^3/a, including conveyance losses. About 75% of the requirement occurred in the Breede River catchment upstream of the Riviersonderend confluence. This area represents only about 38% of the total area of the WMA. A further 8% of the requirements occurred in the Palmiet catchment which comprises only 3% of the land area of the WMA. Irrigation water requirements are less concentrated in other areas of the WMA.

TABLE 5.6.2.2: TYPICAL ANNUAL FIELD EDGE IRRIGATION REQUIREMENTS

AREA	QUATERNARY CATCHMENTS	PREDOMINANT CROP	ASSUMED FIELD EDGE WATER REQUIREMENT ($m^3/ha/a$)
Palmiet	G40C, D G40B	Apples	7 000
Overberg West	G40E to M	Apples	7 000
Overberg East	G50A to K	Pasture	5 000
Warm Bokkeveld	H10A, B, C	Stone fruit, Grapes	7 000
Upper Breede	H10D to L	Grapes, Stone Fruit	7 000
Hex River Valley	H20A to H	Grapes	7 000
Middle Breede	H10D to L	Grapes, Lucerne, Pasture	7 000
Upper Riviersonderend	H60A, B, C	Apples, Pears	6 400
Lower Riviersonderend	H60D to L	Apples, Pears, Grapes	6 400
Lower Breede	H70A to K	Grapes, Pasture	6 100

5.6.3 Water Losses

Irrigation water losses are considered in two categories, namely :

- Canal, pipeline 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, and evaporation losses from farm dams.

The main river conveyance losses occur in the Breede and Riviersonderend Rivers through channel losses and evaporation. The main canal losses occur in the Breede River catchment upstream of the Riviersonderend confluence through evaporation and seepage from canals.

As reliable information on farm conveyance losses is not available, estimates of combined canal, pipeline, river, and on-farm conveyance losses were provided by officials of the DWAF Western 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.

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 Breede 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 Western 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 and provide for both return flows from lands and from seepage from canals.

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

AREA	CATCHMENTS	RETURN FLOWS (% of field edge irrigation requirements)
Palmiet catchment	G40C, D	8%
Overberg West	G40E to M	8%
Overberg East	G50A to K	0%
Warm Bokkeveld	H10A, B, C	10%
Upper Breede	H10D to L	10%
Hex River	H20A to H	10%
Middle Breede	H30 to H50	10%
Upper Riviersonderend	H60A, B, C	5%
Lower Riviersonderend	H60D to L	5%
Lower Breede	H70A to K	5%

5.7 DRYLAND SUGARCANE

No sugarcane is grown commercially in the Breede WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

Along the lower reaches of the Breede River the evaporation losses from the water surface during the summer months exceed the inflow from the surrounding catchment area. The flow that does occur in the area during summer is the result of inflow from the wetter upper catchments, and the flow volume decreases downstream as a result of the evaporation losses and evapotranspiration by riparian vegetation. The volume of these losses has not been accurately measured. As no information on these losses is available and little water is abstracted from the lower Breede River because of the naturally high salinity of the water, no allowance is made for these losses in this report.

A quantity of up to 20 million m^3/a of water is released from Brandvlei Dam into the middle Breede River to reduce the salinity of water abstracted for irrigation. This water is released as part of bigger releases for irrigation, but it is not recovered and is, therefore, regarded in this assessment as a river loss.

However, it is likely that most of the water, contributes to the water quality component of the ecological flow requirements and this has been compensated for by assuming that the ecological flow requirements have no impact on the 1:50 year run-of-river yield in this area (see Section 5.2.5).

Approximately 111 million m^3/a of water is estimated to evaporate from dams. Theewaterskloof Dam is estimated to account for 20 million m^3/a of this quantity, and Greater Brandvlei Dam for 25 million m^3/a. The other large dams in the WMA have combined evaporation losses of some 7 million m^3/a, while the evaporation losses from farm dams are estimated to total 58 million m^3/a.

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 the 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

<table>
<tr><th colspan="6">CATCHMENT</th><th rowspan="3">EVAPORATION LOSSES FROM DAMS (million m³/a)</th></tr>
<tr><th colspan="2">PRIMARY</th><th colspan="2">SECONDARY</th><th colspan="2">QUATERNARY</th></tr>
<tr><th>No.</th><th>Description</th><th>No.</th><th>Description</th><th>No.</th><th>Description</th></tr>
<tr><td rowspan="4">G (part)</td><td rowspan="4">Eastern part of Drainage Region G</td><td>G40 (part)</td><td>Palmiet</td><td>G40C, D
G40B</td><td>Palmiet
Betty's Bay Coast</td><td>5,0 (1)</td></tr>
<tr><td>G40 (part)</td><td>Overberg West</td><td>G40E to M</td><td>Bot, Onrus, Klein, Uitkraals</td><td>1,1</td></tr>
<tr><td>G50</td><td>Overberg East</td><td>G50A to K</td><td>Haelkraal, Ratel, Nuwejaars, heuningnes, De Hoopvlei</td><td>0,2</td></tr>
<tr><td colspan="4">TOTAL IN PALMIET AND OVERBERG</td><td>6,3</td></tr>
<tr><td rowspan="11">H (part)</td><td rowspan="11">Breede</td><td>H10 (part)</td><td>Warm Bokkeveld</td><td>H10A, B, C</td><td>Catchment above Ceres</td><td>14,2</td></tr>
<tr><td>H10 (part)</td><td>Upper Breede</td><td>H10D to L</td><td>Catchment above Brandvlei Dam</td><td>31,7</td></tr>
<tr><td>H20</td><td>Hex</td><td>H20A to H</td><td>Hex River Valley</td><td>4,5</td></tr>
<tr><td>H30 to H50</td><td>Middle Breede</td><td>H30A to D
H40A to L
H50A, B</td><td>Breede between Riviersonderend confluence and Brandvlei Dam</td><td>29,6</td></tr>
<tr><td colspan="4">TOTAL IN BREEDE ABOVE RIVIERSONDEREND CONFLUENCE</td><td>80,0</td></tr>
<tr><td>H60 (part)</td><td>Upper Riviersonderend</td><td>H60A, B, C</td><td>Theewaterskloof Dam Catchment</td><td>22,2</td></tr>
<tr><td>H60 (part)</td><td>Lower Riviersonderend</td><td>H60D to L</td><td>Riviersonderend Valley</td><td>0,8</td></tr>
<tr><td colspan="4">TOTAL RIVIERSONDEREND</td><td>23,0</td></tr>
<tr><td>H70</td><td>Lower Breede</td><td>H70A to K</td><td>Breede between its mouth and the Riviersonderend confluence</td><td>1,3</td></tr>
<tr><td colspan="4">TOTAL IN BREEDE BASIN</td><td>104,3</td></tr>
<tr><td colspan="6">TOTAL IN BREEDE WMA</td><td>110,6</td></tr>
</table>

(1) Includes 2 million m^3/a shown in Table 5.1.1 for hydro-power water use.

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 natural flow sequences for the Water Situation Assessment Model (WSAM) (Department of Water Affairs and Forestry, 2000) based on the WR90 natural 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).

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.

Commercial timber plantations totalling 68 km^2 in area are found in the Breede WMA. The reduction in runoff caused by afforestation is estimated to be 13,4 million m^3/a, 68% of which occurs in the Palmiet and Overberg West areas. The remainder occurs in relatively small pockets of afforestation distributed amongst the high rainfall areas throughout the rest of the WMA, as shown in Table 5.9.1.

The corresponding reduction in the 1:50 year yield (derived from the WSAM model) is estimated to be 6,2 million m^3/a, distributed as shown in Table 5.9.1. Corresponding water use and reduction in system yield values expressed in mm/a on the basis of entire catchment areas (i.e. not just the afforested area) are also shown in Table 5.9.1.

5.10 HYDROPOWER AND PUMPED STORAGE

The Palmiet Pumped Storage Scheme, which is the only hydropower installation in the Breede WMA, is not a consumptive user of water, except for evaporation losses from Kogelberg and Rockview Dams, which provide the storage for the scheme. The combined evaporation losses have been estimated by Eskom to be approximately 2 million m^3/a. These are included in the evaporation losses from dams shown in Table 5.8.1.

TABLE 5.9.1: WATER USE BY AFFORESTATION IN 1995

CATCHMENT						AVERAGE WATER USE		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
PRIMARY		SECONDARY		QUATERNARY					
No.	Description	No.	Description	No.	Description	(million m^3/a)	(mm/a) [(1)]	(million m^3/a)	(mm/a) [(1)]
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	7,8	13,1	3,9	6,6
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	1,4	0,6	0,7	0,3
		G5	Eastern Overberg	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0,0	0,0	0,0	0,0
		TOTAL IN PALMIET AND OVERBERG				**9,2**	**1,3**	**4,6**	**0,6**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0,2	0,3	0,0	0,1
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	0,7	0,5	0,2	0,1
		H20	Hex	H20A to H	Hex River Valley	0,0	0,0	0,0	0,0
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	0,0	0,0	0,0	0,0
			TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE			**0,9**	**0,1**	**0,2**	**0,0**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	1,1	2,2	0,9	1,8
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	0,3	0,2	0,2	0,1
		TOTAL RIVIERSONDEREND				**1,4**	**0,6**	**1,1**	**0,5**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	1,9	0,6	0,3	0,1
		TOTAL IN BREEDE BASIN				**4,2**	**0,3**	**1,6**	**0,1**
TOTAL IN BREEDE WMA						**13,4**	**0,7**	**6,2**	**0,3**

(1) Based on entire catchment area and not area of afforestation.

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 Breede 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.

It can be seen from the table that the most severe reduction in runoff (65% of the total for the WMA) occurs in the Western and Eastern Overberg Areas. However, there is also considerable infestation by alien vegetation in the Breede River catchment upstream of Brandvlei Dam, and in the whole of the Riviersonderend catchment. The total reduction in runoff caused by alien vegetation in the Breede WMA is estimated to be 186 million m^3/a. The reduction in the 1:50 year yield is estimated as 57 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.

TABLE 5.11.1: WATER USE BY ALIEN VEGETATION IN 1995

CATCHMENT						AVERAGE WATER USE		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
PRIMARY		SECONDARY		QUATERNARY					
No.	Description	No.	Description	No.	Description	(million m^3/a)	(mm/a) (1)	(million m^3/a)	(mm/a) (1)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	0,9	1,6	0,5	0,8
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	60,3	25,2	30,6	12,8
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	60,2	14,6	1,6	0,4
		TOTAL IN PALMIET AND OVERBERG				**121,4**	**17,1**	**32,7**	**4,6**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	4,3	6,5	1,1	1,7
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	15,4	11,0	4,1	3,0
		H20	Hex	H20A to H	Hex River Valley	0,9	1,1	0,3	0,3
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	3,3	0,7	0,9	0,2
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**23,9**	**3,2**	**6,4**	**0,9**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	16,8	33,7	9,0	18,0
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	15,4	8,8	8,2	4,7
		TOTAL RIVIERSONDEREND				**32,2**	**14,4**	**17,2**	**7,7**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	8,0	2,7	1,1	0,4
		TOTAL IN BREEDE BASIN				**64,2**	**5,1**	**24,7**	**2,0**
TOTAL IN BREEDE WMA						**185,6**	**9,4**	**57,4**	**2,9**

(1) Based on catchment area, not area of alien vegetation.

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 60% of total water use in the Breede Water Management Area. Irrigation losses are often quite significant and it is estimated that often no more than 83% 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 1% of total water use in the Breede Water Management Area. 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 stream flows 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 suer 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 Breede Water Management Area

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

In the Breede WMA, the Municipality of Hermanus in 1996 introduced a water conservation and demand management programme that reduced water use by 20% within a period of one year. The main scope for water conservation in the WMA appears to be in reducing irrigation water wastage, particularly conveyance losses from old canals and pipelines.

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 requirements and 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 in Government Water Control Areas.
(d) Articles 32A and 32B : Scheduling and quotas in 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 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 rights to the use of water. In all other areas, rights to the use of 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 could otherwise occur.

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

In the Breede WMA, the Warmbokkeveld (H10A, B, C), the Hex River catchment (H20A to H), most of the Breede River valley between Brandvlei Dam and the Riviersonderend confluence (H30, H40, H50), and most of the Riviersonderend valley (H60), were Government Water Control Areas.

Allocations of water for irrigation from 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 summer months. In these circumstances, the quantity of water that was available each year was generally allocated by irrigation boards in proportion to the scheduled or rateable areas of land.

5.13.2 Permits and Other Allocations in the Breede WMA

In parts of the Breede WMA water allocations date back to the nineteenth century, when they were defined as fractions of the total flow in the water courses to which they applied. In areas that subsequently became Government Water Control Areas it appears that these allocations were converted to annual quantities of water, but in the other areas they remain as fractions of flow. (The division of flow into fractions is often achieved by the "turn system" in which the full flow is divided on a time basis instead of dividing the volume of flow). Consequently, water allocations in these areas are not easily quantifiable in terms of annual abstractions. In addition, many pieces of land are scheduled for water from two or more different sources, and often within more than one irrigation district. These factors make the water allocations in the Breede WMA extremely complex, with the result that a comprehensive summary of permits and other allocations is not presented in this report. Nevertheless, information on allocations under Government Water Schemes is summarised in Tables 5.13.2.1 and 5.13.2.2 for comparison with the yields of the dams that provide the storage for the schemes.

TABLE 5.13.2.1: ARTICLE 63 SCHEDULING AND QUOTAS FROM GOVERNMENT WATER SCHEMES IN THE BREEDE WMA

SCHEME	QUATERNARY CATCHMENTS	SCHEDULING (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)
Riviersonderend/Berg River (Theewaterskloof Dam)	H60A to H60L	5 316,4 <u>5 258,8</u> 10 575,2	7 100 6 000	37,75 <u>31,55</u> 69,30
Elands River (Elandskloof Dam)	H60B, C	1 856,6	6 860	12,73
Sanddrift (Lakenvallei and Roode Elsberg Dams)	H20A, B, F, G	2 744,1 <u>682,6</u> 3 426,7	1 500 6 500	4,12 <u>4,43</u> 8,55
Breede River (Brandvlei Dam)	H20H, H40G, J, L H50A, B	21 806,6	7 450	162,46
TOTALS		**37 665,1**	**---**	**253,04**

Table 5.13.2.1 shows allocations to irrigation under Article 63 of the Water Act of 1956. The scheduled areas in the table were obtained from a list supplied by DWAF. The total scheduled area of 37 665 ha is 73% of the total area scheduled in the irrigation districts described in Chapter 4. The total allocation to irrigation from Government Water Schemes of 253 million m^3/a was approximately 75% of the total of allocations in the irrigation districts in 1995.

It should be noted that the allocations from the Riviersonderend/Berg River Government Scheme shown in Table 5.13.2.1 are those in the Breede WMA only. An additional 101 million m^3/a is allocated from the Scheme to irrigation in the Berg WMA. The combined allocations to irrigation in the Breede WMA and the Berg WMA of 170,3 million m^3/a is greater than the 109 million m^3/a at 1:50 year assurance shown in Table 4.1.1 because the water is supplied at less than 1:50 year assurance and some of the water in the Berg WMA is supplied from Kleinplaas Dam (see Section 4.2.1). Therefore the values are not directly comparable.

It can be seen from Table 5.13.2.2 that allocations under Article 56(3) of the Water Act of 1956 totalled only 7,34 million m^3/a in 1995 and were small in comparison to the Article 63 allocations. The biggest single allocation was 3,0 million m^3/a to the Ruensveld Rural Water Supply Schemes. Application was made in 1998 for the allocation to be increased to 9,2 million m^3/a. The bulk industrial allocations are to several wine cellars or fruit processing factories.

TABLE 5.13.2.2: ARTICLE 56(3) ALLOCATIONS FROM GOVERNMENT WATER SCHEMES TO CONSUMERS IN THE BREEDE WMA

SCHEME	QUATERNARY CATCHMENTS	ALLOCATION (million m³/a)					
		HOUSEHOLD & STOCK WATERING	MUNICIPALITIES	BULK INDUSTRIAL	BULK MINING	IRRIGATION	TOTAL
Riviersonderend/ Berg River	H60A to H60L	3,09	0,00	0,07	0	0,35	3,51
Elands River	H60B, C	Negligible	0,69	0,33	0	0,00	1,02
Sanddrift	H20A, B, F, G	0,31	0,40	0,00	0	0,00	0,71
Breede River	H20H, H40G, J, L H50A, B	0,03	1,30	0,25	0	0,52	2,10
TOTALS		**3,43**	**2,39**	**0,65**	**0**	**0,87**	**7,34**

5.13.3 Allocations in Relation to Water Requirements and Availability

In this section, allocations of water are compared with the 1:50 year yields of dams. The allocations in most cases exceed the 1:50 year yields because they contain a large component of water for irrigation, which is supplied at less than 1:50 year assurance. It can be deduced by comparing the equivalent water requirements for agriculture at 1:50 year assurance, shown in Table 5.1.1 with the same requirements at no assurance, that the equivalent requirements are about 85% of the latter. This provides a very approximate basis for comparing allocations with 1:50 year yields.

The total allocation from the Riviersonderend-Berg River Scheme in 1995 was 245 million m^3/a, including allocations to the Berg WMA, which compares with a 1:50 year yield of 224 million m^3/a. However, the total water use from the scheme between the end of June 1995 and the beginning of July 1996 was, according to DWAF records, only 190 million m^3, which is 77% of the allocation and less than the 1:50 year yield of the scheme. The water use in the Breede WMA was 65% of the allocations to users within the WMA.

The low water use in 1995 relative to allocations may be ascribed partially to farmers not having developed land for which they had acquired irrigation rights and partially to good rains that fell at the end of winter and in mid-summer and resulted in the requirement for irrigation water being about 20 million m^3 less than it would normally have been. (Deduced from DWAF records of annual quantities of water supplied from Theewaterskloof Dam). Water use was exceptionally low in 1995, but it is less than the allocations in most years, possibly because some farmers may use their allocations as insurance against drought because they do not pay for the allocated water if they do not use it.

The total allocation from Elandskloof Dam was 13,75 million m^3/a which was slightly higher than the 1:50 year of 12 million m^3/a. The volume of water actually supplied from the dam is normally about 11 million m^3/a (DWAF, 2001), which suggests that the area under irrigation may be less than the scheduled area.

The Sanddrift Government Water Scheme has a 1:50 year yield of 9 million m^3/a, before allowing for compensation releases. The allocations from the scheme listed in Tables 5.13.2.1 and 5.13.2.2 totalled 9,26 million m^3/a. In addition, 2,5 million m^3/a of water is supplied in summer as compensation flow, 0,14 million m^3/a is allocated to releases into the river in summer in compliance with water court orders, and 0,6 million m^3/a is allocated under a separate agreement (apparently not an Article 56(3) allocation) to industrial use in the Hex River valley. This brings the total allocation to 12,5 million m^3/a (DWAF, 2001). Actual use is reported (DWAF, 2001) to be about 11,7 million m^3/a, which can be supplied at less than 1:5 year assurance.

Allocations from Brandvlei Dam in 1995 totalled 164,56 million m^3/a, which exceeded the 1:50 year yield of the dam of 152 million m^3/a. In addition to the allocations, water needs to be released for conveyance losses, which are estimated to be about 20% of the allocations, and for freshening releases to maintain acceptable water quality in the Breede River in summer. The available water in most years is less than the allocations and is supplied pro rata to the allocations (DWAF, 2001).

It was mentioned earlier that allocations of water from Government Water Schemes to irrigation in 1995 accounted for only 75% of the total allocations in irrigation districts. In amplification of this, scheduled areas and known allocations in irrigation districts are shown per key area in Table 5.13.3.1. Estimates of actual areas irrigated and of actual field edge water requirements, obtained respectively from Table 3.5.2.1 and Table 5.6.2.1, are also shown.

It can be seen that in the Palmiet Catchment, and in the Breede Catchment upstream of the Riviersonderend confluence, the scheduled areas are roughly half of the total irrigated areas. In contrast, the total scheduled area in the Riviersonderend Catchment is greater than the estimated actual area of irrigated land. This may mean that the true area of irrigated land is greater than estimated or, alternatively, that all the land that is scheduled has not been developed.

Table 5.13.3.1 also shows that in all areas except the Riviersonderend and middle Breede River valleys, the estimated actual field edge water requirement is much greater than the allocations within irrigation districts. This suggests that considerable quantities of water are obtained from what were irrigators "own sources" in 1995. These included boreholes which were estimated to have supplied about 9% of the total irrigation requirements in 1995.

5.14 EXISTING WATER TRANSFERS

5.14.1 Introduction

Utilisation of the water related infrastructure described in Chapter 4 results in many transfers of water between river basins as well as transfers between quaternary catchments in the same river basin that would not occur naturally. In the context of the water resources of the Breede WMA, these transfers fall into two categories, namely :

- transfers between WMAs, which result in an increase (for imports) and a decrease (for exports) in the total water resources of the Breede WMA, and
- transfers between quaternary catchments within the Breede WMA, which would not occur under natural conditions and which affect the water resources in localised areas but do not affect the quantum of the water resources of the Breede WMA as a whole.

The transfers in both categories are shown on Figure 5.14.1 and are described below.

TABLE 5.13.3.1: SUMMARY OF AREAS OF LAND SCHEDULED IN IRRIGATION DISTRICTS IN 1995

CATCHMENT						SCHEDULED AREA	APPROXIMATE ALLOCATION OF WATER	ESTIMATED ACTUAL AREA IRRIGATED	ESTIMATED ACTUAL FIELD EDGE WATER REQUIREMENT
PRIMARY		SECONDARY		TERTIARY/QUATERNARY					
No.	**Description**	**No.**	**Description**	**No.**	**Description**	**(ha)**	**(million m^3/a)**	**(ha)**	**(million m^3/a)**
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	5 460	29	7 630	53,4
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	0	0	3 680	25,8
		G5	Eastern Overberg	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0	0	60	0,3
		TOTAL IN PALMIET AND OVERBERG				**5 460**	**29**	**11 370**	**79,5**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	2 805	23	6 970	48,8
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	3 090	Not known (1)	14 180	99,3
		H20	Hex	H20A to H	Hex River Valley	4 212	14	5 180	36,3
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	24 722	200 (2)	39 950	237,6
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**34 829**	**227**	**60 280**	**422,0**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	3 733	27	4 870	31,2
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	6 018	47	3 640	23,3
		TOTAL RIVIERSONDEREND				**9 751**	**74**	**8 510**	**54,5**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	1 450	9	5 230	31,9
		TOTAL IN BREEDE BASIN				46 030	**310**	**74 020**	**508,4**
TOTAL IN BREEDE WMA						**51 490**	**339**	**85 390**	**587,8**

(1) Allocations are in terms of fractions of streamflow and the quantities supplied are not measured.
(2) Excludes the allocations to 1 474 ha for which the quantities allocated are not known. The 1 474 ha is included in the total scheduled area of 24 722 ha shown for this catchment.

5.14.2 Transfers Between Water Management Areas

There are two schemes that make major transfers from the Breede WMA to the Berg WMA. These are the Riviersonderend/Berg River Scheme, which in summer transfers an average of 186 million m^3/a to the Berg WMA, and the Palmiet Scheme which has been in operation only since 1998 and which has been estimated from flow records for the Palmiet River to be capable of transferring an average of 29 million m^3/a and 23 million m^3/a at 1:50 year assurance.

In the Riviersonderend/Berg River Scheme, average transfers of 25 million m^3/a are made from the Berg WMA to Theewaterskloof Dam in the Breede WMA during the winter months. Thus the net transfer out of the Breede WMA via this scheme is 161 million m^3/a.

A further 9 million m^3/a is transferred from the Breede WMA to the Berg WMA via two smaller schemes : a canal from Michell's Pass (H10C) transfers approximately 4 million m^3/a to the Klein Berg River catchment (G10E) for irrigation, and 5 million m^3/a is transferred, also for irrigation, from the Wit River catchment (H10E) to the Kromme River catchment (G10D).

The only other transfers out of the Breede WMA are the Inverdoorn Canal Scheme which transfers 2,5 million m^3/a of water for irrigation from catchment H20C in the Breede WMA to catchment E22C in the Olifants/Doring WMA, and the Du Toits River to Franschhoek transfer which supplies 0,6 million m^3/a to water from catchment H60B to the town of Franschheok (G10A) in the Berg WMA.

There is a small import to the Breede WMA from the Gouritz WMA via the Duiwenhoks Rural Water Supply Scheme. The scheme supplies consumers in both WMAs and the quantity supplied to the Breede WMA is not accurately known, but is estimated from population data to have been about 0,4 million m^3 in 1995. Transfers between WMAs are summarised in Table 5.14.2.1.

TABLE 5.14.2.1: 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 (	TOTAL
TRANSFERS OUT OF WMA :						
Theewaterskloof Dam to Cape Town and Berg River	Breede	Berg	186,0	186,0	0	186,0
Gawie se Water	Breede	Berg	5,0	5,0	0	5,0
Dwarsrivier	Breede	Berg	4,0	4,0	0	4,0
Inverdoorn Canal	Breede	Olifants/Doring	2,5	2,5	0	2,5
Du Toits River to Franschhoek	Breede	Berg	0,6	0,6	0	0,6
TRANSFERS INTO WMA :						
Duiwenhoks	Gouritz	Breede	0,4	0,4	0	0,4
Berg River to Theewaterskloof Dam	Berg	Breede	25,0	25,0	0	25,0
Total water exports in 1995	:	198,1 million m^3				
Total water imports in 1995	:	25,4 million m^3				

(1) Losses are not known and have therefore been assumed to be zero.

5.14.3 Transfers within the Breede WMA

It can be seen from Figure 5.14.1 that a number of transfers occur within the Breede WMA. Information on these is summarised in Table 5.14.3.1. The Ruensveld West and Ruensveld East transfers provide water for rural household use, livestock and some towns, and are therefore shown as urban transfers. The Stettynskloof to Worcester transfer is entirely for urban use and is shown as such. Even though some of the other transfers within the WMA have an urban component, they are predominantly for irrigation and are, therefore, shown as irrigation transfers. Details of urban components are given in the descriptions of infrastructure in Chapter 4.

TABLE 5.14.3.1: AVERAGE TRANSFERS WITHIN THE BREEDE WMA AT 1995 DEVELOPMENT LEVELS

DESCRIPTION OF TRANSFER	SOURCE & QUATERNARY	DESTINATION & QUATERNARY	QUANTITY (million m^3/a)
Ruensveld West Rural Water Supply Scheme	Riviersonderend from Thee-waterskloof Dam (H60D)	Caledon and Overberg rural areas H60E, F, G, H, J. G40F, K G50D, G	3,2
Ruensveld East Rural Water Supply Scheme	Riviersonderend and Thee-waterskloof Dam (H60K)	Overberg rural areas H60J, L, H70A, G, H G50D to G50J	0,8
Rooikloof Irrigation District	Rooikloof Dam (H10B)	Farm dams H10A	0,7
Stettynskloof to Worcester	Stettynskloof Dam (H10K)	Worcester (H20H)	13,0
Sanddrift Scheme	Roode Elsberg Dam (H20D)	Hex River valley (H20B, H20F)	8,5
Agterkliphoogte Irrigation District	Breede River (H40J)	Farm dams (H40G)	2,1
Uitnood Irrigation District	Breede River (H40L)	Farms dams (H40K)	1,4
Cogmanskloof Irrigation District	Breede River (H40L	Storage dams (H30A, B, C, D, E)	13,3

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. About 94% of the water requirements in the WMA (excluding transfers to other WMAs) are for irrigation. Conveyance losses (excluding evaporation losses from storage in farm dams) were estimated to be 15% of the field edge requirement, or 13% of the total irrigation requirement including losses. Evaporation losses from farm dams and water used for freshening releases in the Breede River are included in losses from rivers, wetlands and dams.

Urban losses, which include conveyance losses, unaccounted for water, and leakage in the reticulation system are estimated to be 25% of the total urban requirement, including losses. The relative sizes of the losses occurring in the different water use sectors are shown on Diagram 5.15.1.

The return flows from irrigation are re-usable, but in the middle and lower reaches of the Breede River they are saline owing to natural soil salinity and need to be diluted by freshening releases of low salinity water from Brandvlei Dam before they can be re-used. Most of the urban return flows are re-usable, except for about 3 million m^3/a from coastal towns which are discharged either directly to the sea or into watercourses too close to the coast for re-use. The relative proportions of return flows from the different user sectors are shown on Diagram 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			588	92	13	53
Urban			27	9	25	21
Rural			11	2	20	0
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, dams			0	111	--	0
TOTAL			626	**214**	**--**	**74**

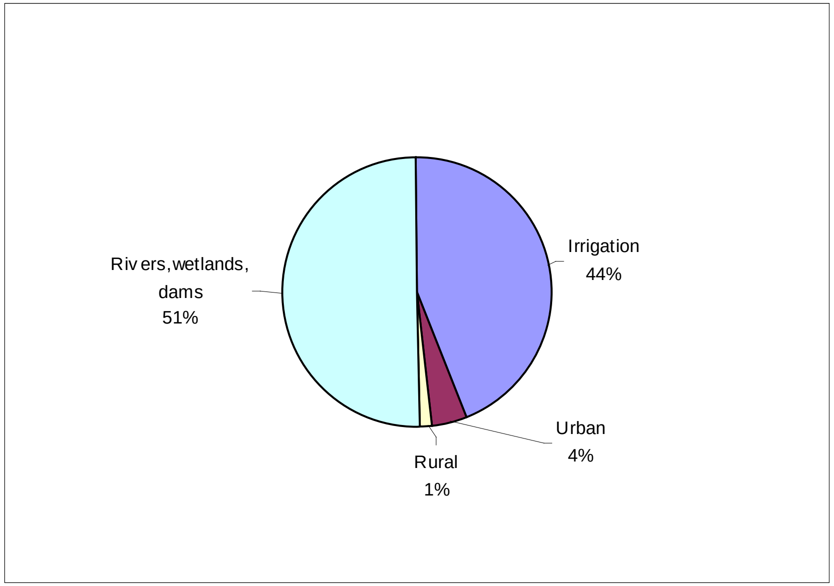


Diagram 5.15.1: Category loss as a proportion of the total losses in the WMA

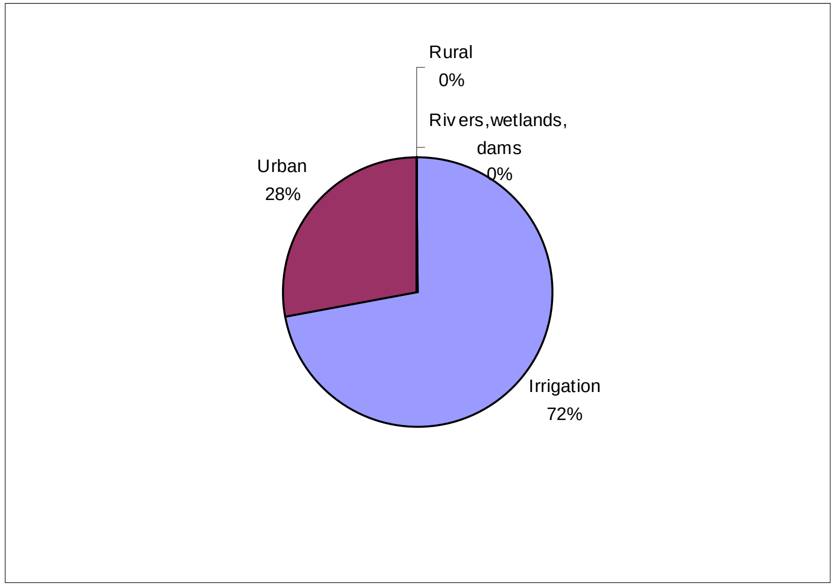


Diagram 5.15.2: Category return flow as a proportion of the total return flow in the WMA

CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

It has been estimated from 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 MAR of the Breede WMA was 2 472 million m^3. Approximately 76% of this, or 1 882 million m^3, flowed out to sea through the mouth of the Breede River. A further 14%, or 341 million m^3 flowed out to sea from the catchments of the Palmiet and Bot Rivers. The remaining 10% of the runoff, or 249 million m^3 came from the catchments of the smaller rivers along the southern edge of the WMA.

The natural runoff has been reduced by the construction of dams, the pumping of water from rivers and, to a small extent, by the effects of timber plantations and alien vegetation. As a result, the present day MARs at the river mouths are reduced.

The natural MAR in the Palmiet River estuary is estimated to be 252 million m^3 and the present day MAR, 192 million m^3, a reduction of 60 million m^3 (DWAF, 1999f). For the Breede River estuary the present day MAR is estimated 1 034 million m^3 (DWAF, 2002), which is 848 million m^3/a less than the natural MAR. This is a reduction of 45% of the natural runoff. The present day MAR from the Overberg East and Overberg West areas is estimated from the water use and return flow data provided in this report to be 135 million m^3. Thus, the present day MAR for the whole WMA is estimated to be 1 361 million m^3.

Table 6.1.1 shows the distribution of natural runoff within the Breede WMA, the 1:50 year yield developed in 1995, and the estimated total potential 1:50 year yield. The total potential 1:50 year yield is the maximum quantity of water that could be abstracted at 1:50 year assurance from the water resources of the WMA if the maximum economically sustained combination of dams and boreholes were to be constructed. The developed yields in 1995 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 other water users in the allocation of water resources, the yield available for other user sectors is less than the totals shown in Table 6.1.1. It has been estimated, as described in Chapter 7, that the effect of making releases for the ecological Reserve, once the details of the releases have been determined and implemented, will be to reduce the 1:50 year yield available for other users by about 67 million m^3/a. Riverine ecologists believe that the Reserve requirements have been under-estimated, in which case the reduction in yield would be greater.

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.

TABLE 6.1.1: WATER RESOURCES

CATCHMENT						SURFACE WATER RESOURCES (million m^3/a)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL (million m^3/a)		TOTAL WATER RESOURCES (million m^3/a)	
PRIMARY		SECONDARY		QUATERNARY								
No.	Description	No.	Description	No.	Description	CUMULATIVE NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995 (1)	1:50 YEAR TOTAL POTENTIAL YIELD (2)	DEVELOPED IN 1995	TOTAL POTENTIAL (3)	YIELD DEVELOPED IN 1995 (million m^3/a)	1:50 YEAR TOTAL POTENTIAL (4)] YIELD (million m^3/a)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	302	76	103	0,5	44	76,5	103,5 (5)
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	178	11	19	2,5	51	13,5	21,5 (5)
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	110	2	2	1,4	29	3,4	30,2 (6)
		TOTAL IN PALMIET AND OVERBERG				**590**	**89**	**124**	**4,4**	**124**	**93,4**	**155,2**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	155	28	40	18,5	19	46,5	58,5 (5)
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	861	274	369	32,3	85	306,3	401,3 (5)
		H20	Hex	H20A to H	Hex River Valley	105	16	19	20,5	28	36,5	45,3
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	1 213	56	56	28,8	77	84,8	132,5 (6)
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**1 213**	**374**	**483**	**100,1**	**209**	**474,1**	**636,6**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	291	259	259	1,5	23	260,5	260,5 (5)
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	460	18	18	0,4	9	18,4	26,0 (6)
		TOTAL RIVIERSONDEREND				**460**	**277**	**277**	**1,9**	**32**	**278,9**	**286,5**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	1 883	31	61	2,9	9	33,9	63,9 (5)
		TOTAL IN BREEDE BASIN				**1 883**	**682**	**822**	**104,9**	**250**	**807,9**	**988,0**
TOTAL IN BREEDE WMA						**2 473**	**771**	**946**	**109,3**	**374**	**880,3**	**1143,2**

1. Includes yields of major dams and minor farm dams existing in 1995 and run-of-river yields utilised in 1995.
2. The maximum quantity of water that could be abstracted from the surface water resources of the WMA, after allowing for ecological flow requirements, if storage dams of the maximum economically viable capacity were provided and no additional groundwater connected to surface water base flow was abstracted.
3. The maximum quantity of groundwater that could be abstracted at 1:50 year assurance if sufficient boreholes were developed.
4. The maximum quantity of surface water and groundwater combined that can be abstracted by providing sufficient boreholes and sufficient economically viable dams.
5. Comprising total surface water potential plus groundwater yield developed in 1995.
6. Comprising total surface water potential plus total groundwater potential not contributing to baseflow.

In an assessment of the extent to which the groundwater resources are additional to the surface water resources of the Breede 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. It has, however, also been assumed that the surface water yields determined for development in 1995 made allowance for the effects on surface water runoff of groundwater use as it was in 1995. Therefore, in Table 6.1.1, the total water resource developed in 1995 is the sum of the developed surface water and groundwater yield. The total potential water resource includes, in addition to the surface and groundwater development in 1995, all potential additional surface water resource developments that comprehensive separate detailed studies have shown to be economically viable. However, the development of the full groundwater potential that was not developed in 1995 has been added only in those areas not suitable for significant further surface water development, and where it will not affect large existing surface water resource developments. It has been simplistically assumed that in other areas, any further development of groundwater yield would result in an equal reduction in surface water yield. The areas in which further development of groundwater has been added to the total potential water resource are described in Section 6.2.

The total developed water resource (excluding imports from other WMAs) in 1995 was estimated to have a yield, at 1:50 year assurance, of 880 million m^3/a (771 million m^3/a from surface water and 109 million m^3/a from groundwater). The total potential yield at 1:50 year assurance is estimated to be 1 143 million m^3/a. The distribution of the yield in 1995 is shown diagrammatically on Figure 6.1.1 and Figure 6.1.2 shows the total potential yield.

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).

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 (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		QUATERNARY						
No.	Description	No.	Description	No.	Description					
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	44	0,5	43,5	15,5	28,5
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	51	2,5	48,5	1,7	49,3
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	29	1,4	27,6	0,8	28,2
		TOTAL IN PALMIET AND OVERBERG				**124**	**4,4**	**119,6**	**18,0**	**106,0**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	19	18,5	0,5	2,1	16,9
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	85	32,3	52,7	17,0	68,0
		H20	Hex	H20A to H	Hex River Valley	28	20,5	7,5	1,7	26,3
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	77	28,8	48,2	0,5	76,5
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**209**	**100,1**	**108,9**	**21,3**	**187,7**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	23	1,5	21,5	6,1	16,9
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	9	0,4	8,6	1,0	8,0
		TOTAL RIVIERSONDEREND				**32**	**1,9**	**31,1**	**7,1**	24,9
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	9	2,9	6,1	5,3	3,7
		TOTAL IN BREEDE BASIN				**250**	**104,9**	**145,1**	**33,7**	**216,3**
TOTAL IN BREEDE WMA						**374**	**109,3**	**264,7**	**51,7**	**322,3**

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 Figure 6.2.3). 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. However, in the case of the Breede WMA, most of the potential for groundwater development is downstream of the major dams that have been constructed to develop surface water yield. Therefore, for the purpose of this water resources assessment the portion of the utilisable groundwater not contributing to the base flow of the surface water has been added to the developed surface water yield in 1995 to estimate the total utilisable resources.

The existing groundwater use was determined by Baron and Seward (2000). Estimates of groundwater use were also made at a workshop held in the Breede 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). 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.

In the Breede WMA, groundwater is heavily utilised only in catchment G10C. It is under-utilised in all the other catchments.

Total groundwater use in 1995 was estimated to be 109 million m^3, of which about 3,5 million m^3 was for municipal use, 0,5 million m^3 for livestock, and 105 million m^3 for irrigation. About 60 million m^3/a of the agricultural use is in the Warmbokkevled and the Breede River valley upstream of Brandvlei Dam, about 20 million m^3/a in catchments H40C to H40G, and the remainder is spread throughout the Breede and Riviersonderend valleys (see **Appendix G** for details).

In estimating the total potential water resource, it has been assumed that the total utilisable groundwater exploitation potential in the Overberg East area (G50A to G50K) not contributing to base flow, amounting to some 28 million m^3/a (see Table 6.2.1), will contribute as there is little potential for the development of surface water in this area.

The utilisable groundwater exploitation potential not contributing to baseflow of the Hex River valley (H20A to H20H), amounting to 26 million m^3/a, and of the Middle Breede catchments (H3, H4 and H5), amounting to 77 million m^3/a has been assumed to contribute to the total potential water resource. It has also been assumed that the groundwater potential developed in 1995 in the other catchments of 59 million m^3/a will continue to contribute to the total resource. Thus, the total contribution of groundwater to the total potential water resource shown in Table 6.1.1 is 190 million m^3/a.

The City of Cape Town is currently investigating the possibility of extracting water from deep boreholes in aquifers of the Table Mountain Group of geological strata. Several possible areas have been identified in the Breede WMA along its boundary with the Berg WMA (catchments G40C, H60A, H60B, H60C, H40E, H10L). One of these areas, to the south-west of Theewaterskloof Dam in catchment H60B, has been investigated in slightly more detail than the others and it has been estimated (City of Cape Town 2002a) that 15 million m^3/a could be abstracted from 10 deep boreholes and pumped into Theewaterskloof Dam when storage capacity is available in the dam.

It is not known what the effects of these wellfields, if developed, would be on surface water yield, or if their development would be cost effective. Therefore, the potential of these deep aquifers has not been included in the estimated total potential resource shown in Table 6.1.1. Similarly, because the economic feasibility of exploiting these aquifers is still being investigated, their yield is not included in the other figures and tables in this chapter, or in Appendix G.

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 natural 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 natural flow time series generated for the whole calibration catchment.

(3) The natural 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) natural 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 natural 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) natural flows and the re-calibrated "true" natural flows were within 5%, which was considered to be acceptable.

Based on the three steps described above, the WR90 natural 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 Breede WMA the adjustments showed decreases in MARs of less than 1% in the Palmiet River catchment (G40C to G40G) and negligible changes in the other afforested areas.

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 that :

- The updated afforestation water use was estimated by means of the CSIR curves (as described in (3)), but the uncorrected natural 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 natural 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 natural MAR of the total catchment less accurate, as the MARs of unafforested catchments were not adjusted.

In areas where the adjustments made for afforestation have caused significant changes to the MARs, the perfect solution would be to re-calibrate all affected catchments. However, this is not necessary for the Breede WMA as the changes were negligible.

Two detailed studies of the hydrology of portions of the Breede WMA have been carried out in the past and a third study is in progress at present.

- The Western Cape System Analysis, carried out by Ninham Shand and BKS, investigated the Upper Riviersonderend catchment (DWAF, 1994) and the Palmiet River catchment (DWAF, 1993).

- The Breede River Hydrological Study (DWAF, 1995) investigated the hydrology of the Breede River catchment upstream of the confluence with the Riviersonderend.

- The Skuifraam Dam Feasibility Study (DWAF, 1997) investigated the hydrology of the Riviersonderend catchment upstream of Theewaterskloof Dam.

- The current Breede River Basin Study is investigating the hydrology of the whole of the Breede River Basin, including the Riviersonderend catchment.

After comparing the WR90 data with the results of these studies, the natural MAR of catchment G40C was increased from 105,6 million m^3 to 109,7 million m^3 to agree with hydrology used in the Western Cape System Analysis, which was deemed to be more reliable. Similarly, the natural MAR of catchment H20C was increased from 3,6 million m^3 to 8,4 million m^3 to agree with the value derived during the Breede River Basin Study.

No other changes were made to the WR90 values. However, it has been found in the work carried out for the Breede River Basin Study that there are insufficient rainfall gauges in the high lying mountainous areas where rainfall is higher than it is in the valleys, and where most of the runoff from the catchment originates. It is, therefore, important to establish additional rainfall stations at appropriate locations within the catchment to achieve a good spatial coverage. The quality of the data at some of the existing rainfall stations was found to be poor. It is also important that the gathering of rainfall records from existing stations be continued and that the quality of the data be maintained or improved, as applicable.

The number and distribution of streamflow gauges within the Breede WMA is good and runoff is measured at most of the significant points. One point at which a gauge is lacking is close to the head of the Breede River estuary. This is required to provide the information needed to improve estimates of the ecological freshwater flow requirements of the estuary. A rated river section with gauge plates would suffice for this purpose. The distribution of natural MAR within the WMA is shown in Figure 6.3.1.1, and the natural MAR per key area is shown in Table 6.3.1.1, which also shows the estimated developed yield of the surface water resources in 1995 and the estimated total potential surface water yield. An explanation of the derivation of these values follows.

6.3.2 Yield Analysis

The yields obtainable from the water resources of different portions of the Breede WMA have been investigated in several separate studies. These include :

- The Western Cape System Analysis in which the yields of the existing dams and the development of the full potential yields of the Palmiet catchment (DWAF, 1999c) and the upper Breede catchment (DWAF, 1990) were investigated.
- An investigation into further development of the water resources of the Hex River Valley (Hexvallei Irrigation Board, 1997).
- An investigation of the water resources of the Eastern Overberg area (DWAF, 1998b).
- An investigation of the bulk provision of water to the Greater Hermanus Area (Greater Hermanus Municipality, 1999).
- The current Breede River Basin Study in which various schemes for the future development of the water resources are being investigated.

The results of these investigations, together with the yields of existing dams determined from the sources listed in Table 4.1.1, and the information on farm dams listed in Table 4.1.2, were used to derive the 1995 and total potential yields of dams. (The yields of the farm dams were roughly estimated from their capacities and surface areas, as registered with DWAF, and consideration of annual average evaporation and rainfall data, to be approximately 85% of their capacity).

The run-of-river yields were estimated in consultation with officials of the DWAF Western Cape Regional Office on the following basis. It was assumed that, because of the high investment cost of developing the vineyards and orchards that are the predominant crops grown under irrigation in the WMA, the development of irrigated land has been balanced against the availability of water. In this regard, the availability of water from what was private water and from riparian water allocations is seen as particularly important because it costs less than water supplied from government water schemes. As the yield from "private" sources is not well documented, it was assumed that the portion of estimated irrigation requirements that is not provided for from government water schemes is provided from farm dams and run-of-river yield. Thus, the run-of-river yield was calculated by subtracting the yields of major dams allocated to irrigation, and the estimated yields of farm dams, from the equivalent 1:50 year irrigation requirement after adjusting it for re-used return flows.

TABLE 6.3.1.1: SURFACE WATER RESOURCES

CATCHMENT						CATCHMENT AREA (km^2)	MEAN ANNUAL PRECIPITATION (mm/a)	MEAN ANNUAL EVAPORATION (mm/a)	NATURAL MAR		INCREMENTAL YIELD (1:50 YEAR)	
PRIMARY		SECONDARY		QUATERNARY								
No.	Description	No.	Description	No.	Description				INCREMENTAL (million m^3/a)	CUMULATIVE (million m^3/a)	DEVELOPED IN 1995 (million m^3/a)	TOTAL POTENTIAL (million m^3/a)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay Coast	594	1 068	1 414	302	302	76	103
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uilkraals	2 392	588	1 425	178	178	11	19
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	4 128	428	1 449	110	110	2	2
		TOTAL IN PALMIET AND OVERBERG				**7 114**	**535**	**1 438**	**590**	**590**	**89**	**124**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	656	625	1 657	155	155	28	40
		H10 (part)	Upper Breede	H10D to L	Catchment above Brandvlei Dam	1 391	1 045	1 600	706	861	274	369
		H20	Hex	H20A to H	Hex River Valley	832	612	1 657	105	105	16	19
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	4 512	426	1 560	247	1213	56	56
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**7 391**	**581**	**1 587**	**1213**	**1213**	**374**	**484**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam Catchment	500	1 137	1 464	291	291	259	259
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	1 741	489	1 426	169	460	18	18
		TOTAL RIVIERSONDEREND				**2 241**	**633**	**1 434**	**460**	**460**	**277**	**277**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	2 922	446	1 433	210	1883	31	61
		TOTAL IN BREEDE BASIN				**12 554**	**559**	**1 524**	**1883**	**1883**	**682**	**822**
TOTAL IN BREEDE WMA						**19 668**	**550**	**1 493**	**2473**	**2473**	**771**	**946**

On the above basis, developed surface water yields of key areas shown in Table 6.3.1 were derived as follows :

- Palmiet River area (G40B, G40C, G40D)
  - the combined yields of the Nuweberg, Grootvlei, Eikenhof, Applethwaite and Arieskraal Dams of 43 million m^3/a.
  - the impact of the ecological Reserve on the yield of Kogelberg Dam of 12,5 million m^3/a (as described in Section 4.2.2, the yield of Kogelberg was in 1995 allocated to meeting ecological flow requirements only).
  - the combined yields of the smaller farm dams of 17 million m^3/a.
  - run-of-river yield of 3,5 million m^3/a

    to give a total yield of 76 million m^3/a.

- The Overberg West area (G40E to G40M)
  - the combined yields of De Bos, Fisherhaven and Franskraal Dams of approximately 4 million m^3/a.
  - the yield of farm dams and run-of-river yield, combined, of 7 million m^3/a

    to give a total yield of 11 million m^3/a.

- The Overberg East area (G50A to G50K)
  - run-of-river yield of 1,1 million m^3/a.
  - a yield from farm dams of 0,5 million m^3/a.
  - the yield of Klein Sanddrif Dam of 0,4 million m^3/a

    to give a total yield of 2 million m^3/a.

- The Warm Bokkeveld (H1AB, H10B, H10C)
  - a yield of 25 million m^3/a from farm dams and
  - a run-of-river yield of 3 million m^3/a,

    giving a combined yield of 28 million m^3/a.

- The Upper Breede area (H10D to H10L)
  - the yields of the major dams of Greater Brandlvei (152 million m^3/a) and Stettynskloof (25 million m^3/a) totalling 177 million m^3/a.
  - the yield of Fairy Glen Dam and farm dams totalling 3 million m^3/a.
  - run-of-river yield of 94 million m^3/a

    giving a total yield of 274 million m^3/a.

- The Hex River Valley (H20A to H20H*)*
  - the combined yields of Lakenvallei and Roode Elserg Dams of 9 million m^3/a.
  - the combined yields of farm dams of 6 million m^3/a.
  - run-of-river yield of 1 million m^3/a

    to give a total yield of 16 million m^3/a.

- The Middle Breede area (H3, H4, H5)
  - the combined yields of Poortjieskloof, Pietersfontein, Keerom, Draaivlei and Klipberg Dams of 10 million m^3/a.
  - the combined yields of small farm dams and Knipes Hope Dam of 20 million m^3/a.
  - run-of-river yield of 26 million m^3/a

    giving a total yield of 56 million m^3/a.

- The Upper Riviersonderend area (H60A to H60C)
  - the combined yields of Theewaterskloof Dam and Elandskloof Dam of 216 million m^3/a.
  - the combined yields of farm dams of 15 million m^3/a.
  - run-of-river yield of 28 million m^3/a
    to give a total yield of 259 million m^3/a.

- The Lower Riviersonderend area
  - the combined yields of farm dams of 3 million m^3/a.
  - run-of-river yield of 15 million m^3/a
    to give a total yield of 18 million m^3/a.

- The Lower Breede area (H70A to H70K)
  - the yield of Buffeljagts Dam of 11 million m^3/a.
  - the yield of farm dams of 3 million m^3/a.
  - run-of-river yield of 17 million m^3/a.
    to give a combined yield of 31 million m^3/a.

The approaches to determining the yields of farm dams and run-of-river yield described above led to an estimated yield from these sources combined in the Upper and Middle Breede areas (H10D to H10L, H3, H4, H5) of 140 million m^3/a. From subsequent consideration of the estimated capacity of farm dams in the areas and of run-of-river yield derived by means of the WR90 Deficient Flow-Duration-Frequency curves for 1:50 year drought conditions (Midgley *et al*, 1994), it appears that the estimate of 140 million m^3/a may be too high. The combined capacity of farm dams is estimated to be 27 million m^3, and as these are filled by natural runoff, diversion furrows, and pumping from rivers during the winter months, and used for irrigation during the summer months, they can be expected to give a yield of about 23 million m^3/a. From consideration of the WR90 curves, it appears that a run-of-river yield of about 15 million m^3/a could be obtained during the six months of summer under 1:50 year drought conditions. On this basis, the yield from farm dams and run-of-river flow would total 38 million m^3/a, which is considerably less than 140 million m^3/a assumed for this situation assessment. This aspect requires further investigation.

Similar considerations apply to most of the other areas. The exceptions are the Warm Bokkeveld, Hex River Valley and Palmiet where the original estimates appear to be reasonable. The original estimates have been adjusted in the Overberg West area because the originally assumed contribution of the 1:50 year run-of-river yield seemed to be unrealistically high. In the other areas the original higher estimates have been retained as, historically, there have not been sustained shortages of water for irrigation. Nevertheless, it should be noted that the quantity of water obtained from local sources needs to be reliably established.

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. Net incremental storage capacities have been adopted within the WMA for each group of quaternary catchments that falls within the same hydrological zone, as defined in WR90 (Midgley *et al*, 1994). 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.

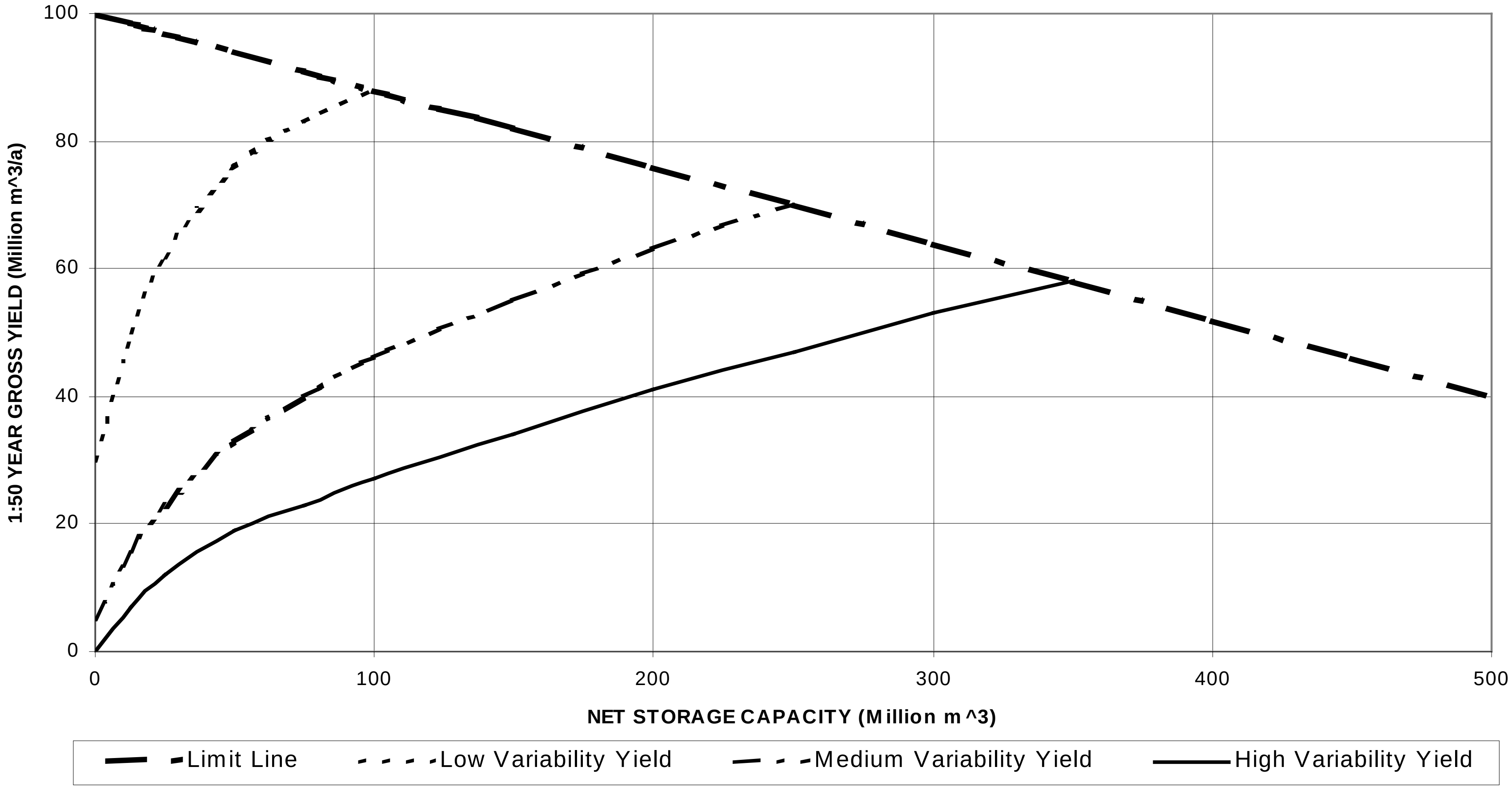


DIAGRAM 6.3.1: DAM STORAGE LIMITS

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 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 6.3.1. 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 6.3.1. This is illustrated by means of the typical net storage-gross yield relationships shown in Diagram 6.3.1 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.

For the Palmiet River area and the Breede and Riviersonderend Rivers upstream of Brandvlei and Theewaterskloof Dams, respectively, the value is 150% of MAR. For the high rainfall area in the mountains adjacent to Swellendam (H70B, E, D, F) it is 100% of MAR. The values of 300% of MAR occur in the Hex River Valley and on the northern side of the Langeberg Mountain Range in catchments H40A, H40B and H70C. In the remainder of the WMA, the maximum feasible storage capacity is 200% MAR.

The total live storage capacity of dams in the Breede and Riviersonderend catchments in 1995 was estimated to have been 965 million m^3. This included 87 million m^3 of storage in farm dams. The storage of 965 million m^3 is 51% of the natural MAR of 1 882 million m^3. On the basis of the maximum feasible storage capacities, derived as described above, and the MARs of the various hydrological zones, there appears to be scope for the development of an additional 1 800 million m^3 of storage to fully utilise their potential yields.

It can be deduced using Diagram 6.3.1 and the MARs of the different hydrological zones that a total gross yield (i.e. before evaporation losses are allowed for) of about 1 548 million m^3/a could be expected if the additional storage were developed. The estimates, shown in Table 5.8.1, of evaporation losses from the existing dams in the WMA amount to approximately 9% of the capacity of the dams. If it is assumed that similar evaporation losses would occur from any new storage provided, the total potential net yield of the surface water resources of the Breede and Riviersonderend catchments is estimated to be 1 300 million m^3/a (1 548 million m^3/a gross yield – 248 million m^3/a evaporation losses).

The storage existing in 1995 (965 million m^3) has a yield of 498 million m^3/a. Therefore 1 800 million m^3 of additional storage would, together with any run-of-river yield abstracted, provide an additional 802 million m^3/a of yield.

Investigations of the ecological freshwater flow requirements of the Breede River estuary carried out as part of the Breede River Basin Study have indicated that the ecological flow requirements would limit the abstraction of water from the river system to between 80 million m^3/a and 140 million m^3/a more than was abstracted in 1995. If the estimated developed yield in 1995 of 682 million m^3/a (498 million m^3/a from dams and

184 million m^3/a from run-of-river) is correct, the upper limit of an additional 140 million m^3/a would limit total developable yield to 822 million m^3/a.

The total potential surface water yield of the Breede River Basin shown in Table 6.3.1.1 has been limited to 822 million m^3/a on that basis. Several different ways in which additional yield could be provided have been investigated in the studies referred to earlier in this section. For purposes of estimating the total potential yields of the key areas in the Breede and Riviersonderend catchments, developments as listed below, which would provide a total additional yield of 140 million m^3/a, have been assumed.

- The Warm Bokkeveld (H10A, H10B, H10C)
  - Koekedouw Dam was completed in 1998 with a live storage capacity of 22,5 million m^3. The dam has a 1:50 year yield of 17 million m^3/a, but it is estimated that a run-of-river yield of about 5 million m^3/a was obtained from the site prior to the construction of the dam. Thus, the net increase in yield is estimated to be 12 million m^3/a, bringing the total potential yield to 40 million m^3/a when added to the 1995 developed yield of 28 million m^3/a.

- The Upper Breede area (H10D to H10C)
  - a diversion scheme on the Molenaars River (H10J) which would transfer 20 million m^3/a of water to the proposed Skuifraam Dam in the Berg River catchment at 1:50 year assurance.
  - an 86 million m^3 capacity dam on the Wit River (H10F) which will provide an additional 48 million m^3/a of yield at 1:50 year assurance.
  - a diversion scheme on the Breede River at the foot of Michell's Pass which would transfer 27 million m^3/a of water to Voëlvlei Dam at 1:50 year assurance.

  These schemes will provide 95 million m^3/a of yield in addition to the estimated 1:50 year yield of 274 million m^3/a developed in 1995, thereby bringing the total potential yield to 369 million m^3/a. The total storage will be 380 million m^3 regulating an MAR of 706 million m^3/a.

- The Hex River Valley area (H20A to H20H)
  - construction of a 3,5 million m^3 capacity dam with a 1:50 year yield of 3 million m^3/a at Osplaas (H20B), to increase the total potential yield from the 16 million m^3/a developed in 1995 to 19 million m^3/a.

- The Middle Breede area (H3, H4, H5)
  - The total potential yield of 56 million m^3/a was fully developed in 1995.

- The Upper Riviersonderend area (H60A to H60C)
  - No additional surface water yield assumed to the total of 259 million m^3/a developed in 1995.

- The Lower Riviersonderend area (H60D to H60L)
  - No additional surface water yield assumed to the total of 18 million m^3/a developed in 1995.

- The lower Breede area (H70A to H70K)
  - the raising of the existing Buffelsjagts Dam to increase its 1:50 year yield by 30 million m^3/a, which, added to the estimated developed yield in 1995 of 31 million m^3/a, would bring the total potential yield to 61 million m^3/a.

Thus, the total additional storage provided in the Breede River Basin would be 131 million m^3 for an increase in yield of 93 million m^3/a. An additional 47 million m^3/a of yield would be provided by diversion schemes to storage in the Berg WMA.

The potential for the further development of the surface water resources of the catchments between the Breede River Basin and the coast appears, from studies carried out on the Palmiet River (DWAF, 1999e) and for water supplies to towns in the Western and Eastern Overberg (Greater Hermanus Municipality, 1999 and DWAF, 1998b) to be about 38 million m^3/a in addition to the yield developed in 1995, which was estimated to have totalled 89 million m^3/a. The remaining potential is distributed as described below :

- Palmiet River area (G40B, G40C, G40D)
  - the transfer from Kogelberg Dam to the Steenbras Dams which was implemented in 1999 and can provide 22,5 million m^3/a at 1:50 year assurance.
  - the raising of the existing Eikenhof Dam (G40C) to increase its capacity from 25,5 million m^3 to 30 million m^3, thereby providing additional yield of 4,5 million m^3/a.

  With these developments the total 1:50 year yield of the Palmiet area would be increased to 103 million m^3/a. Total storage capacity would be 81 million m^3, including 20 million m^3 in small farm dams. The storage would be only 27% of the MAR of 301,8 million m^3, but the ecological freshwater flow requirements of the Palmiet River would limit further development.

- The Western Overberg area (G40E to G40M)
  - the construction of Kraaibosch Dam (G40M) on the Uilkraals River was completed in 1999. The dam has a capacity of 5,5 million m^3 and a 1:50 year yield of 8 million m^3/a (V3 Consulting Engineers, 2002)

  The construction of Kraaibosch Dam brings the total storage capacity in the area to 12,7 million m^3, which is only 14% of the natural MAR of 178 million m^3. However, the potential for further development of the surface water resources is limited by the ecolgocial freshwater flow requirements of the estuaries, the small sizes of the rivers, and the high salinity of the water in some of the rivers. Thus, the total potential 1:50 year yield is estimated to be approximately 19 million m^3/a.

- The Eastern Overberg area (G50A to G50K)
  - no further development of surface water resources.

  Even though the natural MAR of this area is approximately 110 million m^3, and the capacity of storage dams in 1995 totalled only 2,5 million m^3, or 2% of the MAR, there is little potential for further development of surface water yield because the runoff occurs in numerous small rivers, many of which are saline.

The above developments would require a total of 141 million m^3 in the basin as a whole to provide additional yield of 105,5 million m^3/a. The construction of two diversion schemes using storage outside the WMA would provide yield of 47 million m^3/a, and

Kogelberg Dam and the Palmiet Pumped Storage Scheme can be used to transfer 22,5 million m^3/a at 1:50 year assurance to the Berg WMA. The potential developments together with the developments that have occurred since 1995 would increase the 1:50 year yield from 771 million m^3/a by 175 million m^3/a to 946 million m^3/a.

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.

The surface water quality monitoring stations that were used to provide the data are shown in Figure 6.4.1.1. The distribution of monitoring stations in the upper and middle Breede River Basin is quite extensive and was sufficient to classify most of the quaternary catchments. The distribution of monitoring points in the Lower Breede River is quite sparse. There is no monitoring point on the Breede River downstream of the Buffelsjags River confluence that could be used to characterise water quality flowing into the Breede River Estuary. There are about 20 monitoring points in the G40 catchment. However, only about seven monitoring points complied with the criteria described below to classify the mineralogical status and only five of the twelve quaternary catchments could be classified. There were only four monitoring points in the G50 tertiary catchment and only two quaternary catchments could be classified.

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 the consultants to use only those data sets that spanned at least two years and contained at least 24 data points for analysis. These were to 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 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 (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 Red
Green	Green Yellow Red Purple	Green Yellow Yellow Red
Yellow	Yellow Red Purple	Yellow Red Purple
Red	Red Purple	Red Purple
Purple	Purple	Purple

The water quality of the Breede Water Management Area is summarised in Table 6.4.1.3 and is shown in Figure 6.4.1.1.

TABLE 6.4.1.3: SUMMARY OF MINERALOGICAL SURFACE WATER QUALITY OF THE BREEDE WATER MANAGEMENT AREA

SECONDARY CATCHMENT	NO OF QUATERNARY CATCHMENTS	NO OF QUATERNARY CATCHMENTS IN CLASS					
		BLUE	GREEN	YELLOW	RED	PURPLE	NO DATA
G40	12	3	1	1	0	0	7
G50	9	0	0	0	0	2	7
H10	11	10	1	0	0	0	0
H20	8	5	2	0	1	0	0
H30	5	0	1	0	0	4	0
H40	11	5	3	0	1	2	0
H50	2	0	2	0	0	0	0
H60	11	5	6	0	0	0	0
H70	10	1	2	0	0	0	7

The mineralogical surface water quality of the Breede Water Management Area was generally ideal to good in the upper reaches of the rivers but it became poorer towards the lower reaches, mainly as the result of agricultural return flows and natural geological formations. This was especially the case in some of the tributaries of the Breede River.

Salinity in the mainstream Breede River was ideal in the headwaters and increased slowly in a downstream direction. In the Middle Breede River, downstream of Brandvlei Dam, there was a rapid increase in salinity as a result agricultural return flows to the mainstream river and its tributaries. Salinity in this section of the river is controlled by releases from Brandvlei Dam to meet irrigation water quality requirements in the Middle Breede River. Downstream of Zanddrift Weir (the lowest salinity control point), high TDS concentrations occurred until the river was diluted by lower TDS water from the Riviersonderend River. There was a slow increase downstream of the Riviersonderend confluence until salinity in the Lower Breede River was again diluted by water with a lower salinity from the Buffelsjags River. There are no monitoring points between Swellendam and the Breede River Estuary to characterise the salinity status of the lower reaches of the Breede River.

The mineralogical water quality in the H10 catchment (Upper Breede River) was largely ideal. There was a small increase in salinity as a result of irrigation of deciduous fruit orchards in the Ceres area and vineyards in the Wolseley and Rawsonville area but this was mitigated by better quality water from most of the tributaries in the H10 catchment.

Salinities in the Hex River catchment (H20) were classified as ideal in the headwaters but then deteriorated to poor in the lower reaches of the river, largely as a result of irrigation runoff from vineyards and from geological sources.

Salinities in the Kogmanskloof catchment (H30) were high and classified as completely unacceptable. The cause of the poor mineralogical status was largely geological (naturally high salinity) with some contributions from irrigation return flows.

The H40 catchment in the upper reaches of the Middle Breede River contains a number of key tributaries that affect the salinity status, namely the Nuy River (H40 A, B and C), the Vink River (H40H), the Poesjenels River (H40G) and the Keisers River (H40K). In most of these tributaries the water quality was ideal in the headwaters but it then deteriorated to poor before it entered the Breede River. The cause of the poor quality in the lower reaches of the tributaries was related to irrigation runoff and the underlying salt bearing Bokkeveld sediments. Salinity in the Middle Breede River is controlled during the summer irrigation months by releases of low salinity water from Brandvlei Dam. The objective of the salinity control program is to supply irrigation water with a TDS concentration of less than 455 mg/ℓ for 50% of the time and, 30% of the water can vary between 455 and 780 mg/ℓ, and 20% of the water should not exceed 780 mg/ℓ TDS (DWAF, 2000). The control programme was largely successful and the targets were met most of the time.

Downstream of the Zanddrift Weir (H50 A and B), salinities in the Breede River deteriorated to a marginal water quality but improved downstream of the Riviersonderend confluence.

Water quality in the Riviersonderend River (H60) was classified as ideal in the upper to middle reaches (H60 A-E) and classified as good in the lower reaches (H60 F-L) as a result of a moderate increase in salinity due to agricultural activities in the catchment.

Water quality in the Lower Breede River (H70) was classified as marginal due to elevated salinities. The quality in some of the tributaries was probably good but there was insufficient data to classify these rivers.

The mineralogical status of the Palmiet and Rooi Els Rivers was classified as ideal and in the upper reaches of the Bot River it was classified as good. The mineralogical quality in the Klein and Onrus catchments was marginal and there was insufficient data and monitoring to determine whether this was valid for all the G40 J-L quaternary catchments. It was difficult to assess the salinity status of the G50 catchment because there was only one monitoring point on the De Hoop Vlei where the mineralogical status was classified as unacceptable, probably related to naturally high salinity in some of the coastal rivers.

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 salts (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, 1998c).

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 microbial 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 Breede WMA is given in Figure 6.4.3.1 and shows that there are apparently no areas with a medium to high risk of surface water faecal contamination. There are many quaternaries with no or missing data but the general trend in the Breede River WMA is that of a low risk of faecal contamination of surface waters.

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 sub-surface, 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 Breede 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 the risk of faecal contamination of groundwater is medium to low in the Overberg area but medium to high for the most of the Breede River Basin. Particular areas of high risk of groundwater contamination are catchments along the middle and lower Riviersonderend (H60 H, J, K and L), the Palmiet River Basin (H40C, D and B), the Doring River (H40D and F), the Keisers River (H40K), and the upper and lower reaches of the Kogmanskloof River (H30A and E).

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

There are a number of site specific or impact specific concerns in the Breede River Basin (Figure 6.4.4.1):

- The water of many of the mountain streams, particularly in the Western Overberg, is coloured dark brown due to the presence of humic substances. These streams are also naturally acidic with low pH values. This has implications for treating water for domestic water supplies. By the time the water reaches the foothills and lowlands, the low pH values have largely been neutralised.
- Turbidity in the Middle Breede River is unnaturally elevated during the low rainfall summer months as a result of irrigation water releases from Brandvlei Dam. This negatively affects the aquatic ecosystem because it affects light penetration and therefore primary productivity.
- Elevated nitrate levels have been observed in the mainstream Breede River during the winter high flow months. It appears to indicate wash-off of fertilizer from agricultural areas. This has not been observed in some of the tributaries that are not affected by intensive agriculture.
- A Water Research Commission project found pesticide residues in the water of the Hex River and concluded that pesticides may be a concern in other areas where intensive irrigation takes place.
- Concerns have been expressed about organic and nutrient pollution from aquaculture activities in largely natural mountain streams.

- There are signs of nutrient enrichment and eutrophication in the middle and lower reaches of the Breede River. These signs include large stands of rooted macrophytes and filamentous algae.
- Water quality in the Middle Breede River up to the Zanddrift Canal is good because it is managed to meet the water quality requirements of irrigation farmers. Any development in the catchment that would reduce the amount of dilution in the Middle Breede River, would have a large negative effect on salinities in the Middle and Lower Breede River and would have a cumulative negative effect on aquatic ecosystems in these river reaches.

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 Breede WMA are shown in Table 6.5.1. It can be seen that measured yields vary from 1 t/km^2.a for Klipberg Dam to 269 t/km^2.a for Pietersfontein Dam. The wide variation may be caused by any of a number of factors which include :

- accelerated erosion caused by agricultural or forestry activities;
- differences in the accuracies of dam basin surveys by means of which the sediment accumulation was measured;
- steepness of the dam catchment and local geological conditions;
- the presence of upstream dams acting as silt traps.

TABLE 6.5.1: RECORDED RESERVOIR SEDIMENTATION RATES FOR RESERVOIRS IN THE BREEDE WMA

SECONDARY CATCHMENT	RIVER	DAM NAME	ECA (km^2)	PERIOD	V_T (Mm3)	V_{50} (Mm3)	YIELD (t/km^2.a)
H100	Stettynskloof	Stettynskloof	55	1954 - 1984	0,088	0,109	54
H100	Koekedouw	Ceres	50	1953 - 1981	0,018	0,023	12
H200	Sanddrift	Roode Elsburg	59	1968 - 1983	0,373	0,682	202
H300	Groot	Poortjieskloof	94	1957 - 1979	0,247	0,358	103
H300	Keisies	Pietersfontein	116	1968 - 1981	0,57	1,155	269
H400	Nuy	Keerom	378	1954 - 1981	0,946	1,232	88
H400	Konings	Klipberg	54	1964 - 1983	0,002	0,002	1
H400	Hoeks	Moordkuil	176	1950 - 1985	0,048	0,056	9
H700	Buffelsjags	Buffelsjags	601	1966 - 1983	0,09	0,152	7

V_T = Sediment volume at end of period.
V_{50} = Estimated volume after 50 years at the same average yield.
ECA = Total catchment area - catchment area of next major dam upstream.

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 catchments calculated from the sediment yield and soil erodibility maps. Mean values of sediment yield in the Breede WMA, calculated from the WR90 estimates range from a low of 6 $t/km^2.a$ at the south-western corner (G40B) of the WMA to 36 $t/km^2.a$ in the Bredasdorp area (G50C). 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 many areas of the country. However, in the case of the Breede 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 Appendixes 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% of the total irrigation requirement. 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. The impacts on yield of afforestation and alien vegetation were estimated external to the WSAM model by the WSAM development team. The estimates are at a low level of confidence.

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 on Table 7.2.1.

In Table 7.2.2 the sums of the water requirements at the range of assurances at which they are normally provided for are shown for the key points.

It can be seen from Table 7.2.2 that the total water requirement in the WMA in 1995 is estimated to have been 2 016 million m^3 per year. This value includes the provision of 892 million m^3 per year for the ecological Reserve.

Within the Breede WMA, 77% of the water requirements are in the Breede River catchment and 23% are in the Palmiet and Overberg areas.

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. Thse are shown in Table 7.2.3, where it can be seen that the conversion to total equivalent water requirements has reduced the quantity by 53% from 2 016 million m^3/a to 953 million m^3/a.

TABLE 7.2.1: KEY POINTS FOR YIELD DETERMINATION

LOCATION OF KEY POINT					DESCRIPTION
PRIMARY CATCHMENT		SECONDARY CATCHMENT		QUATERNARY CATCHMENT	
No.	Area	No.	Area	No.	
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40D G40B	Hypothetical point for Palmiet River mouth and Betty's Bay coast
		G40 (part)	Overberg West	G40E to M	Hypothetical point for combined Overberg West river mouths
		G50	Overberg East	G50A to K	Hypothetical point for combined Overberg East river mouths
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10C	Outlet of Warm Bokkeveld catchments
		H10 (part)	Upper Breede	H10L	Breede River opposite Brandvlei Dam
		H20	Hex	H20H	Hex River at its confluence with the Breede River
		H30 to H50	Middle Breede	H50B	Breede River immediately upstream of its confluence with the Riviersonderend
		H60 (part)	Upper Riviersonderend	H60C	Riviersonderend at Theewaterskloof Dam
		H60 (part)	Lower Riviersonderend	H60L	Riviersonderend at its confluence with the Breede River
		H70	Lower Breede	H70K	Breede River at its mouth

The main reductions relative to the requirements shown in Table 7.2.2 are for the ecological Reserve, water use by alien vegetation and streamflow reduction by afforestation, where the impact on the 1:50 year yield is shown in Table 7.2.3. The impact on yield is considerably less than the long term average water requirements shown in Table 7.2.2.

Irrigation water requirements are also reduced significantly in Table 7.2.3 because some of the total requirements shown are at less than 1:50 year assurance. Most of the afforestation is in the catchments of major dams, with the result that its effects have been taken into account in determining the yields of the dams in separate, more detailed studies than this situation assessment. The yields determined in these studies have been used as described in Section 6.3, to estimate the 1:50 year developed yield in the various key areas of the Breede WMA. Therefore, when comparing water requirements with the 1:50 year developed yield for purposes of determining the yield balance, it is necessary to add the impact of afforestation, shown in Table 7.2.3, to the developed 1:50 year surface water yield in 1995 shown in Table 6.1.3. The situation is similar with regard to water use by alien vegetation, where it is necessary to add its impact on the 1:50 year yield, also shown in Table 7.2.3, to the 1:50 year developed surface water yield in 1995. The combined yields are shown in Table 7.2.4 in the "surface water" column under the "utilised 1:50 year yield in 1995" column.

TABLE 7.2.2: TOTAL WATER REQUIREMENTS AT VARIOUS ASSURANCES OF SUPPLY IN 1995

CATCHMENT OF KEY POINT						STREAMFLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENTS						ECOLOGICAL RESERVE	TOTAL
PRIMARY		SECONDARY		TERTIARY		AFFORES-TATION	DRYLAND SUGAR CANE	ALIEN VEGETATION	RIVER FRESHEN-ING	BULK [1]	IRRI-GATION [2]	RURAL [3]	URBAN [4]	HYDRO [5] POWER	WATER TRANSFERS OUT OF WMA		
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)	(million m3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay coast	7,8	0,0	0,9	0,0	0,0	56,1	1,0	1,3	2,0	0,0	142	211,1
		G40 (part)	Overberg West	G40E to M	Bot. Onrus, Klein, Uitkraals	1,4	0,0	60,3	0,0	0,0	27,0	1,4	6,0	0,0	0,0	48	144,1
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0,0	0,0	60,2	0,0	0,0	0,3	1,9	2,0	0,0	0,0	44	108,4
	TOTAL IN PALMIET AND OVERBERG					**9,2**	**0,0**	**121,4**	**0,0**	**0,0**	**83,4**	**4,3**	**9,3**	**2,0**	**0,0**	**234**	**463,6**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0,2	0,0	4,3	0,0	0,0	58,6	0,7	0,2	0,0	0,0	32	96,0
		H10 (part)	Upper Breede	J25	Catchment above Brandvlei Dam	0,7	0,0	15,4	0,0	0,0	119,2	1,4	4,8	0,0	9,0	257	407,5
		H20	Hex	H20A to H	Hex River Valley	0,0	0,0	0,9	0,0	0,6	43,5	1,0	13,9	0,0	2,5	20	82,4
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	0,0	0,0	3,3	20,0	0,3	285,2	2,4	5,0	0,0	0,0	265	581,2
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**0,9**	**0,0**	**23,9**	**20,0**	**0,3**	**506,4**	**5,5**	**23,9**	**0,0**	**11,5**	**265**	**857,4**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam catchment	1,1	0,0	16,8	0,0	0,4	32,1	0,7	0,4	0,0	161,0 [6]	91	303,5
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	0,3	0,0	15,4	0,0	0,0	24,0	1,4	0,7	0,0	0,0	128	169,8
		TOTAL RIVIERSONDEREND				**1,4**	**0,0**	**32,2**	**0,0**	**0,4**	**56,1**	**2,1**	**1,1**	**0,0**	**161,0**	**128**	**383,3**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	1,9	0,0	8,0	0,0	0,0	33,5	1,8	1,7	0,0	0,0	659	705,9
		TOTAL IN BREEDE BASIN				**4,2**	**0,0**	**64,2**	**20,0**	**0,7**	**596,0**	**9,4**	**26,7**	**0,0**	**172,5**	**659**	**1552,7**
TOTAL IN BREEDE WMA						**13,4**	**0,0**	**185,6**	**20,0**	**1,3**	**679,4**	**13,7**	**36,0**	**2,0**	**172,5**	**892**	**2015,9**

(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) Hydropower use shown is only the evaporation loss from the dams.
(6) Water transfers out of the Berg River to Theewaterskloof Dam of about 25 million m^3/a on average occur during winter months but are offset by transfers from Theewaterskloof into the Berg/Eerste Rivers during the summer of 186 million m^3/a on average. Thus the net result is a transfer of 161 million m^3/a out of the Breede WMA.

TABLE 7.2.3: EQUIVALENT WATER REQUIREMENTS IN 1995 AT 1:50 YEAR ASSURANCE

CATCHMENT OF KEY POINT						STREAMFLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENTS						ECOLOGICAL RESERVE	TOTAL
PRIMARY		SECONDARY		TERTIARY		AFFORES-TATION	DRYLAND SUGAR CANE	ALIEN VEGETATION	RIVER FRESEN-ING	BULK [1]	IRRI-GATION [2]	RURAL [3]	URBAN [4]	HYDRO [5] POWER	WATER TRANSFERS OUT OF WMA		
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 $^3/a$)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay coast	3,9	0,0	0,5	0,0	0,0	43,2	1,0	1,3	2,0	0,0	12,5	64,4
		G40 (part)	Overberg West	G40E to M	Bot, Onrus, Klein, Uitkraals	0,7	0,0	30,6	0,0	0,0	20,8	1,4	6,0	0,0	0,0	2,0	61,5
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	0,0	0,0	1,6	0,0	0,0	0,2	1,9	2,0	0,0	0,0	0,5	6,2
	TOTAL IN PALMIET AND OVERBERG					**4,6**	**0,0**	**32,7**	**0,0**	**0,0**	**64,2**	**4,3**	**9,3**	**2,0**	**0,0**	**15,0**	**132,1**
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	0,1	0,0	1,1	0,0	0,0	50,3	0,6	0,2	0,0	0,0	2,5	54,8
		H10 (part)	Upper Breede	J25	Catchment above Brandvlei Dam	0,1	0,0	4,1	0,0	0,0	102,5	1,4	4,8	0,0	9,0	12,5	134,4
		H20	Hex	H20A to H	Hex River Valley	0,0	0,0	0,3	0,0	0,6	37,4	1,0	13,9	0,0	2,5	1,0	56,7
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	0,0	0,0	0,9	20,0	0,3	245,3	2,4	5,0	0,0	0,0	2,0	275,9
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				**0,2**	**0,0**	**6,4**	**20,0**	**0,9**	**435,5**	**5,4**	**23,9**	**0,0**	**11,5**	**18,0**	**521,8**
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam catchment	0,9	0,0	9,0	0,0	0,4	27,9	0,7	0,4	0,0	161,0 [6]	30,0	230,3
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	0,2	0,0	8,2	0,0	0,0	20,9	1,4	0,7	0,0	0,0	0,0	31,4
		TOTAL RIVIERSONDEREND				**1,1**	**0,0**	**17,2**	**0,0**	**0,4**	**48,8**	**2,1**	**1,1**	**0,0**	**161,0**	**30,0**	**261,7**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	0,3	0,0	1,1	0,0	0,0	28,5	1,8	1,7	0,0	0,0	4,0	37,4
		TOTAL IN BREEDE BASIN				**1,6**	**0,0**	**24,7**	**20,0**	**1,3**	**512,8**	**9,2**	**26,7**	**0,0**	**172,5**	**52,0**	**820,8**
TOTAL IN BREEDE WMA						**6,2**	**0,0**	**57,4**	**20,0**	**1,3**	**577,0**	**13,5**	**36,0**	**2,0**	**172,5**	**67,0**	**952,9**

(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) Hydropower use shown is only the evaporation loss from the dams.
(6) Water transfers out of the Berg River to Theewaterskloof Dam of about 25 million m^3/a on average occur during winter months but are offset by transfers from Theewaterskloof into the Berg/Eerste Rivers during the summer of 186 million m^3/a on average. Thus the net result is a transfer of 161 million m^3/a out of the Breede WMA.

Transfers of water out of the WMA, which are shown as part of the total water requirements in Table 7.2.3, are not included in the water requirements column in Table 7.2.4 because they appear in a separate column for exports.

The detailed results of the yield balance shown in Table 7.2.4 are at a low level of confidence at most of the key points because of the uncertainty associated with the estimates of run-of-river yields (see Section 6.3) and the impact of the ecological Reserve.

The table shows an overall surplus yield of approximately 64 million m^3/a in the WMA, of which 50 million m^3/a is in the Breede River Basin. There was a surplus in the Breede Basin in 1995, partially because 13 million m^3/a of the yield of Stettynskloof Dam was not yet used by Worcester, and partially because allocations from Theewaterskloof Dam amounting to 27 million m^3/a at 1:50 year equivalent assurance were not utilised. It is also likely that the run-of-river yield has been over-estimated. These three factors between them, would account for most of the surplus yield shown for the Breede Basin.

In the Palmiet catchment, the surplus yield of 23 million m^3/a has been utilised since 1999 for the Palmiet to Steenbras transfer.

The deficit of 8,5 million m^3/a shown for the Western Overberg area may be a result of under-estimation of the run-of-river yield.

The yield balance for each key area is shown diagrammatically on Figure 7.2.1.

TABLE 7.2.4: WATER REQUIREMENTS AND AVAILABILITY IN 1995

CATCHMENT OF KEY POINT						UTILISED 1:50 YEAR YIELD IN 1995 [15]			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE [8]	YIELD BALANCE AT 1:50 YEAR ASSURANCE [4]
PRIMARY		SECONDARY		TERTIARY		SURFACE WATER	GROUNDWATER	TOTAL	IMPORTS	EXPORTS	RE-USABLE	TO SEA		
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)	(million m^3/a)	(million m^3/a)	(million m^3/a)
G (part)	Eastern part of Drainage Region G	G40 (part)	Palmiet	G40C, D, G40B	Palmiet, Betty's Bay coast	80,4	0,5	80,9	0,0	0,9 [1]	5,4	0,0	62,4 [14]	+23,0
		G40 (part)	Overberg West	G40E to M	Bot. Onrus, Klein, Uitkraals	41,6	2,5	44,1	2,6 [2]	0,0	6,3	0,0	61,5	-8,5
		G5	Overberg East	G50A to K	Haelkraal, Ratel, Nuwejaars, Heuningnes, De Hoopvlei	3,6	1,4	5,0	0,8 [3]	0,0	0,0	1,3	6,2	-0,4
	TOTAL IN PALMIET AND OVERBERG					125,6	4,4	130,0	2,5	0,0	11,7	1,3	130,1	+14,1
H (part)	Breede	H10 (part)	Warm Bokkeveld	H10A, B, C	Catchment above Ceres	29,2	18,5	47,7	0,0	0,0	5,4	0,0	54,8	-1,7
		H10 (part)	Upper Breede	J25	Catchment above Brandvlei Dam	278,2	32,3	310,5	0,0	-186,0 [5]	12,6	0,0	125,4	+11,7
		H20	Hex	H20A to H	Hex River Valley	16,3	20,5	36,8	12,0	-2,5 [6]	11,0	0,0	54,2	+3,1
		H30 to H50	Middle Breede	H30 to H50	Breede between Riviersonderend confluence and Brandvlei Dam	56,9	28,8	85,7	165,0 [7]	-2,0 [11]	27,2	0,0	275,9	0,0
		TOTAL BREEDE ABOVE RIVIERSONDEREND CONFLUENCE				380,6	100,1	480,7	0,0	-13,5	56,2	0,0	510,3	+13,1
		H60 (part)	Upper Riviersonderend	H60A, B, C	Theewaterskloof Dam catchment	268,9	1,5	270,4	0,0	-183,2 [9]	1,7	0,0	69,3	+19,6
		H60 (part)	Lower Riviersonderend	H60D to L	Riviersonderend Valley	26,4	0,4	26,8	22,0 [10]	-18,9 [12]	1,5	0,0	31,4	0,0
		TOTAL RIVIERSONDEREND				**295,3**	**1,9**	**297,2**	**0,0**	**180,1**	**3,2**	**0,0**	**100,7**	**+19,6**
		H70	Lower Breede	H70A to K	Breede between its mouth and the Riviersonderend confluence	32,4	2,9	33,9	18,8 [13]	0,0	0,0	2,3	37,4	+16,7
		TOTAL IN BREEDE BASIN				708,3	104,9	813,2	0,4	-175,2	59,4	2,3	648,4	+49,4
TOTAL IN BREEDE WMA						833,9	109,3	943,2	0,4	-172,7	71,1	3,6	778,5	+63,5

1. Export from Palmiet River to Kleinmond.
2. Import of 1,7 million m^3/a from Riviersonderend River for Ruensveld West Scheme and 0,9 million m^3/a from Palmiet River for Kleinmond.
3. Import of 0,8 million m^3/a from Riviersonderend River for Ruensveld East Scheme.
4. A + represents a surplus, a – represents a deficit, and 0,0 indicates that the yield and requirements are balanced.
5. Run-of-river flow and releases from Brandvlei to lower Breede totalling 165 million m^3/a, 5,0 million m^3/a, Gawie se Water export to Berg WMA, 4,0 million m^3/a Dwarsrivier transfer to Berg WMA, and 12,0 million m^3/a from Stettynskloof Dam to Worcester.
6. Inverdoorn Canal export to Olifants/Doring WMA.
7. Run-of-river flow from upper Breede and releases from Brandvlei Dam.
8. The water requirements shown in Table 7.2.3 have been reduced by removing quantities exported from the WMA as these are allowed for in the "Exports" column.
9. An export of 161 million m^3/a to the Berg WMA and 21,6 million m^3/a released from Theewaterskloof Dam to the lower Riviersonderend, and 0,6 million m^3/a exported to Franschhoek.
10. Water released from Theewaterskloof Dam.
11. Surplus yield of 2,0 million m^3/a flowing to the Lower Breede catchment.
12. Exports of 1,7 million m^3/a to the Ruensveld West Water Supply Scheme, 0,8 million m^3/a to the Ruensveld East Water Supply Scheme and 16,4 million m^3/a of surplus yield flowing to the Lower Breede catchment.
13. Surplus yield of 2,0 million m^3/a from the MIddle Breede catchment, 16,4 million m^3/a from the lower Riviersonderend catchment, and 0,4 million m^3/a imported from the Gouritz WMA via the Duiwenhoks Water Supply Scheme.
14. Hydro-power evaporation losses of 2,0 million m^3/a not included as they were allowed for in determining the yield of Kogelberg Dam.
15. Combined yields of major dams, farm dams, run-of-river abstractions, groundwater and impacts of afforestation and alien vegetation on yield.

CHAPTER 8: COSTS OF WATER RESOURCES DEVELOPMENT

A number of significant water resources developments have been implemented in the Breede WMA since 1995. The yields of these schemes have been included in the estimate of maximum potential yield. The new developments are listed below.

- The transfer from Kogelberg Dam to Steenbras Dam which was implemented in 1999 and currently operates at about 22,5 million m^3/a at 1:50 year assurance.
- Koekedouw water supply scheme (incremental yield approximately 12 million m^3/a after accounting for a run-of-river yield of about 5 million m^3/a which was previously utilised at the site).
- Kraaibosch Dam on the Uilkraals River (capacity 5,5 million m^3, yield approximately 8 million m^3/a).
- The raising of Eikenhof Dam in the Palmiet River catchment by means of fusegates to raise its capacity from 25,5 million m^3 to 30 million m^3, thereby providing additional yield of 4 million m^3/a.

Costs of the further development of the water resources of the Breede River Basin were determined on a preliminary basis for use in the Breede River Basin Study (DWAF, 2000). These cost estimates are base dated for the year 2000, and were used to derive an estimate of the cost of fully developing the water resources of the Breede River basin portion of the WMA.

Costs of the further development of the water resources of the Palmiet and Overberg portions of the Breede WMA were obtained from the Western Cape Systems Analysis (DWAF, 1994). These cost estimates have been escalated to reflect costs for the year 2000.

The cost estimates are for the development of the infrastructure components listed below:

- Upper Molenaars River diversion to Skuifraam Dam (yield of approximately 20 million m^3/a)
- Lower Wit River Dam (capacity 86 million m^3, yield of approximately 48 million m^3 /a)
- Michell's Pass diversion to Voëlvlei Dam (yield of approximately 27 million m^3 /a)
- Osplaas Dam, an off-channel storage dam with a yield of approximately 3 million m^3/a.
- The raising of the existing Buffeljagts Dam to increase its 1:50 year yield by approximately 30 million m^3/a.

It should be noted that the water resources of the Breede River, in particular, could be developed in a number of different ways and the selection of schemes above may not necessarily be the most economical or the most appropriate. As an alternative to the Lower Wit River Dam, for instance, or in combination with a smaller dam, the yield of Brandvlei Dam could be increased by pumping water into it from the Breede River. (One of the obstacles to developing the Lower Wit River Dam is that it would require diversion of the road in Bains Kloof, which is a declared historical monument).

In addition, it has been assumed that remaining groundwater resources with a potential yield of 61 million m^3/a could be developed in the Breede River basin, comprising of the utilisable potential not contributing to baseflow in the :

- Hex River valley (6 million m^3/a),
- Middle Breede catchments (48 million m^3/a),
- Riviersonderend catchment (7 million m^3/a).

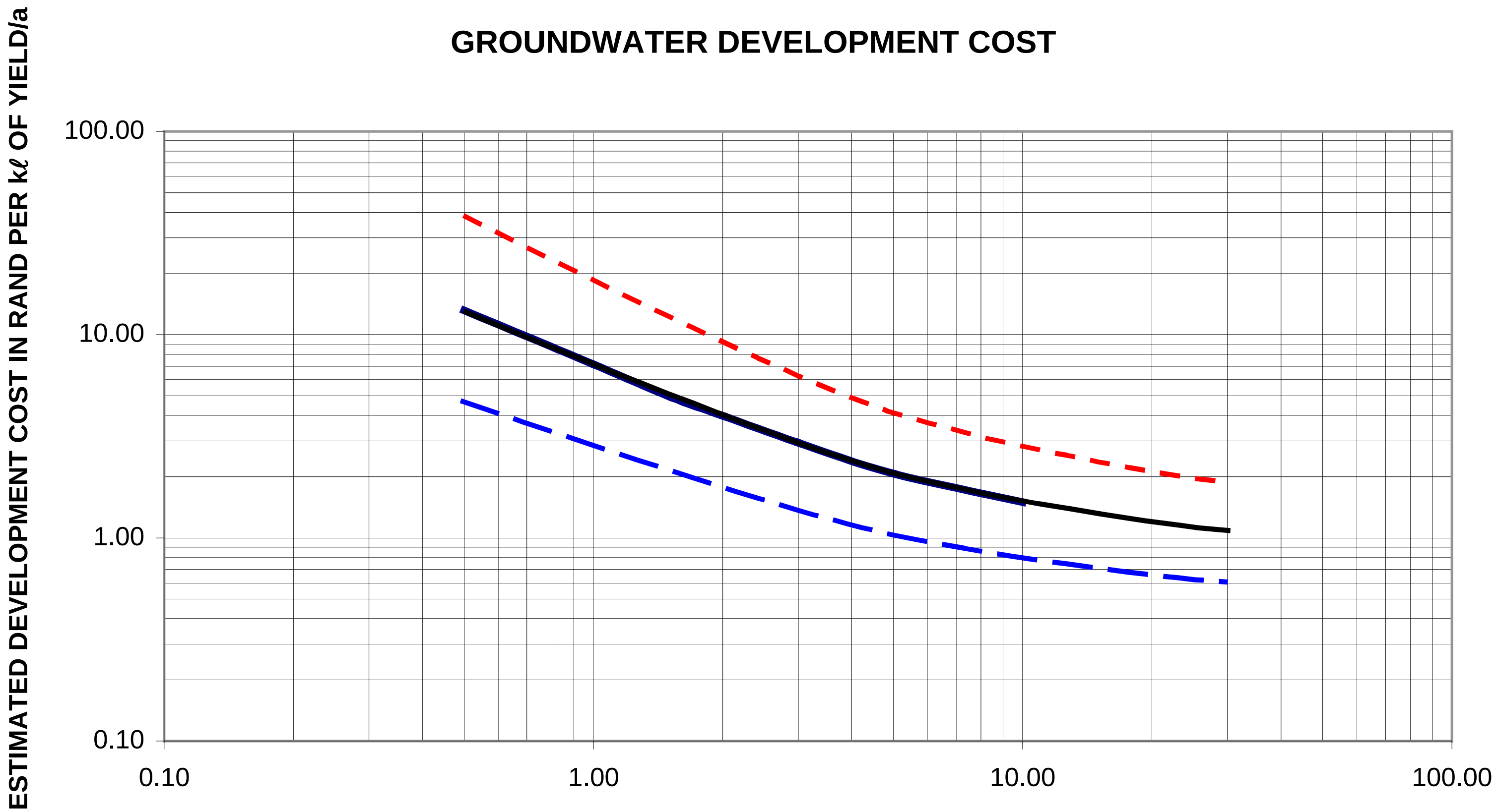

GROUNDWATER DEVELOPMENT COST
ESTIMATED DEVELOPMENT COST IN RAND PER kℓ OF YIELD/a
100.00
10.00
1.00
0.10
0.10
1.00
10.00
100.00
PRODUCTION BOREHOLE YIELD (l/s)

Diagram 8.1

In the Eastern Overberg, it has been assumed that the total remaining groundwater potential of some 27 million m^3/a can be developed, as there is little potential for the further development of surface water resources in the area.

The costs of developing the groundwater resources were estimated with the data shown in Diagram 8.1. Estimates of average borehole yields for these developments are based on the results of groundwater assessments carried out for the Breede River Basin Study (DWAF, 2000d) and the Eastern Overberg Coastal Zone Water Supply Study (DWAF, 1998a).

The estimated combined capital cost of developing the surface water and groundwater resources to their full economic potential is R1 260 million at 2000 price levels, including VAT. The estimated capital costs are summarised in Table 8.1.

TABLE 8.1: COSTS OF FURTHER WATER RESOURCE DEVELOPMENTS

CATCHMENT NO.	SCHEME	STORAGE VOLUME (million m^3/a)	INCREMENTAL SURFACE WATER YIELD (million m^3/a)	WELLFIELD YIELD (million m^3/a)	COSTS (R million) (7)			
					DAMS	WELLFIELDS	WEIRS, CANALS AND PIPELINES	TOTALS
G40C	Raising of Eikenhof Dam (5,6)	4,5	4,0		0,5			0,5
G40D	Kogelberg Dam to Steenbras Dam transfer (6)		22,5				89,6	89,6
G40M	Kraaibosch Dam (6)	5,5	8,0		10,0			10,0
G50B,D,E,H	Small groundwater schemes (1)			27		54,0		54,0
H10C	Koekedouw water supply scheme (6)	17,0	12,0		100,0			100,0
H10D	Michell's Pass Diversion		27,0				70,0	70,0
H10J	Lower Wit River Dam	86,0	48,0		300,0			300,0
H10J	Upper Molenaars Diversion		20,0				290,0	290,0
H20B	Osplaas Dam	3,5	3,0		25,0			25,0
H20D,E	Small groundwater schemes (2)			6		7,8		7,8
H40A-L	Small groundwater schemes (3)			48		144,0		144,0
H60A-L	Small groundwater schemes (4)			7		49,0		49,0
H70E	Raising of Buffeljagts Dam (5)	24,0	30,0		121,0			121,0
		180,5	174,5	**88**	556,5	254,8	449,6	1260,9

(1) Assumed average yield of 5 ℓ/s
(2) Assumed average yield of 10 ℓ/s
(3) Assumed average yield of 3 ℓ/s
(4) Assumed average yield of 1 ℓ/s
(5) Net increase in capacity
(6) Existing scheme implemented after 1995
(7) Costs at year 2000 price levels including VAT.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

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

(i) The Breede WMA covers an area of 19 668 km^2 in which the mean annual precipitation ranges from 1 500 mm in the high mountains to less than 400 mm in parts of the main river valleys. The north-western portion of the WMA is a winter rainfall region, but rainfall occurs throughout the year in the southern and eastern portions.

(ii) The Breede WMA falls entirely within the Western Cape Province.

(iii) The geology of the WMA is dominated by strata of the Cape Supergroup with the mountain ranges comprising mainly Table Mountain Sandstone. The main river valleys and the coastal hills consist of tillites, sandstones, shales and mudstones, with porous unconsolidated to semi-consolidated sediments in parts. Extensive areas of limestone occur along the coastal strip.

(iv) The present ecological status classes of the rivers of the WMA are nearly all moderately modified or largely modified, but many of them are of high to very high ecological importance and sensitivity, and, consequently, the ecological flow requirements to maintain their existing condition are high.

(v) The population of the WMA in 1995 was approximately 382 000 people, 66% of whom lived in towns.

(vi) Much of the economic activity is concentrated in the western part of the WMA, with the Worcester and Caledon Magisterial Districts between them contributing 64% of the GGP in 1997. The GGP for the whole WMA was R4,3 billion in 1997, with the most important economic sectors, in terms of contributions to GGP, being Agriculture (32%), Trade (18,5%) and manufacturing (12,4%). The agricultural sector has a high comparative advantage relative to other WMAs.

(vii) Land-use is predominantly for agriculture and large areas of wheat are grown under dryland conditions in the southern part of the WMA. Approximately 33% of the total land area of the WMA is cultivated. Some 860 km^2 is irrigated, 68 km^2 is under timber plantations, and approximately 5 560 km^2 is used for dryland crops. Urban areas occupy about 0,6% of the total land area, and nature reserves 10%. The remaining 56% is used mainly for rough grazing for livestock.

(viii) There were about 1 100 000 head of livestock in the WMA in 1995. Sheep and goats made up 92% of the livestock numbers, with sheep predominating.

(ix) Parts of the WMA are severely infested by alien vegetation which causes significant reductions in streamflow.

(x) Water related infrastructure is well developed with 21 large dams and 320 smaller farm dams providing 1 118 million m^3 of storage, which is 45% of the natural MAR.

(xi) Town bulk water supply schemes were generally adequate in 1995, but a number of towns will need to augment their raw water supplies in the near future to keep pace with growing requirements. Within the Breede River Basin, sources of additional raw water are available close to the towns, but sources of additional supplies are more of a problem in the Overberg East and West areas.

(xii) In the Greater Hermanus area in Overberg West a successful water conservation and demand management programme has postponed the need for the development of an additional raw water source by several years, but it is expected that additional supplies will be required within a few years. It appears that these will have to be obtained from some distance away and detailed investigations are required to determine the most appropriate source of supply for the area.

(xiii) Similarly, in the coastal area to the south of Bredasdorp, the small but rapidly growing water requirements of the coastal resort towns are approaching the maximum capacities of the existing schemes. As the development of surface water resources in this area is not economical, groundwater has been identified as the probable source of supplementary water supplies. However, the groundwater resources have not been proved by means of a drilling programme and it would be prudent for this to be done before the development occurs of erven which cannot adequately be supplied by the existing water supply schemes.

(xiv) Infrastructure for supplying irrigation water is very well developed and there are numerous water supply schemes, both State owned and privately owned. Included amongst these are two large schemes (one only commissioned in 1998) and four smaller schemes, all owned by the State, that transfer water out of the WMA.

(xv) While the quantities of water supplied to irrigation from government water schemes are accurately known, data on use from other sources is of low reliability. As the available data suggests that less than 60% of irrigation water requirements in the WMA as a whole are supplied from government water schemes, it is apparent that other sources contribute signficant quantities. The quantities contributed by these sources under average conditions and under 1:50 year drought conditions in the Breede River basin, particularly, are not accurately known. The information is more reliable for the Palmiet catchment where more detailed gathering of information and modelling has been carried out.

(xvi) Water requirements in 1995 were estimated to total 1 124 million m^3/a, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. With the ecological Reserve requirements added, the total becomes 2 016 million m^3/a. The equivalent total requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by afforestation and alien vegetation all included as impacts on the yield, was 953 million m^3/a. The values of the impacts on yield of the ecological Reserve, afforestation and alien vegetation have been determined at a low level of confidence and may be under-estimated.

(xvii) The major water user sector was agriculture, which required 684 million m^3/a, or 61% of the total consumptive water requirement (i.e. excluding the ecological Reserve). The next biggest water user was alien vegetation, at 16% of the total consumptive water requirement, followed by water transfers out of the WMA (15%), urban and rural domestic requirements (4%), and afforestation, hydro-power, bulk supplies and river freshening releases which together accounted for the remaining 4%.

(xviii) The geology of the Breede River Basin has a strong effect on the quality of the water resources in that much of the runoff is generated in the sandstones of the mountain ranges, and is generally of a high quality with a low total dissolved salts content. However, its quality deteriorates when it reaches the main river channels because it mixes with saline water draining from shales and mudstones of the lower lying ground. Consequently, flow in the lower reaches of the Breede River during the dry summer months is naturally of high salinity. Return flows from irrigated lands increase the salinity.

(xix) Surface water quality in the Palmiet and Rooi Els River catchments, where the geological strata consist mainly of sandstone, is of low salinity, and in the Overberg East and West areas it is variable, with high natural salinities occuring in much of the area because of the effects of the geological strata.

(xx) The potential for faecal contamination of surface water is low throughout the WMA, but the risk to groundwater is medium to high in most areas.

(xxi) The natural MAR of the Breede WMA was 2 472 million m^3 and the utilisable yield from the surface water resources in 1995 was 834 million m^3/a at 1:50 year assurance. Some 58% of the utilisable yield was from major dams, 12% from farm dams and small municipal dams, 22% from run-of-river abstractions, and 8% was the impact on the yield of water use by alien vegetation and afforestation. In addition, groundwater resources with a yield of 109 million m^3/a had been developed, bringing the total utilisable yield to 943 million m^3/a at 1:50 year assurance.

(xxii) It is estimated that, after allowing for the requirements of the ecological Reserve, a maximum additional quantity of utilisable yield of 263 million m^3/a could be developed. This value, added to the utilisable yield in 1995 of 943 million m^3/a, gives a total potential yield of 1 206 million m^3/a. This estimate is at a low level of confidence because of uncertainty regarding the true impact of the ecological Reserve on the yield.

(xxiii) Comparison of the equivalent 1:50 year water requirements of 951 million m^3/a with the utilisable 1:50 year yield of 943 million m^3/a shows a deficit of 8 million m^3/a. Re-usable return flows of 71 million m^3/a change this to a surplus of 63 million m^3/a.

(xxiv) The unused yield from Theewaterskloof, Stettynskloof and Kogelberg Dams totalled 63 million m^3/a in 1995 and accounts for the surplus referred to above. However, the yield of these dams has all been allocated either to irrigation or to expected increases in urban requirements.

(xxv) Additional minor surpluses in some parts of the Breede River Basin may be a result of over-estimation of run-of-river yield. These are offset in the overall yield balance for the WMA by deficits in the Overberg East, Overberg West and Warm Bokkeveld areas. These deficits are attributed to irrigation requirements which can accommodate water supplies at less than 1:50 year assurance.

(xxvi) The capital cost of developing an additional 263 million m^3/a of yield at 1:50 year assurance, in order to fully utilise the water resources of the WMA, was estimated to be R1 260 million at year 2000 prices, including VAT.

The above information led to the conclusions set out below.

- The developed yield of the Breede WMA was not fully utilised in 1995, but the unutilised portion was fully allocated to urban or agricultural requirements and is likely to be fully utilised in the near future.

- Confidence in the estimates of the yields of farm dams and run-of-river abstractions is low and, as they constitute a significant portion of the total yield, it is essential that they be reliably determined to improve the level of confidence of the yield balance determination.

- The likely water requirements of the ecological component of the Reserve, and their impact on the 1:50 year yield of the water resources, have been determined at a low level of confidence in this study. It is only in the Palmiet River, where detailed work has been done in earlier studies, that the estimates of ecological flow requirements used in this study are considered to be reliable. As the quantity of water available for consumptive use cannot be reliably determined before the requirements of the ecological Reserve are known, both the yield balance and the estimate, given above, of 263 million m^3/a of potential additional yield from the water resources of the WMA are of uncertain reliability. (The uncertainties regardign the requirements of the ecological Reserve are being addressed in the current Breede River Basin Study where the ecological flow requirements at a representative selection of sites on the Breede River and its tributaries are being determined at the technical "comprehensive" level (i.e. without the stakeholder involvement) and the freshwater flow requirement of the Breede River estuary is being determined at the intermediate level).

- Parts of the Breede WMA are severely infested by alien vegetation which causes significant reductions in streamflow. Presently, available data on the extent of the infestation and its effect on the hydrology of the WMA is of low reliability and needs to be improved. This is being addressed for the Breede and Riviersonderend River catchments in the current Breede River Basin Study, but it also needs to be addressed in the Overberg East and West areas where there is severe infestation. From the planning point of view, the priority for addressing the problem is higher in the Breede River Basin than in the Overberg area because little further development of the water resources in the latter area is envisaged, but urgent action for eradication of alien vegetation may be required to protect existing development.

- Large quantities of water are at present exported to the Berg WMA for agricultural use and for the steadily increasing requirements of the Cape Metropolitan Area. In time, much of the surplus water in the Breede WMA is likely to be required to meet the growing urban requirements in the Berg WMA. For the planning for this to be carried out on a sound basis, it is necessary that the potential yield of the water resources of the Breede WMA, as well as present and probable future water requirements within the WMA, be reliably determined.

It became apparent in the course of carrying out this assessment that the available data on the following aspects, in addition to those mentioned above, is inadequate :

- Hydrological data is generally adequate except for a lack of rainfall data for the high lying mountainous areas where much of the runoff of the WMA originates. This additional data is required to improve understanding of the distribution of streamflow in the WMA.
- Water quality data is sparse for the lower Breede River catchment and a routine monitoring point is required in this area to improve the water quality database. This is not of high priority.

- The areas of crops grown under irrigation in the Breede River Basin, and hence the water requirements for irrigation, are not accurately known, but more accurate information is being collected as part of the current Breede River Basin Study.
- No information was obtained in this study on the quantity of untreated "leiwater" used in towns for irrigation of gardens. While the quantity is likely to be small in relation to total irrigation requirements, it may be a significant part of urban water requirements. Therefore, it needs to be determined for information on urban water requirements to be comprehensive.
- Similarly, no information on the numbers and types of game, or the number of ostriches in the catchment, was obtained. The need to obtain this information 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.

Areas of uncertainty that are currently being addressed by the Breede River Basin Study are :

- The requirement for improved data on alien vegetation and its effect on streamflow in the Breede River Basin
- More reliable determination of run-of-river yields in the Breede River Basin, and of quantities of irrigation water supplied from farm dams.
- The requirement for improved data on the areas of crops irrigated and the quantities of water used.
- Reliable data on the ecological component of the Reserve in the Breede River Basin.

Areas of uncertainty that will not be covered by the Breede River Basin Study are :

- The quantities of "leiwater" used for irrigation in towns.
- Water requirements of game and ostriches.
- Water use by alien vegetation in the Overberg area.

This data is not critical to the reliability of the water balance, but it is recommended that, for completeness, it should be collected in due course.

It is recommended that the yield balance performed in this study be reviewed once the improved data from the Breede River Basin Study is available.

At the more localised level of urban water supplies in the Overberg area, it is recommended that :

- Alternative schemes for augmenting the water supply to the Greater Hermanus Area should be investigated at feasibility study level to identify the most appropriate scheme for implementation.
- A borehole drilling programme should be carried out to establish a groundwater supply for the future requirements of the coastal towns to the south of Bredasdorp. This should include the establishment of a groundwater monitoring network to ensure that water quality in the De Hoop Vlei and in Soet Vlei is not adversely affected by groundwater abstraction.

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APPENDICES

LIST OF CONTENTS

NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

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.

BREEDE WATER MANAGEMENT AREA

APPENDIX A

DEMOGRAPHIC DATA PER QUATERNARY CATCHMENT

QUATERNARY CATCHMENT	OPOPi URBAN POPULATION Number	oPORi RURAL POPULATION Number	TOTAL POPULATION Number
G40B	0	222	222
G40C	14 300	3 235	17 535
G40D	0	7 296	7 296
G40E	1 950	1 913	3 863
G40F	9 400	1 072	10 472
G40G	4 450	1 089	5 539
G40H	20 650	515	21 165
G40J	0	755	755
G40K	0	1 057	1 057
G40L	6 050	949	6 999
G40M	0	1 213	1 213
G50A	400	0	400
G50B	0	1 165	1 165
G50C	0	304	304
G50D	2 450	1 163	3 613
G50E	10 950	255	11 205
G50F	2 700	223	2 923
G50G	0	845	845
G50H	0	1 400	1 400
G50J	750	294	1 044
G50K	0	119	119
H10A	0	2 325	2 325
H10B	0	1 492	1 492
H10C	1 850	6 270	8 120
H10D	21 250	422	21 672
H10E	0	717	717
H10F	5 500	4 513	10 013
H10G	0	6 493	6 493
H10H	0	3 282	3 282
H10J	0	1 136	1 136
H10K	0	1 111	1 111
H10L	1 500	2 066	3 566
H20A	0	1 260	1 260
H20B	6 800	4 570	11 370
H20C	0	321	321
H20D	0	1 245	1 245
H20E	0	719	719
H20F	0	5 126	5 126
H20G	0	1 662	1 662
H20H	75 700	477	76 177
H30A	0	1 120	1 120
H30B	8 800	1 015	9 815
H30C	0	956	956
H30D	0	968	968
H30E	8 450	1 589	10 039
H40A	0	225	225
H40B	0	857	857
H40C	0	3 073	3 073
H40D	0	1 040	1 040
H40E	0	3 691	3 691
H40F	0	2 770	2 770
H40G	0	1 031	1 031
H40H	0	1 349	1 349
H40J	17 150	2 843	19 993
H40K	1 850	931	2 781
H40L	0	3 543	3 543
H50A	0	2 459	2 459
H50B	5 050	2 824	7 874
H60A	0	1 035	1 035
H60B	0	2 195	2 195
H60C	3 300	3 309	6 609

QUATERNARY CATCHMENT	OPOPi	oPORi	TOTAL POPULATION
	URBAN POPULATION	RURAL POPULATION	
	Number	Number	Number
H60D	0	3 496	3 496
H60E	3 700	3 410	7 110
H60F	650	1 106	1 756
H60G	0	223	223
H60H	0	673	673
H60J	2 650	700	3 350
H60K	0	574	574
H60L	0	682	682
H70A	0	694	694
H70B	10 750	356	11 106
H70C	1 700	569	2 269
H70D	0	760	760
H70E	1 600	1 495	3 095
H70F	0	1 048	1 048
H70G	0	1 605	1 605
H70H	0	471	471
H70J	1 850	1 014	2 864
H70K	0	245	245
TOTALS	**254 150**	**128 234**	**382 384**

APPENDIX B

SUPPLEMENTARY ECONOMIC DATA

APPENDICES

SUPPLEMENTARY ECONOMIC INFORMATION

APPENDIX B.1

DESCRIPTION OF GRAPHS

Diagram No	Graphic Illustration	Description
B.1	• **Gross Geographic Product**: Contribution by Magisterial District to Breede 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.
B.3	• **Labour Force Characteristics**: Composition of Breede 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 Breede Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.5	Contribution by Sectors of Breede 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 Breede versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.
B.7	• **Shift-Share**: 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 Breede economy, 1997 (%)

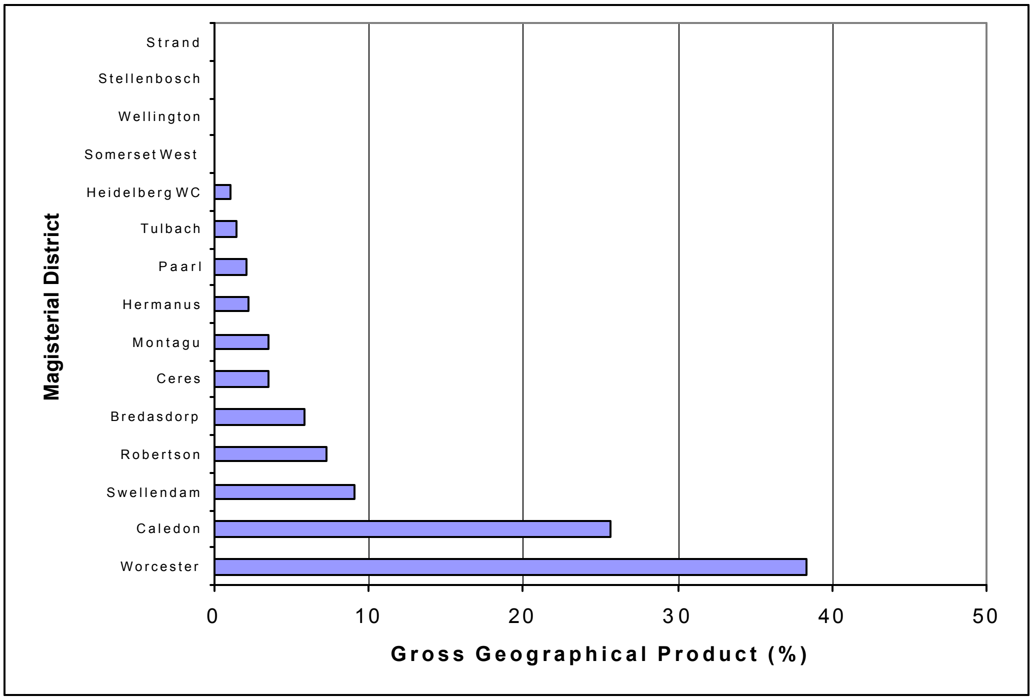


Figure B.2: Contribution by Sector to National Economy, 1988 and 1997 (%)

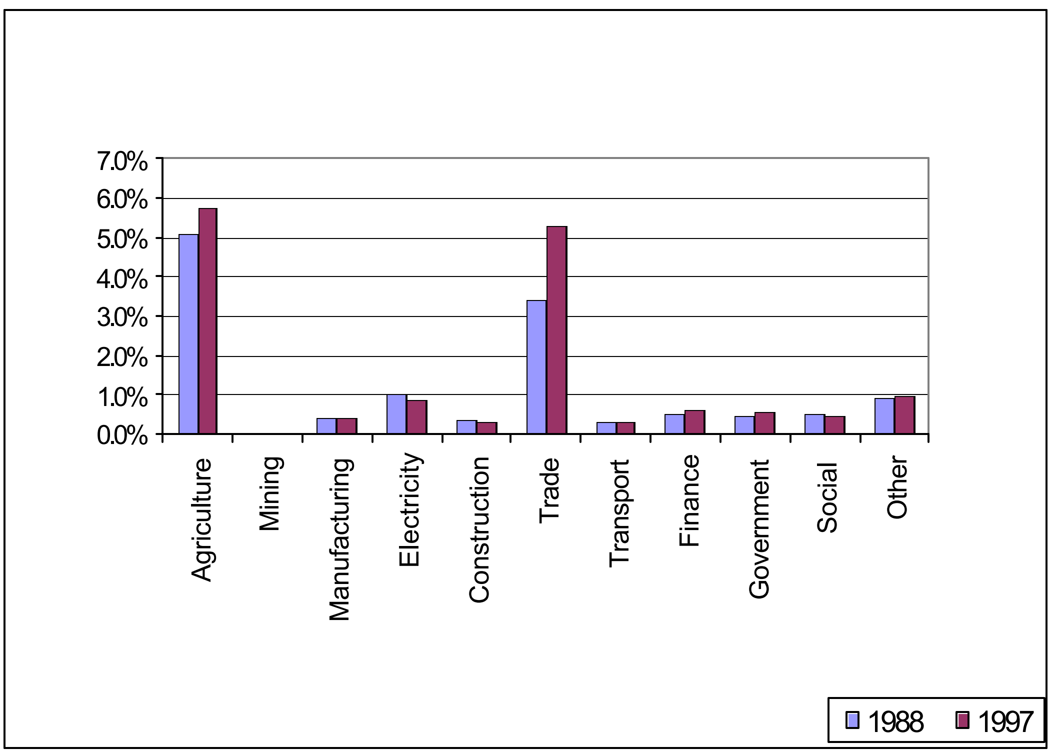


Figure B.3: Composition of Breede Labour Force, 1994 (%)

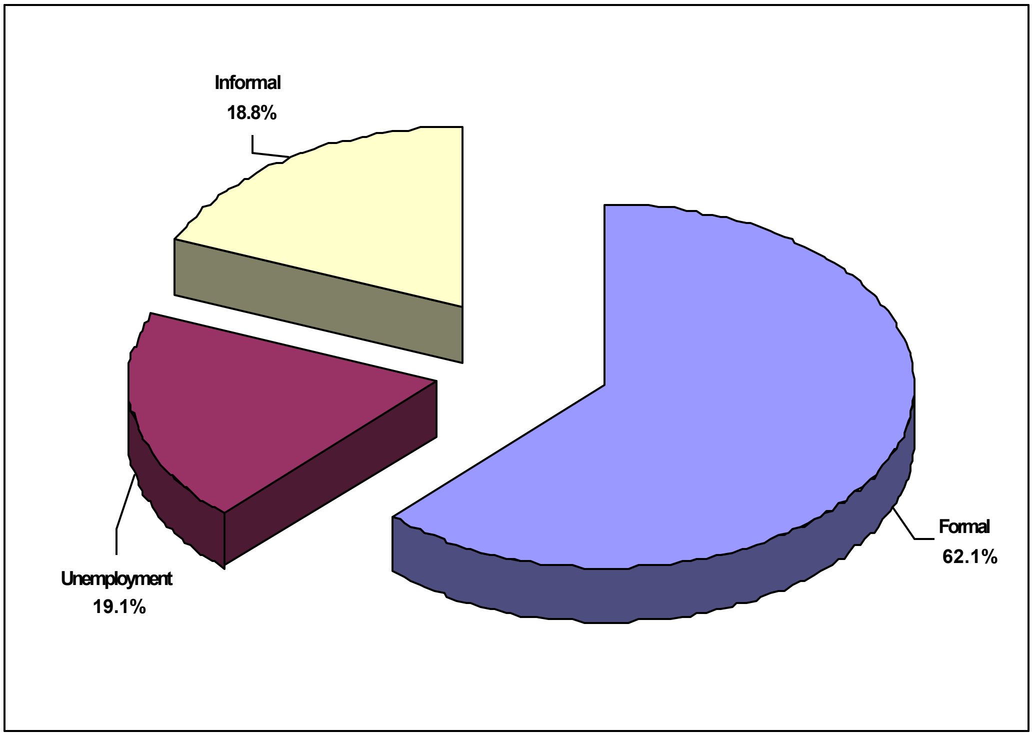


Figure B.4: Contribution by Sector to Breede Employment, 1980 and 1994 (%)

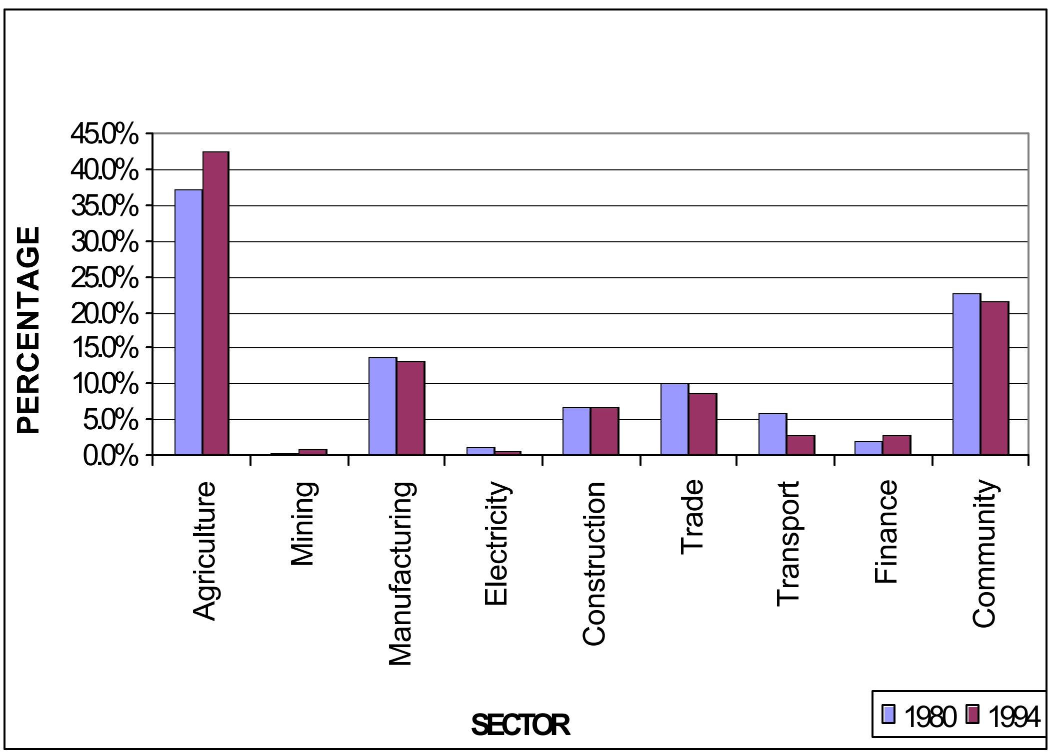


Figure B.5 Contribution by Sectors of Breede Employment to National Sectoral Employment, 1980 and 1994 (%)

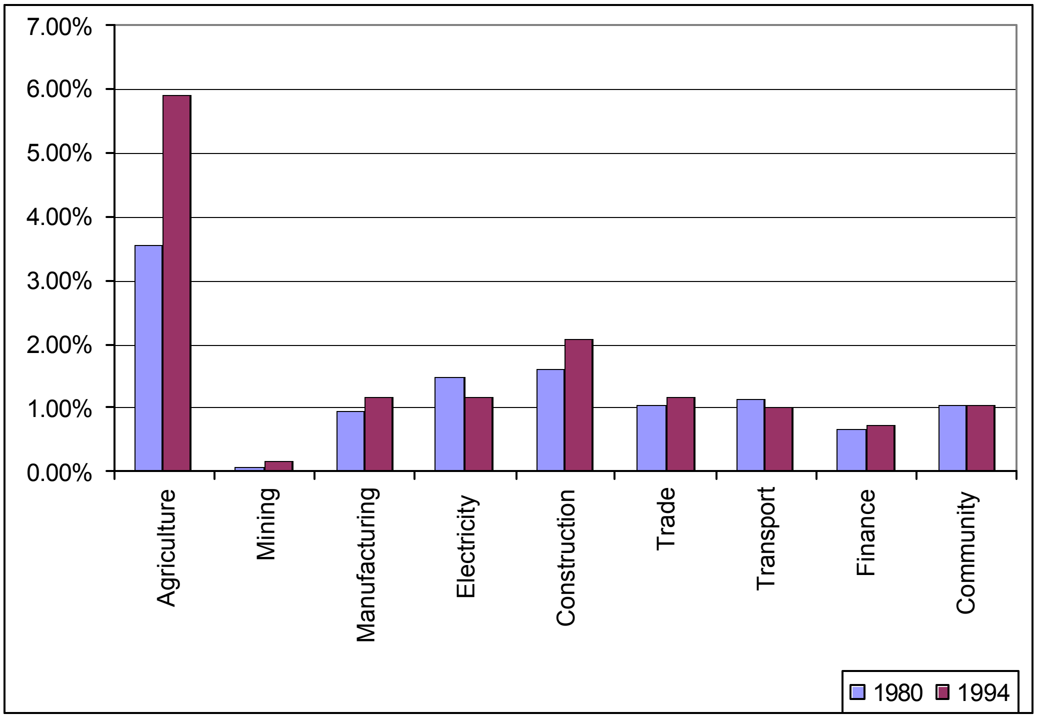


Figure B.6: Average Annual Employment Growth by Sector of Breede versus South Africa, 1980 to 1994 (%)

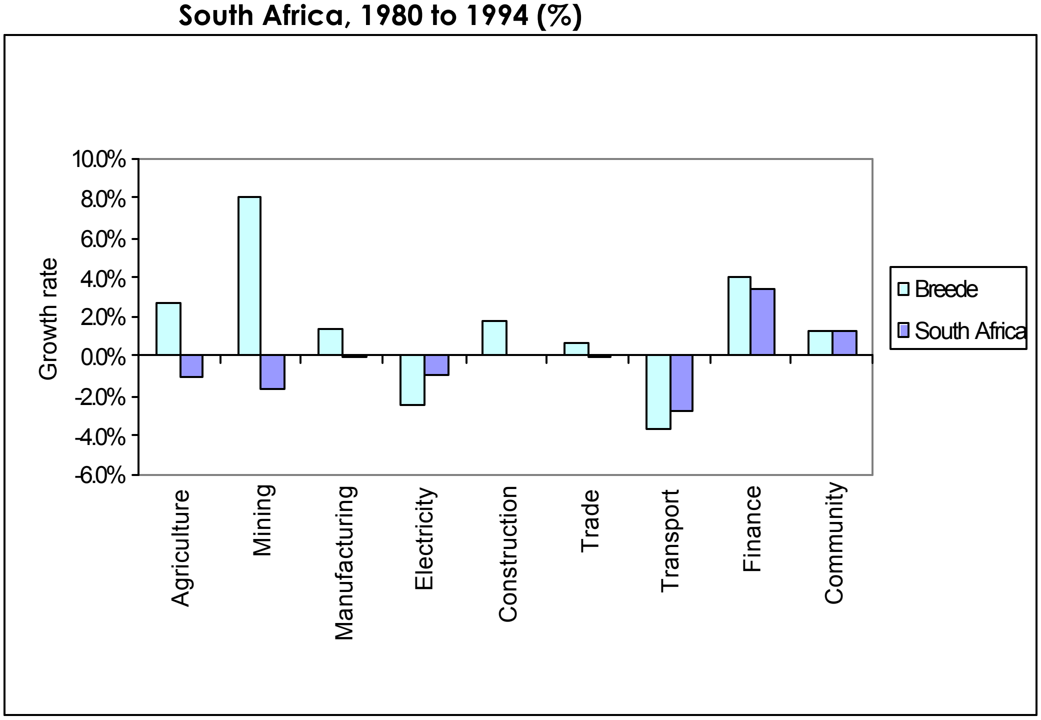
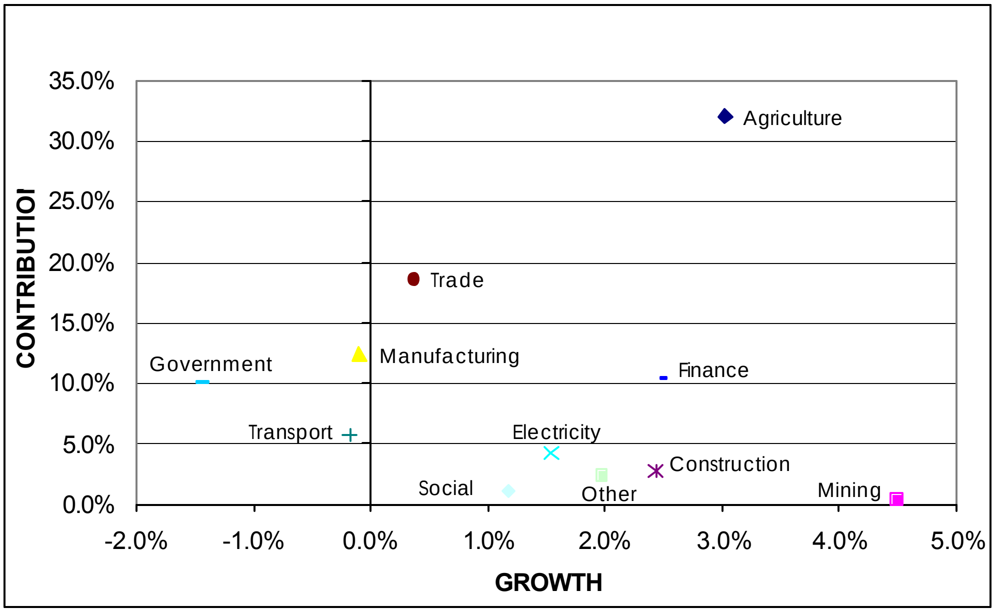


Figure B.7 Shift-Share Analysis, 1997



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

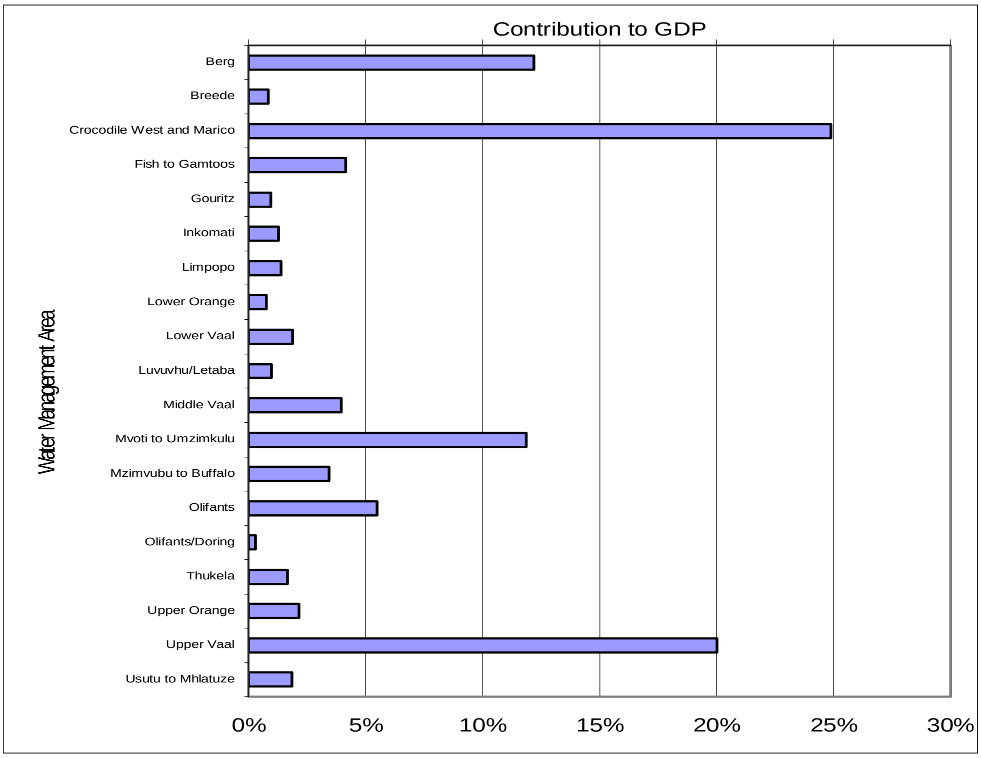
- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.

- 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.

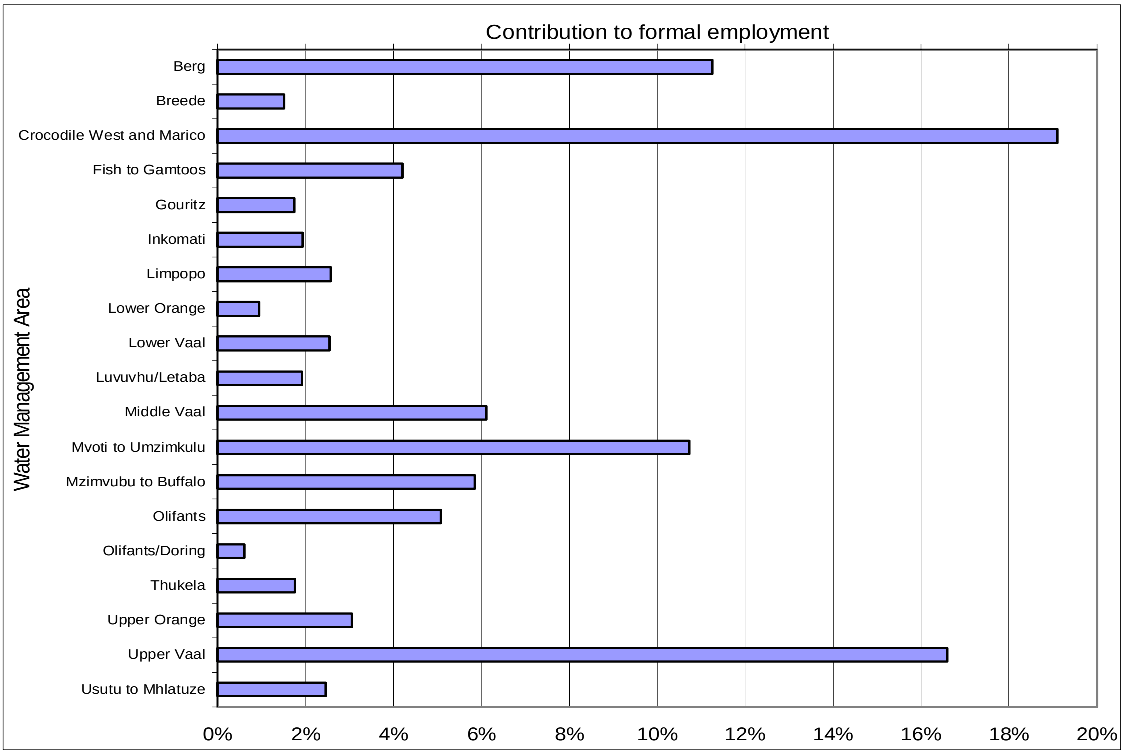
Figure B.1: Total GGP by Water Management Area (% of Country)



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.

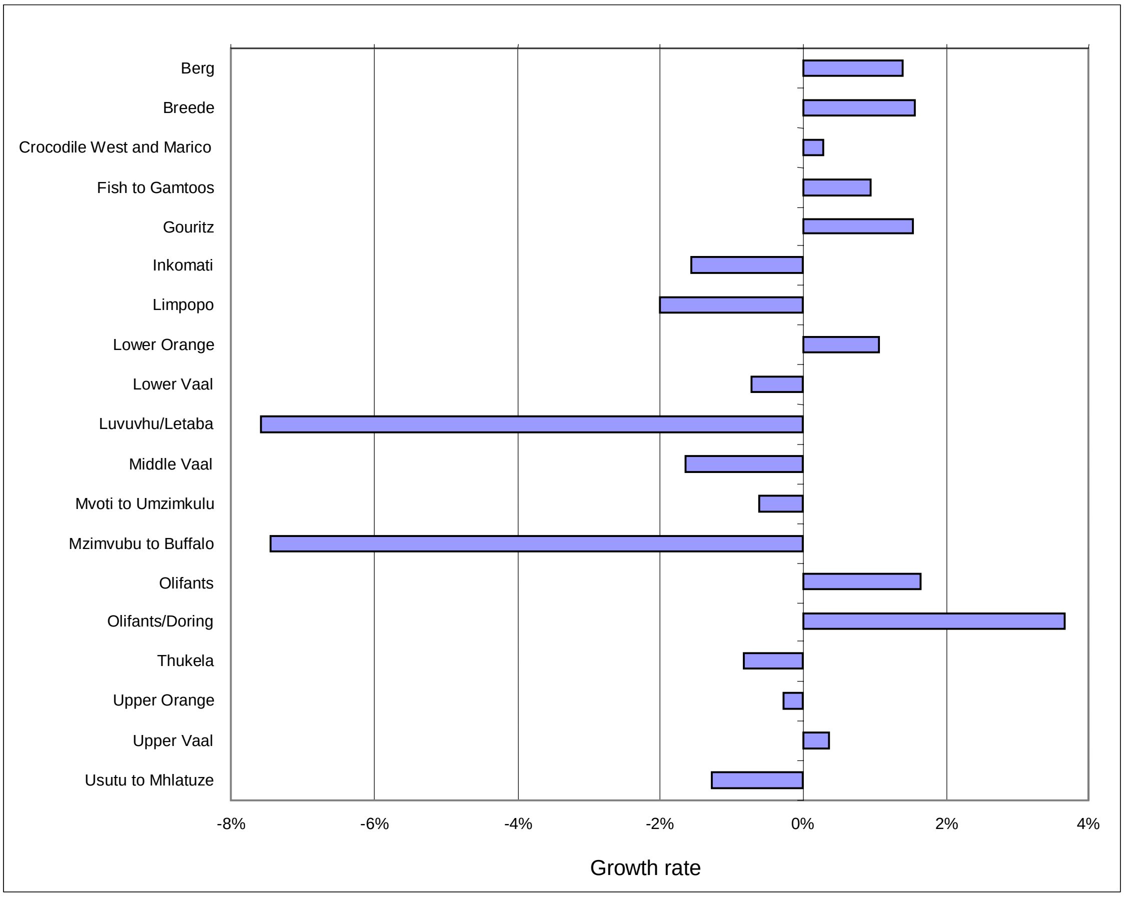
Figure B.2: Formal Employment by Water Management Area (% of country)



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.

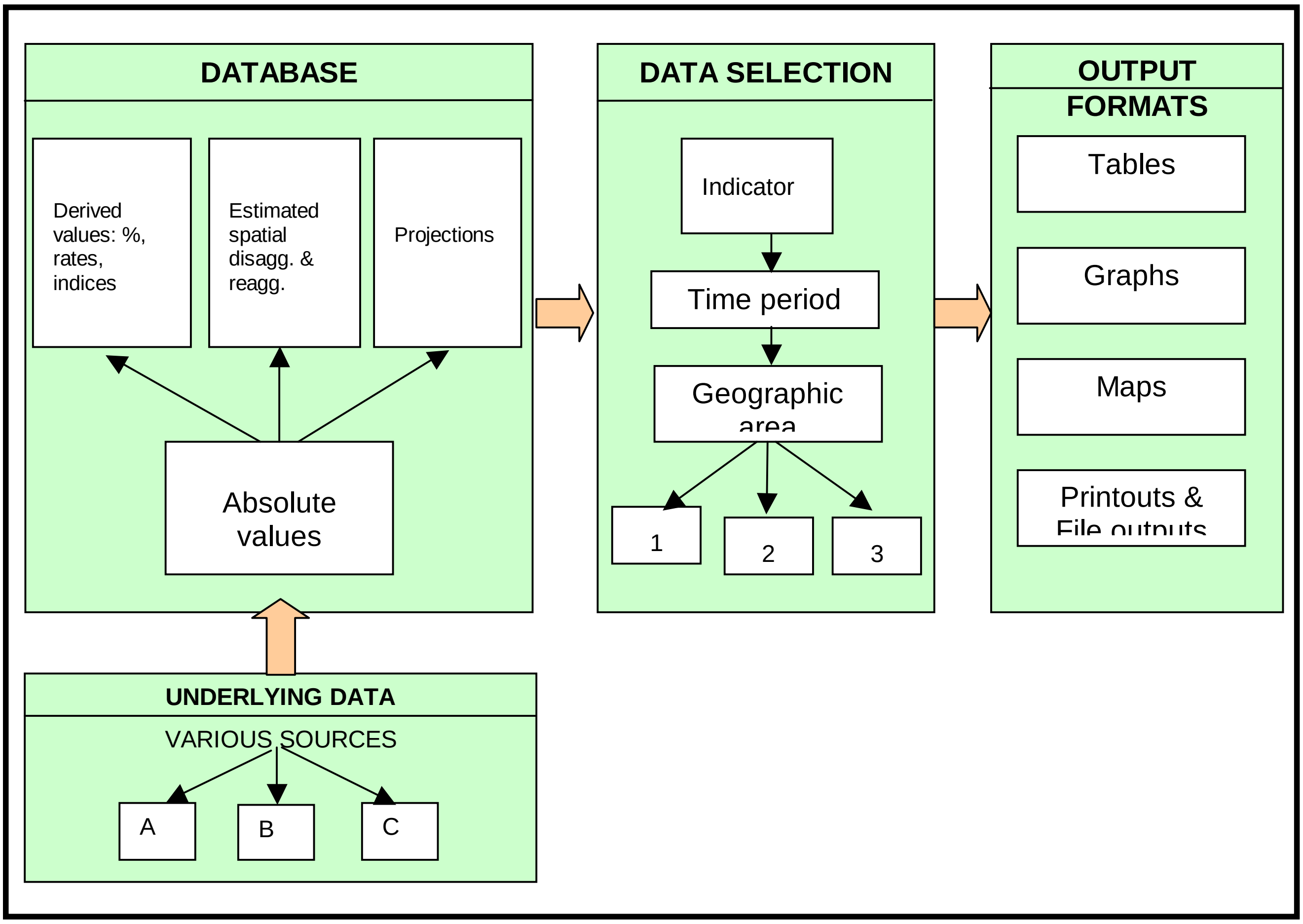
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service 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.**

BREEDE WATER MANAGEMENT AREA

APPENDIX D.1

LAND USE DATA CONTAINED IN THE DATABASE OF THE WATER SITUATION ASSESSMENT MODEL

Quaternary Catchment	aAAAi	aFCAi	aFINi	aISAi	aNAEi	oRSUi
	Area under alien vegetation	Area under afforestation	Indigenous forest area	Field area irrigated	Urban Areas	Number of large stock units
	km^2	km^2	km^2	km^2	km^2	Number
G40B	2.55	0.00	0.00	0.00	6.46	2799.00
G40C	0.84	16.36	0.00	29.37	1.94	3556.00
G40D	0.88	16.03	0.00	46.90	0.00	7768.00
G40E	12.15	4.65	0.00	15.30	1.05	6641.00
G40F	41.59	0.00	0.00	0.68	3.24	10030.00
G40G	41.38	7.62	0.00	4.41	3.52	3995.00
G40H	39.28	0.00	0.00	9.14	8.97	1032.00
G40J	24.43	0.00	0.00	5.09	0.00	4022.00
G40K	29.24	0.00	0.00	1.16	0.00	10270.00
G40L	209.40	0.00	0.00	0.00	3.96	4257.00
G40M	230.40	0.00	0.00	1.01	0.34	5586.00
G50A	159.50	0.00	0.00	0.00	0.00	3944.00
G50B	227.30	0.00	0.00	0.43	0.50	5527.00
G50C	249.60	0.00	0.00	0.00	0.00	6865.00
G50D	21.86	0.00	0.00	0.15	2.20	9673.00
G50E	79.48	0.00	0.00	0.00	4.06	5103.00
G50F	65.93	0.00	0.00	0.00	2.15	4727.00
G50G	0.00	0.00	0.00	0.00	0.00	7387.00
G50H	15.34	0.00	0.00	0.00	0.00	14520.00
G50J	197.40	0.00	0.00	0.00	0.19	8411.00
G50K	71.67	0.00	0.00	0.00	0.00	2662.00
H10A	0.66	0.00	0.00	12.41	0.00	829.00
H10B	0.40	0.00	0.00	16.00	0.00	576.00
H10C	18.15	1.16	0.00	41.29	7.58	967.00
H10D	3.39	0.00	0.00	0.00	0.03	352.00
H10E	0.51	0.01	0.00	0.00	0.00	957.00
H10F	28.19	7.13	0.00	33.57	2.85	2907.00
H10G	6.47	0.00	0.00	71.89	0.75	1454.00
H10H	1.87	0.00	0.00	8.55	0.99	1000.00
H10J	13.41	0.00	0.00	4.72	0.05	4032.00
H10K	24.13	0.00	0.00	3.65	0.00	1690.00
H10L	1.10	0.00	0.00	19.46	0.22	515.00
H20A	0.00	0.00	0.00	3.40	0.00	750.00
H20B	0.15	0.00	0.00	15.75	0.93	666.00
H20C	0.63	0.00	0.00	5.77	0.00	286.00
H20D	1.18	0.00	0.00	0.58	0.00	510.00
H20E	0.03	0.00	0.00	1.36	0.00	503.00
H20F	1.92	0.00	0.00	18.01	0.45	623.00
H20G	2.33	0.00	0.00	3.61	0.00	457.00
H20H	4.11	0.00	0.00	3.32	12.53	479.00
H30A	0.87	0.00	0.00	14.33	0.00	1331.00
H30B	0.74	0.00	0.00	10.18	1.65	1101.00
H30C	0.02	0.00	0.00	7.69	0.00	1144.00
H30D	0.17	0.00	0.00	10.63	0.17	444.00

Quaternary Catchment	aAAAi	aFCAi	aFINi	aISAi	aNAEi	oRSUi
	Area under alien vegetation	Area under afforestation	Indigenous forest area	Field area irrigated	Urban Areas	Number of large stock units
	km^2	km^2	km^2	km^2	km^2	Number
H30E	0.62	0.00	0.00	18.16	1.44	816.00
H40A	0.00	0.00	0.00	0.00	0.00	783.00
H40B	1.13	0.00	0.00	8.39	0.00	873.00
H40C	1.36	0.00	0.00	43.10	0.00	1455.00
H40D	0.89	0.00	0.00	17.56	0.00	979.00
H40E	15.46	0.00	0.00	17.54	0.00	1556.00
H40F	0.24	0.00	0.00	28.68	0.00	2040.00
H40G	5.82	0.00	0.00	18.97	0.00	1915.00
H40H	0.34	0.00	0.00	9.71	0.00	1376.00
H40J	0.49	0.00	0.00	21.54	4.38	1383.00
H40K	8.02	0.00	0.00	18.40	1.49	1867.00
H40L	0.16	0.00	0.00	27.29	0.00	1082.00
H50A	4.98	0.00	0.00	34.01	0.00	1875.00
H50B	2.96	0.00	0.00	33.29	1.68	6414.00
H60A	3.01	0.49	0.00	23.00	0.00	1799.00
H60B	35.94	0.63	0.00	1.70	0.00	5252.00
H60C	18.90	4.55	0.00	24.00	2.14	4933.00
H60D	12.22	1.50	0.00	14.73	0.00	5421.00
H60E	22.80	0.30	0.00	4.29	1.42	3983.00
H60F	17.59	0.00	0.00	4.37	1.68	3612.00
H60G	11.60	0.00	0.00	0.14	0.00	3378.00
H60H	10.45	0.00	0.00	3.14	0.00	5834.00
H60J	25.83	0.00	0.00	2.39	0.93	5697.00
H60K	12.84	0.00	0.00	2.18	0.00	4272.00
H60L	9.81	0.00	0.00	5.21	0.00	3804.00
H70A	0.78	0.00	0.00	3.46	0.00	3668.00
H70B	1.04	4.20	0.88	9.11	2.48	2409.00
H70C	0.98	0.00	0.00	14.86	1.01	4747.00
H70D	16.99	1.70	4.46	5.03	0.35	3681.00
H70E	3.71	1.13	0.00	0.78	0.80	2840.00
H70F	2.53	0.49	0.34	12.88	0.00	1996.00
H70G	8.20	0.00	0.00	4.88	0.00	11120.00
H70H	5.76	0.00	0.00	1.28	0.00	7434.00
H70J	14.73	0.00	0.00	0.00	0.00	12520.00
H70K	23.22	0.00	0.00	0.00	0.30	4352.00
TOTALS	**2132.05**	**67.95**	**5.67**	**853.88**	**86.86**	**279514.00**

BREEDE 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.

BREEDE WATER MANAGEMENT AREA

APPENDIX D3

TREE SPECIES IN COMMERCIAL FORESTS PER QUATERNARY CATCHMENT

Quaternary Catchment	aFCAi Area under afforestation km2	species
G40B	0.00	
G40C	16.36	Pine
G40D	16.03	Pine/Eucalyptus
G40E	4.65	Pine
G40F	0.00	
G40G	7.62	Pine
G40H	0.00	
G40J	0.00	
G40K	0.00	
G40L	0.00	
G40M	0.00	
G50A	0.00	
G50B	0.00	
G50C	0.00	
G50D	0.00	
G50E	0.00	
G50F	0.00	
G50G	0.00	
G50H	0.00	
G50J	0.00	
G50K	0.00	
H10A	0.00	
H10B	0.00	
H10C	1.16	Pine
H10D	0.00	
H10E	0.01	Pine
H10F	7.13	Pine/Eucalyptus
H10G	0.00	
H10H	0.00	
H10J	0.00	
H10K	0.00	
H10L	0.00	
H20A	0.00	
H20B	0.00	
H20C	0.00	
H20D	0.00	
H20E	0.00	
H20F	0.00	
H20G	0.00	
H20H	0.00	
H30A	0.00	
H30B	0.00	
H30C	0.00	
H30D	0.00	
H30E	0.00	

Quaternary Catchment	aFCAi Area under afforestation km2	species
H40A	0.00	
H40B	0.00	
H40C	0.00	
H40D	0.00	
H40E	0.00	
H40F	0.00	
H40G	0.00	
H40H	0.00	
H40J	0.00	
H40K	0.00	
H40L	0.00	
H50A	0.00	
H50B	0.00	
H60A	0.49	Pine
H60B	0.63	Pine
H60C	4.55	Pine
H60D	1.50	Pine
H60E	0.30	Pine
H60F	0.00	
H60G	0.00	
H60H	0.00	
H60J	0.00	
H60K	0.00	
H60L	0.00	
H70A	0.00	
H70B	4.20	Pine
H70C	0.00	
H70D	1.70	Pine
H70E	1.13	Pine
H70F	0.49	Pine
H70G	0.00	
H70H	0.00	
H70J	0.00	
H70K	0.00	
TOTAL	**67.95**	

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.**

BREEDE WATER MANAGEMENT AREA

APPENDIX E.1

EXISTING POTABLE WATER SUPPLY SCHEMES

DISTRICT COUNCIL AREA	QUATERNARY CATCHMENT	SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED IN 1995	WATER REQUIREMENT IN 1995 (million m^3/a)	SCHEME CAPACITY		
						(million m^3/a)	(ℓ/c/d)	LIMITING FACTOR
Overberg	G40B	Betty's Bay Pringle Bay Rooi Els	Buffels River Dam	220	Not known	Not known	Not known	Treatment capacity
	G40C	Grabouw	Eikenhof Dam	14 300	0,5	2,0	383	Raw water pipelines
	G40G	Kleinmond	Palmiet River	4 500	0,9	1,5	913	Raw water pipelines
	G40E	Botrivier	Boreholes	1 950	0,18	0,19	267	Borehole yield
	G40H	Greater Hermanus	De Bos Dam	20 700	2,93	3,0	397	Yield of De Bos Dam
	G40L	Gansbaai	Springs, Franskraal Dam	5 000	1,2	1,2	240	Raw water source
	H60D, E, F, G, H, J G40F, K G50D, G	Ruensveld West	Riviersonderend, Theewaterskloof Dam	17 000 (1)	1,7	2,4	141	Pipeline capacity
	H60J, K, L H70A, G, H G50D, E, F, G, H, J	Ruensveld East	Riviersonderend Theewaterskloof Dam	6 000 (2)	0,8	0,85	388	Pipeline capacity
	G50E	Bredasdorp	Boreholes, dam	11 000	0,8	1,08	269	Raw water source
	G50D	Napier	Boreholes	2 450	0,25	0,25	280	Borehole yield
	G50B	Elim	Borehole, spring	400	0,05	0,06	410	Raw water source
	G50F	L'Agulhas, Struisbaai Suiderstrand	Boreholes	2 700	0,33	0,8	812	Borehole yield
	H70B	Swellendam	River/small dam	10 800	1,0	2,0	330	Raw water storage
	H70C	Barrydale	River	1 700	0,22	Not known	---	Not known
	H70D	Suurbraak	Stream	1 600	0,13	Not known	---	Not known
	G60C	Villiersdorp	Borehole Elandskloof Dam	3 300	0,4	0,68	565	Raw water source
	H60E	Genadendal	Mountain stream	3 700	0,3	Not known	---	Not known
	H60F	Greyton	Mountain streams	650	0,1	0,6	2 500	Not known
	H60J	Riviersonderend	Mountain stream and Rivier-sonderend	2 650	0,32	Not known	---	Not known
TOTALS FOR OVERBERG DISTRICT COUNCIL AREA				**110 620**	**12,11**	**17,58 (3)**	**435**	---
Southern Cape	H70D, E, H, J, K	Duiwenhoks	Duiwenhoks Dam	3 000 (4)	0,4	0,4 (5)	365	Pipeline capacities
	H10C	Prince Alfred Hamlet	Borehole, spring	1 850	0,4	0,88	1 300	Raw water source
	H10C	Ceres	Koekedouw Dam	21 300	2,8	3,9 (6)	502	Not known
	H10F	Wolseley	River	5 500	0,6	Not known	---	Not known

DISTRICT COUNCIL AREA	QUATERNARY CATCHMENT	SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED IN 1995	WATER REQUIREMENT IN 1995 (million m^3/a)	SCHEME CAPACITY		
						(million m^3/a)	(ℓ/c/d)	LIMITING FACTOR
	H10L	Rawsonville	Smalblaar River	1 500	0,12	Not known	---	Not known
	H20H	Worcester	Stettynskloof Dam	75 700	11,8	21	760	Pipeline capacity
	H20F	De Doorns	Stream Sanddrift Govt Water Scheme	6 800	0,73	Not known	---	Treatment works capacity
	H40J	Robertson	Small dams	17 200	1,98	2,6 (6)	414	Not known
	H40K	McGregor	Houtbaais and Hoeks Rivers	1 850	0,2	Not known	---	Not known
	H30E	Ashton	Breede River	8 450	1,4	1,82	590	Raw water sources
	H30B	Montagu	Mountain streams Breede River	8 800	0,92	1,4	436	Raw water sources
	H50B	Bonnievale	Breede River	5 050	1,0	1,2	651	Raw water sources
TOTALS FOR BREEDE RIVER DISTRICT COUNCIL AREA				**154 000**	**21,95**	**34,45 (3)**	**612**	---
TOTALS FOR WHOLE BREEDE WMA				**267 120**	**34,46**	**52,43 (3)**	**537**	---

NOTES:

1. This value is a rough estimate made as follows: 370 farms @ 20 people/farm = 7 400 people + 9 400 people in Caledon = 16 800 rounded to 17 000
2. This value is a rough estimate made as follows: 264 farms @ 20 people/farm = 5 280 people + 120 people in Protem = 5 400 rounded to 6 000
3. Where scheme capacities are not known they have been assumed to equal water requirements in 1995 in this total value.
4. This value is a rough estimate made as follows: 145 farms @ 20 people/farm = 2 900 people + 300 people in Witsand = 3 200 rounded to 3 000. The portion of the Overberg District Council area to the east of the Breede River is included.
5. Rough estimate of water requirements.
6. Scheme capacity is not known but has been assumed equal to requirements in 2000.

BREEDE WATER MANAGEMENT AREA

APPENDIX E.2

MAIN DAMS

QUATERNARY CATCHMENT	NAME	LIVE STORAGE (million m^3)	NATURAL MAR (million m^3)	YIELD (million m^3/a) [1]				OWNER	NOTES	SOURCE OF DATA
				DOMESTIC	IRRIGATION	OTHER	TOTAL			
G40C	Nuweberg	3,9	17,2	0,5	4,2	0	4,7	Nuweberg Dam Syndicate	Yield includes releases of 0,5 million m^3/a for abstraction at Wesselsgat Weir	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40C	Eikenhof	25,5	66,6	0,0	30,8	0	30,8	Groenland Irrigation Board	Yield includes 27,8 million m^3/a abstracted from the dam and 3 million m^3/a released to river in summer	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40C	Grootvlei	1,6	3,1	0,0	1,7	0	1,7	Elgin Orchards		Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40C	Applethwaite	3,5	116,8	0,0	2,1	0	2,1	Elgin Orchards	8,3 million m^3/a compensation flows released in winter not included in yield.	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40D	Kogelberg	17,28	137,8	24,5	0,0	0	24,5	DWAF	Not a true yield as absractions made only when the dam is overflowing.	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40H	De Bos	6,3	8,4	2,8	0,5	0	3,3	Hermanus	0,5 million m^3/a for irrigation is a compensation flow release	Report to Greater Hermanus Municipality on Provision of Bulk Water. Ninham Shand Report No. 2790/8142, September 1999.
G40D/G40A	Rockview	17,5	Off channel	0,0	0,0	0	0,0	DWAF	Upper reservoir of hydro-power scheme	Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
G40D	Arieskraal	4,4	143,4	0,0	3,6	0	3,6	Arieskraal Farm		Western Cape System Analysis : Palmiet/Steenbras Sub-system Analysis DWAF Report No. P G000/00/4393.
H10C	Koekedouw	22,5	Not known	7,0	10,0	0	17,0	Ceres Municipality	Completed in 1998. Assurance of yield not known.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H10K	Stettynskloof	15,5	60,2	25,0	0,0	0	25,0	Worcester Municipality	The yield is not fully utilised by Worcester at present and water is stored in the dam for the Holsloot Irrigation District by agreement with the Municipality.	Report on Augmentation of the Stettynskloof Water Supply Scheme (Ninham Shand, 1977)
H10L/H40E	Greater Brandvlei	319,3	Off channel	0,0	152,0	0	152,0	DWAF	Live storage is for current operating level of 207,12 masl. Live storage at maximum possible operating level of 210,5 masl is 453,0 million m^3. Dead storage is 22,8 million m^3.	Yield from DWAF Report No. PH100/00/0690 (DWAF, 1990), Capacity data from a report on the Integration of Raw Water Sources Supplying the Cape Metropolitan Area (City of Cape Town, 2001)
H20D	Lakenvallei	10,3	8,8	0,6	8,4	0	9,0	DWAF	Actual allocation to irrigation at lower assurance is 11,9 million m^3/a.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H20C	Roode Elsberg	7,7	12,3							
H30A	Poortjieskloof	9,2	7,5	0,0	2,0	0	2,0	DWAF	Dam operated by Kingna Irrigation Board	Yield estimated by Ninham Shand for this study.
H30B	Knipes Hope	3,1	Not known	--	---	0	---	Cogmanskloof Irrigation Board	Storage dam for water pumped from the Breede River.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H30C	Pietersfontein	2,0	3,0	0,0	0,7	0	0,7	DWAF		Yield estimated by Ninham Shand for this study.

QUATERNARY CATCHMENT	NAME	LIVE STORAGE (million m³)	NATURAL MAR (million m³)	YIELD (million m³/a) [1]				OWNER	NOTES	SOURCE OF DATA
				DOMESTIC	IRRIGATION	OTHER	TOTAL			
QUATERNARY CATCHMENT	NAME	LIVE STORAGE (million m³)	NATURAL MAR (million m³)	YIELD (million m³/a) [1]				OWNER	NOTES	SOURCE OF DATA
				DOMESTIC	IRRIGATION	OTHER	TOTAL			
H40B	Keerom	10,4	8,7	0,0	3,8	0	3,8	Nuy Irrigation Board	MAR is present day and not natural. 1:20 year yield estimated to 4,17 million m³/a. 1:50 year yield estimated from WR90 as 90% of this.	Yield Analysis of Keerom Dam. Ninham Shand Report No. 1678/4537, June 1990.
H40E	Moordkuil/ Draaivlei	1,07	Not known	0,0	2,6	0	2,6	Moordkuil Irrigation Board	Assurance of yield not known.	Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H40K	Klipberg	2,0	Not known	0,0	0,63	0	0,6	DWAF		Breede River Basin Study draft report on infrastructure (DWAF, 2001)
H60C	Elandskloof	11,4	26,6	0,7	11,3	0	12,0	DWAF	Allocation to irrigation at lower assurance than 1:50 year is 12,9 million m³/a.	Yield from White Paper H-72. Other data from Breede River Basin Study draft report on infrastructure (DWAF, 2001).
H60D	Theewaterskloof	480,2	290,7	95,0	109,0	0	204,0	DWAF	Allocations total 245 million m³/a supplied at less than 1:50 year assurance.	Skuifraam Dam Feasibility Study. DWAF Report No. P G100/00/0896.
H70E	Buffelsjags	5,2	79,0	0,0	8,8	2,2	11,0	DWAF	2,2 million m³/a of yield is not allocated at present.	Breede River Basin Study draft report on infrastructure (DWAF, 2001). Yield calculated by DWAF.
TOTALS		979,9	---	156,1	352,13	14,5	522,73			

1) Yields are at 1:50 year assurance unless stated otherwise in the notes column. The allocation shown under the "Yield" column are what was available at 1:50 year assurance under catchment development conditions at the time when the yield was determined. The true allocations to irrigation are generally greater quantities supplied at lower, but unspecified, assurance.

APPENDIX E.3

FARM DAM DATA
PER QUATERNARY CATCHMENT

	oDISi	aDMIi	oDIEo
Quaternary Catchment	Full supply capacity	Full supply area	Evaporation Losses
	Mm^3	km^2	Mm^3/annum
G40B	0.00	0.00	1.00
G40C	8.67	1.71	1.26
G40D	43.56	4.59	1.93
G40E	2.84	0.53	0.37
G40F	1.30	0.25	0.20
G40G	0.94	0.17	0.12
G40H	0.30	0.06	0.04
G40J	0.61	0.12	0.09
G40K	0.00	0.00	0.00
G40L	0.22	0.05	0.04
G40M	0.19	0.03	0.02
G50A	0.00	0.00	0.00
G50B	0.05	0.03	0.03
G50C	0.00	0.00	0.00
G50D	0.99	0.24	0.22
G50E	0.00	0.00	0.00
G50F	0.00	0.00	0.00
G50G	0.00	0.00	0.00
G50H	0.00	0.00	0.00
G50J	0.00	0.00	0.00
G50K	0.00	0.00	0.00
H10A	4.78	1.34	3.67
H10B	6.60	1.61	3.02
H10C	9.69	3.31	7.56
H10D	0.00	0.00	0.00
H10E	0.00	0.00	0.00
H10F	0.72	0.20	0.75
H10G	0.40	0.07	0.88
H10H	2.97	0.57	2.10
H10J	0.00	0.00	0.00
H10K	0.15	0.02	0.01
H10L	0.00	0.00	0.00
H20A	0.12	0.06	0.07
H20B	3.54	0.67	1.83
H20C	2.76	0.62	0.73
H20D	0.00	0.00	0.00
H20E	0.00	0.00	0.00
H20F	0.35	0.08	0.16
H20G	0.00	0.00	0.00
H20H	1.25	0.24	0.96
H30A	1.16	0.36	3.56
H30B	1.06	0.16	4.18
H30C	0.53	0.10	0.10
H30D	0.48	0.12	0.13

Quaternary Catchment	oDISi	aDMIi	oDIEo
	Full supply capacity	Full supply area	Evaporation Losses
	Mm^3	km^2	Mm^3/annum
H30E	3.10	0.75	0.75
H40A	0.00	0.00	0.00
H40B	0.69	0.17	2.55
H40C	1.96	0.65	4.17
H40D	1.40	0.22	1.67
H40E	3.46	0.70	1.86
H40F	0.84	0.19	1.42
H40G	0.34	0.09	1.46
H40H	1.61	0.37	0.39
H40J	0.95	0.13	1.10
H40K	2.86	0.49	1.29
H40L	0.31	0.09	0.63
H50A	4.64	0.05	0.04
H50B	1.07	0.21	2.67
H60A	0.64	0.11	-0.01
H60B	7.34	1.89	1.36
H60C	5.51	0.89	0.55
H60D	4.77	0.67	0.52
H60E	0.00	0.00	0.00
H60F	0.09	0.02	0.02
H60G	0.00	0.00	0.00
H60H	1.29	0.28	0.25
H60J	0.00	0.00	0.00
H60K	0.00	0.00	0.00
H60L	0.00	0.00	0.00
H70A	0.41	0.11	0.10
H70B	0.73	0.13	0.10
H70C	0.98	0.25	0.25
H70D	0.59	0.08	0.06
H70E	0.87	0.21	0.15
H70F	0.30	0.04	0.03
H70G	0.00	0.00	0.00
H70H	0.00	0.00	0.00
H70J	0.00	0.00	0.00
H70K	0.00	0.00	0.00
TOTAL	**142.97**	**26.10**	**58.37**

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 water requirements.**

BREEDE WATER MANAGEMENT AREA

APPENDIX F.1

URBAN WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	fNuli	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTLo
	Distribution loss factor	Bulk loss factor	Indirect urban use	Total urban water use	Increased runoff due to urban areas	Urban Population	Direct urban use	Indirect urban use	Total Return flows	Total losses
	Factor	Factor	Mm^3/a	Mm^3/a	Mm^3/a	Number	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a
G40B	0.20	0.05	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00
G40C	0.20	0.05	0.30	1.41	0.09	14300.00	0.76	0.29	0.61	0.35
G40D	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40E	0.20	0.05	0.06	0.28	0.06	1950.00	0.15	0.06	0.13	0.07
G40F	0.20	0.05	0.24	1.16	0.15	9400.00	0.62	0.24	0.51	0.29
G40G	0.20	0.05	0.15	0.56	0.21	4450.00	0.27	0.15	0.26	0.14
G40H	0.20	0.05	1.00	3.65	0.52	20650.00	1.73	0.98	1.73	0.91
G40J	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40K	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40L	0.20	0.05	0.15	0.73	0.21	6050.00	0.39	0.15	0.31	0.18
G40M	0.20	0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
G50A	0.20	0.05	0.01	0.05	0.00	400.00	0.02	0.01	0.02	0.01
G50B	0.20	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
G50C	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50D	0.20	0.05	0.05	0.25	0.09	2450.00	0.14	0.05	0.10	0.06
G50E	0.20	0.05	0.27	1.28	0.18	10950.00	0.69	0.27	0.57	0.32
G50F	0.20	0.05	0.09	0.32	0.10	2700.00	0.15	0.09	0.14	0.08
G50G	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50H	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50J	0.20	0.05	0.03	0.09	0.01	750.00	0.04	0.03	0.04	0.02
G50K	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10B	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Areas	fNuli	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTLo
	Distribution loss factor	Bulk loss factor	Indirect urban use	Total urban water use	Increased runoff due to urban areas	Urban Population	Direct urban use	Indirect urban use	Total Return flows	Total losses
	Factor	Factor	Mm^3/a	Mm^3/a	Mm^3/a	Number	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a
H10C	0.20	0.05	0.05	0.22	0.28	1850.00	0.12	0.04	0.10	0.05
H10D	0.20	0.05	1.16	3.60	0.00	21250.00	1.54	1.14	1.60	0.90
H10E	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10F	0.20	0.05	0.19	0.89	0.11	5500.00	0.48	0.19	0.46	0.22
H10G	0.20	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
H10H	0.20	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
H10J	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10K	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10L	0.20	0.05	0.00	0.00	0.01	1500.00	0.00	0.04	0.00	0.00
H20A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H20B	0.20	0.05	0.13	0.61	0.05	6800.00	0.33	0.13	0.27	0.15
H20C	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H20D	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H20E	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H20F	0.20	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
H20G	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H20H	0.20	0.05	4.19	13.01	0.35	75700.00	5.56	4.13	6.34	3.25
H30A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H30B	0.20	0.05	0.31	0.97	0.06	8800.00	0.42	0.31	0.47	0.24
H30C	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H30D	0.20	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
H30E	0.20	0.05	0.23	1.07	0.06	8450.00	0.58	0.22	0.50	0.27
H40A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40B	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40C	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40D	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40E	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40F	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40G	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Areas	fNuli	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTLo
	Distribution loss factor	Bulk loss factor	Indirect urban use	Total urban water use	Increased runoff due to urban areas	Urban Population	Direct urban use	Indirect urban use	Total Return flows	Total losses
	Factor	Factor	Mm^3/a	Mm^3/a	Mm^3/a	Number	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a
H40H	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40J	0.20	0.05	0.40	1.93	0.17	17150.00	1.04	0.40	0.81	0.48
H40K	0.20	0.05	0.04	0.20	0.05	1850.00	0.11	0.04	0.08	0.05
H40L	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H50A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H50B	0.20	0.05	0.23	0.72	0.06	5050.00	0.31	0.23	0.32	0.18
H60A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60B	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60C	0.20	0.05	0.08	0.38	0.10	3300.00	0.21	0.08	0.18	0.10
H60D	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60E	0.20	0.05	0.06	0.29	0.06	3700.00	0.16	0.06	0.10	0.07
H60F	0.20	0.05	0.01	0.06	0.07	650.00	0.03	0.01	0.02	0.02
H60G	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60H	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60J	0.20	0.05	0.07	0.32	0.04	2650.00	0.17	0.07	0.14	0.08
H60K	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60L	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H70A	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H70B	0.20	0.05	0.26	1.24	0.10	10750.00	0.67	0.26	0.54	0.31
H70C	0.20	0.05	0.03	0.15	0.03	1700.00	0.08	0.03	0.06	0.04
H70D	0.20	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
H70E	0.20	0.05	0.03	0.12	0.03	1600.00	0.07	0.03	0.04	0.03
H70F	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H70G	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H70H	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H70J	0.20	0.05	0.03	0.13	0.00	1850.00	0.07	0.03	0.04	0.03
H70K	0.20	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
TOTALS	**--**	**--**	**9.86**	**35.68**	**3.74**	**254150**	**16.90**	**9.74**	**16.52**	**8.92**

BREEDE WATER MANAGEMENT AREA

APPENDIX F.2

RURAL WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	gRCRo	gRIRo	gRSRo	gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural Water consumption rate	1:50 year small scale irrigation	Large stock units consumption rate	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l/c/d	Mm^3/a	l/u/d	Mm^3/a	Number	Mm^3/a	Mm^3/a	Number	Factor
G40B	31.65	0.00	46.97	0.06	221.80	0.00	0.00	2799.00	0.20
G40C	105.50	0.00	46.97	0.23	3235.00	0.00	0.00	3556.00	0.20
G40D	105.50	0.00	46.97	0.52	7296.00	0.00	0.00	7768.00	0.20
G40E	109.30	0.00	48.34	0.24	1913.00	0.00	0.00	6641.00	0.20
G40F	109.30	0.00	48.34	0.27	1072.00	0.00	0.00	10030.00	0.20
G40G	48.09	0.00	48.34	0.11	1089.00	0.00	0.00	3995.00	0.20
G40H	109.30	0.00	48.34	0.05	515.20	0.00	0.00	1032.00	0.20
G40J	48.09	0.00	48.34	0.11	755.40	0.00	0.00	4022.00	0.20
G40K	109.30	0.00	48.34	0.28	1057.00	0.00	0.00	10270.00	0.20
G40L	109.30	0.00	48.34	0.14	949.10	0.00	3.00	4257.00	0.20
G40M	86.34	0.00	48.34	0.17	1213.00	0.00	0.00	5586.00	0.20
G50A	101.60	0.00	48.34	0.09	0.00	0.00	0.00	3944.00	0.20
G50B	48.09	0.00	48.34	0.15	1165.00	0.00	0.00	5527.00	0.20
G50C	109.30	0.00	48.34	0.17	303.70	0.00	0.00	6865.00	0.20
G50D	109.30	0.00	48.34	0.27	1163.00	0.00	0.00	9673.00	0.20
G50E	109.30	0.00	48.34	0.13	255.10	0.00	0.00	5103.00	0.20
G50F	109.30	0.00	48.34	0.12	222.60	0.00	0.00	4727.00	0.20
G50G	86.34	0.00	48.34	0.20	845.30	0.00	0.00	7387.00	0.20
G50H	85.95	0.00	48.17	0.37	1400.00	0.00	0.00	14520.00	0.20
G50J	108.60	0.00	48.09	0.20	294.30	0.00	0.00	8411.00	0.20
G50K	108.80	0.00	48.16	0.06	119.40	0.00	0.00	2662.00	0.20
H10A	106.50	0.00	47.34	0.13	2325.00	0.00	0.00	829.00	0.20
H10B	106.50	0.00	47.34	0.08	1492.00	0.00	0.00	576.00	0.20
H10C	106.50	0.00	47.34	0.33	6270.00	0.00	0.00	967.00	0.20
H10D	106.50	0.00	47.34	0.03	421.50	0.00	0.00	352.00	0.20
H10E	106.50	0.00	47.34	0.06	717.40	0.00	0.00	957.00	0.20
H10F	106.50	0.00	47.34	0.28	4513.00	0.00	0.00	2907.00	0.20
H10G	99.04	0.00	47.34	0.33	6493.00	0.00	0.00	1454.00	0.20
H10H	106.50	0.00	47.34	0.18	3282.00	0.00	0.00	1000.00	0.20
H10J	106.50	0.00	47.34	0.14	1136.00	0.00	0.00	4032.00	0.20
H10K	106.50	0.00	47.34	0.09	1111.00	0.00	0.00	1690.00	0.20
H10L	0.00	0.00	0.00	0.00	2066.00	0.00	0.00	515.00	0.20
H20A	108.90	0.00	48.22	0.08	1260.00	0.00	0.00	750.00	0.20
H20B	109.10	0.00	48.28	0.24	4570.00	0.00	0.00	666.00	0.20
H20C	109.30	0.00	48.34	0.02	320.60	0.00	0.00	286.00	0.20
H20D	106.70	0.00	47.40	0.07	1245.00	0.00	0.00	510.00	0.20
H20E	106.50	0.00	47.34	0.05	719.30	0.00	0.00	503.00	0.20
H20F	106.90	0.00	47.50	0.26	5126.00	0.00	0.00	623.00	0.20
H20G	69.56	0.00	47.52	0.06	1662.00	0.00	0.00	457.00	0.20
H20H	107.00	0.00	47.52	0.03	476.80	0.00	0.00	479.00	0.20
H30A	106.70	0.00	47.42	0.08	1120.00	0.00	0.00	1331.00	0.20
H30B	106.70	0.00	47.42	0.07	1015.00	0.00	0.00	1101.00	0.20

Areas	gRCRo	gRIRo	gRSRo	gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural Water consumption rate	1:50 year small scale irrigation	Large stock units consumption rate	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	l/c/d	M m^3/a	l/u/d	Mm^3/a	Number	Mm^3/a	Mm^3/a	Number	Factor
H30C	106.70	0.00	47.42	0.07	956.00	0.00	0.00	1144.00	0.20
H30D	106.70	0.00	47.42	0.06	967.70	0.00	0.00	444.00	0.20
H30E	106.70	0.00	47.42	0.10	1589.00	0.00	0.00	816.00	0.20
H40A	108.90	0.00	48.22	0.03	224.90	0.00	0.00	783.00	0.20
H40B	109.10	0.00	48.26	0.06	856.60	0.00	0.00	873.00	0.20
H40C	106.60	0.00	47.36	0.18	3073.00	0.00	0.00	1455.00	0.20
H40D	106.70	0.00	47.42	0.07	1040.00	0.00	0.00	979.00	0.20
H40E	106.60	0.00	47.36	0.21	3691.00	0.00	0.00	1556.00	0.20
H40F	106.60	0.00	47.36	0.18	2770.00	0.00	0.00	2040.00	0.20
H40G	106.70	0.00	47.42	0.09	1031.00	0.00	0.00	1915.00	0.20
H40H	106.70	0.00	47.42	0.10	1349.00	0.00	0.00	1376.00	0.20
H40J	106.60	0.00	47.37	0.17	2843.00	0.00	0.00	1383.00	0.20
H40K	106.70	0.00	47.42	0.09	931.30	0.00	0.00	1867.00	0.20
H40L	106.60	0.00	47.37	0.20	3543.00	0.00	0.00	1082.00	0.20
H50A	106.60	0.00	47.37	0.16	2459.00	0.00	0.00	1875.00	0.20
H50B	91.66	0.00	47.37	0.26	2824.00	0.00	0.00	6414.00	0.20
H60A	106.50	0.00	47.34	0.09	1035.00	0.00	0.00	1799.00	0.20
H60B	106.50	0.00	47.34	0.22	2195.00	0.00	0.00	5252.00	0.20
H60C	92.19	0.00	47.59	0.25	3309.00	0.00	0.00	4933.00	0.20
H60D	69.82	0.00	47.67	0.23	3496.00	0.00	0.00	5421.00	0.20
H60E	107.60	0.00	47.72	0.25	3410.00	0.00	0.00	3983.00	0.20
H60F	107.70	0.00	47.76	0.13	1106.00	0.00	0.00	3612.00	0.20
H60G	109.30	0.00	48.34	0.09	223.20	0.00	0.00	3378.00	0.20
H60H	107.80	0.00	47.79	0.16	672.50	0.00	0.00	5834.00	0.20
H60J	107.80	0.00	47.82	0.16	699.60	0.00	0.00	5697.00	0.20
H60K	107.90	0.00	47.83	0.12	574.10	0.00	0.00	4272.00	0.20
H60L	107.90	0.00	47.83	0.12	682.30	0.00	0.00	3804.00	0.20
H70A	106.90	0.00	47.50	0.11	694.20	0.00	0.00	3668.00	0.20
H70B	106.90	0.00	47.48	0.07	355.80	0.00	0.00	2409.00	0.20
H70C	107.40	0.00	47.67	0.13	568.50	0.00	0.00	4747.00	0.20
H70D	105.50	0.00	46.99	0.12	759.70	0.00	0.00	3681.00	0.20
H70E	105.30	0.00	46.92	0.13	1495.00	0.00	0.00	2840.00	0.20
H70F	61.07	0.00	46.91	0.07	1048.00	0.00	0.00	1996.00	0.20
H70G	106.80	0.00	47.43	0.32	1605.00	0.00	0.00	11120.00	0.20
H70H	84.35	0.00	47.44	0.18	470.90	0.00	0.00	7434.00	0.20
H70J	108.60	0.00	48.09	0.33	1014.00	0.00	0.00	12520.00	0.20
H70K	106.80	0.00	47.44	0.11	244.80	0.00	0.00	4352.00	0.20
TOTAL	**--**	**0.00**	**--**	**11.95**	**128233.60**	**0.00**	**3.00**	**279514.00**	**--**

BREEDE WATER MANAGEMENT AREA

APPENDIX F.3

BULK WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic Water Use	Return flow (mining)	Groundwater decant/mine dewatering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
G40B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G40M	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G50K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0

Areas	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic Water Use	Return flow (mining)	Groundwater decant/mine dewatering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
H10C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H10L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H20H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H30A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H30B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H30C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H30D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H30E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0

Areas	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic Water Use	Return flow (mining)	Groundwater decant/mine dewatering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
H40H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H40L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H50A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H50B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H60L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
H70K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
TOTALS	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	0

BREEDE WATER MANAGEMENT AREA

APPENDIX F.4

IRRIGATION WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Quaternary catchment	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Area under high category crops	Area under low category crops	Area under medium category crops	Green cover area	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 water use by irrigators
	km^2	km^2	km^2	km^2	Factor	Factor	Factor	Factor	Factor	Factor	Mm^3/a
G40B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40C	0.00	0.00	0.00	29.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40D	0.00	0.00	0.00	46.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40E	0.00	15.30	0.00	15.30	0.00	0.05	0.00	0.00	0.75	0.00	8.80
G40F	0.00	0.68	0.00	0.68	0.00	0.05	0.00	0.00	0.75	0.00	0.46
G40G	0.00	4.41	0.00	4.41	0.00	0.05	0.00	0.00	0.75	0.00	2.10
G40H	0.00	9.14	0.00	9.14	0.00	0.05	0.00	0.00	0.75	0.00	4.29
G40J	0.00	5.09	0.00	5.09	0.00	0.05	0.00	0.00	0.75	0.00	3.15
G40K	0.00	1.16	0.00	1.16	0.00	0.05	0.00	0.00	0.75	0.00	0.83
G40L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G40M	0.00	0.11	0.90	1.01	0.00	0.05	0.05	0.00	0.75	0.75	0.69
G50A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50B	0.00	0.05	0.38	0.43	0.00	0.00	0.00	0.00	0.75	0.75	0.31
G50C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50D	0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.75	0.00	0.11
G50E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50J	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G50K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10A	7.83	0.00	0.01	12.41	0.10	0.00	0.10	0.80	0.00	0.80	6.99
H10B	9.91	0.00	0.08	16.00	0.10	0.00	0.10	0.80	0.00	0.80	9.66
H10C	26.82	0.00	0.40	41.29	0.10	0.00	0.10	0.80	0.00	0.80	24.17
H10D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Quaternary catchment	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Area under high category crops	Area under low category crops	Area under medium category crops	Green cover area	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 water use by irrigators
	km^2	km^2	km^2	km^2	Factor	Factor	Factor	Factor	Factor	Factor	Mm^3/a
H10E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H10F	21.17	2.18	0.50	33.57	0.10	0.10	0.10	0.80	0.80	0.80	23.04
H10G	49.77	1.19	0.06	71.89	0.10	0.10	0.10	0.80	0.80	0.80	53.54
H10H	5.34	0.64	0.00	8.55	0.10	0.10	0.00	0.80	0.80	0.00	6.65
H10J	3.26	0.05	0.00	4.72	0.10	0.10	0.00	0.80	0.80	0.00	2.93
H10K	2.51	0.04	0.00	3.65	0.10	0.10	0.00	0.80	0.80	0.00	2.48
H10L	13.37	0.25	0.00	19.46	0.10	0.10	0.00	0.80	0.80	0.00	0.00
H20A	2.61	0.15	0.00	3.40	0.10	0.10	0.00	0.80	0.80	0.00	2.39
H20B	12.75	0.04	0.00	15.75	0.10	0.10	0.00	0.80	0.80	0.00	12.08
H20C	4.03	0.67	0.01	5.77	0.10	0.10	0.10	0.80	0.80	0.80	3.58
H20D	0.48	0.00	0.00	0.58	0.10	0.00	0.00	0.80	0.00	0.00	0.43
H20E	1.10	0.01	0.00	1.36	0.10	0.10	0.00	0.80	0.80	0.00	1.12
H20F	14.62	0.00	0.01	18.01	0.10	0.00	0.10	0.80	0.00	0.80	13.81
H20G	2.89	0.04	0.00	3.61	0.10	0.10	0.00	0.80	0.80	0.00	3.03
H20H	1.58	1.11	0.00	3.32	0.10	0.10	0.00	0.80	0.80	0.00	2.96
H30A	10.99	0.00	0.00	14.33	0.00	0.00	0.00	0.81	0.00	0.00	8.20
H30B	7.81	0.00	0.00	10.18	0.00	0.00	0.00	0.78	0.00	0.00	6.09
H30C	5.90	0.00	0.00	7.69	0.00	0.00	0.00	0.79	0.00	0.00	4.57
H30D	8.16	0.00	0.00	10.63	0.00	0.00	0.00	0.85	0.00	0.00	7.26
H30E	13.94	0.00	0.00	18.16	0.00	0.00	0.00	0.75	0.00	0.00	9.30
H40A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H40B	6.60	0.00	0.00	8.39	0.00	0.00	0.00	0.85	0.00	0.00	4.63
H40C	33.89	0.00	0.00	43.10	0.00	0.00	0.00	0.75	0.00	0.00	26.69
H40D	13.81	0.00	0.00	17.56	0.00	0.00	0.00	0.75	0.00	0.00	9.79
H40E	13.79	0.00	0.00	17.54	0.00	0.00	0.00	0.75	0.00	0.00	10.67
H40F	22.95	0.00	0.00	28.68	0.00	0.00	0.00	0.75	0.00	0.00	16.68
H40G	14.92	0.00	0.00	18.97	0.00	0.00	0.00	0.75	0.00	0.00	9.26
H40H	7.64	0.00	0.00	9.71	0.00	0.00	0.00	0.75	0.00	0.00	4.68
H40J	16.94	0.00	0.00	21.54	0.00	0.00	0.00	0.75	0.00	0.00	9.75
H40K	14.47	0.00	0.00	18.40	0.00	0.00	0.00	0.75	0.00	0.00	8.81

Quaternary catchment	alHAi Area under high category crops km^2	alLAi Area under low category crops km^2	alMAi Area under medium category crops km^2	alSAi Green cover area km^2	flHCi Conveyance losses for high category crops Factor	flLCi Conveyance losses for low category crops Factor	flMCi Conveyance losses for medium category crops Factor	flPHi Application efficiency for high category crops Factor	flPLi Application efficiency for low category crops Factor	fIPMi Application efficiency for medium category crops Factor	glARo Total water use by irrigators Mm^3/a
H40L	21.54	0.00	0.00	27.29	0.00	0.00	0.00	0.75	0.00	0.00	14.44
H50A	21.16	0.00	0.00	34.01	0.00	0.00	0.00	0.75	0.00	0.00	13.98
H50B	0.00	0.00	0.00	33.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H60A	16.10	0.00	0.00	23.00	0.10	0.00	0.00	0.80	0.00	0.00	10.05
H60B	1.19	0.00	0.00	1.70	0.10	0.00	0.00	0.80	0.00	0.00	0.97
H60C	16.80	0.00	0.00	24.00	0.10	0.00	0.00	0.80	0.00	0.00	15.33
H60D	10.31	0.00	0.00	14.73	0.10	0.00	0.00	0.80	0.00	0.00	9.21
H60E	0.00	3.00	0.00	4.29	0.00	0.05	0.00	0.00	0.75	0.00	2.17
H60F	0.00	3.06	0.00	4.37	0.00	0.05	0.00	0.00	0.75	0.00	2.28
H60G	0.00	0.09	0.00	0.14	0.00	0.05	0.00	0.00	0.75	0.00	0.07
H60H	0.00	2.20	0.00	3.14	0.00	0.05	0.00	0.00	0.75	0.00	1.74
H60J	0.00	1.68	0.00	2.39	0.00	0.05	0.00	0.00	0.75	0.00	1.36
H60K	0.01	1.52	0.00	2.18	0.05	0.05	0.00	0.75	0.75	0.00	1.28
H60L	0.00	3.65	0.00	5.21	0.00	0.05	0.00	0.00	0.75	0.00	2.99
H70A	0.02	2.40	0.00	3.46	0.05	0.05	0.00	0.75	0.75	0.00	1.92
H70B	0.66	5.63	0.09	9.11	0.05	0.05	0.05	0.75	0.75	0.75	4.62
H70C	10.40	0.00	0.00	14.86	0.05	0.00	0.00	0.85	0.00	0.00	7.74
H70D	0.00	3.52	0.00	5.03	0.00	0.05	0.00	0.00	0.75	0.00	2.43
H70E	0.00	0.55	0.00	0.78	0.00	0.05	0.00	0.00	0.75	0.00	0.38
H70F	0.00	9.01	0.00	12.88	0.00	0.05	0.00	0.00	0.75	0.00	6.40
H70G	0.00	3.42	0.00	4.88	0.00	0.05	0.00	0.00	0.75	0.00	2.72
H70H	0.00	0.90	0.00	1.28	0.00	0.05	0.00	0.00	0.75	0.00	0.75
H70J	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H70K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS	**470.03**	**83.09**	**2.44**	**853.88**	**--**	**–**	**--**	**--**	**--**	**–**	**428.80**

BREEDE 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 RUNOFF DUE TO ALIEN VEGETATION	REDUCTION IN FUNOFF DUE TO DRYLAND SUGAR CANE	REDUCTION IN RUNOFF DUE TO AFFORESTATION	RIVER LOSSES
	km^2	Km^2	km^2	km^2	km^2	km^2	Million m^3/a	Million m^3/a
G10A	12,66	0,00	34,97	0,00	2,77	0,00	10,04	0,22
G10B	19,82	0,00	8,44	0,00	2,86	0,00	1,81	0,16
G10C	8,34	0,00	9,25	0,00	1,87	0,00	2,06	0,41
G10D	23,21	0,00	1,66	0,00	4,07	0,00	0,28	0,87
G10E	8,28	0,00	19,69	0,00	1,50	0,00	1,44	0,50
G10F	16,23	0,00	1,45	0,00	2,09	0,00	0,06	0,68
G10G	0,76	0,00	0,00	0,00	0,26	0,00	0,00	0,23
G10H	58,26	0,00	1,32	0,00	3,34	0,00	0,04	0,85
G10J	37,49	0,00	0,08	0,00	2,56	0,00	0,00	1,09
G10K	243,90	0,00	0,00	0,00	9,89	0,00	0,00	0,81
G10L	181,50	0,00	0,24	0,00	8,17	0,00	0,01	1,21
G10M	408,40	0,00	0,00	0,00	16,55	0,00	0,00	1,38
G21A	135,10	0,00	0,00	0,00	9,73	0,00	0,00	0,36
G21B	67,62	0,00	0,04	0,00	4,63	0,00	0,00	0,21
G21C	8,43	0,00	0,00	0,00	0,72	0,00	0,00	0,17
G21D	55,40	0,00	2,32	0,00	3,48	0,00	0,11	0,00
G21E	8,89	0,00	0,13	0,00	0,73	0,00	0,01	0,00
G21F	21,40	0,00	0,00	0,00	1,54	0,00	0,00	0,00
G22A	24,55	0,00	0,05	0,00	3,44	0,00	0,01	0,00

QUATERNARY CATCHMENT	aAAAi AREA UNDER ALIEN VEGETATION km²	aCAUi AREA UNDER DRYLAND SUGAR CANE Km²	aFCAi AREA UNDER AFFORESTATION km²	aFINi AREA OF INDIGENOUS FORESTS km²	oARDo REDUCTION IN RUNOFF DUE TO ALIEN VEGETATION km²	oCDo REDUCTION IN FUNOFF DUE TO DRYLAND SUGAR CANE km²	oFRDo REDUCTION IN RUNOFF DUE TO AFFORESTATION Million m^3/a	VLRLi RIVER LOSSES Million m^3/a
G22B	8,46	0,00	2,38	0,00	1,90	0,00	0,62	0,00
G22C	2,32	0,00	0,76	0,00	0,25	0,00	0,07	0,00
G22D	5,53	0,00	7,97	0,00	1,24	0,00	1,77	0,00
G22E	0,00	0,00	0,16	0,00	0,00	0,00	1,01	0,00
G22F	1,76	0,00	4,09	0,00	0,39	0,00	1,46	0,00
G22G	0,28	0,00	2,47	0,00	0,05	0,00	0,38	0,00
G22H	0,58	0,00	3,19	0,00	0,07	0,00	0,33	0,00
G22J	8,08	0,00	10,53	0,00	1,23	0,00	3,83	0,00
G22K	7,92	0,00	0,00	0,00	1,32	0,00	0,00	0,00
G40A	0,23	0,00	8,58	0,00	0,06	0,00	1,75	0,00
TOTALS	**1375,40**	**0,00**	**119,75**	**0,00**	**86,69**	**0,00**	**26,08**	10,00

APPENDIX F.6

WESTERN 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

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WESTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2: NOTES ON PROCEEDINGS

CONTENTS

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Western 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

A two day workshop was held and a number of experts representing various disciplines relating to rivers and people knowledgeable of the Western Cape rivers were invited to attend. The workshop was held on 15 and 16 July 1999 at Ninham Shand in Cape Town and was facilitated by Mike Luger of Ninham Shand's Environmental Section. The delegates who took part in the workshop were as follows:

? Cate Brown of Southern Waters
? Rebecca Tharme of the Freshwater Research Unit at the University of Cape Town
? Charlie Boucher of Stellenbosch University's Botany Department
? Dean Impson of Cape Nature Conservation
? Wietsche Roets of Cape Nature Conservation
? Neels Kleynhans of DWAF (IWQS)
? Gareth McConkey of DWAF Water Quality Management (Western Cape Region)
? Gerrit van Zyl of DWAF (Western Cape Region)
? Jan van Staden of DWAF (Western Cape Region)
? Mike Luger of Ninham Shand
? Susie Tyson of Ninham Shand
? Liesl Nettmann 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 Western 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.

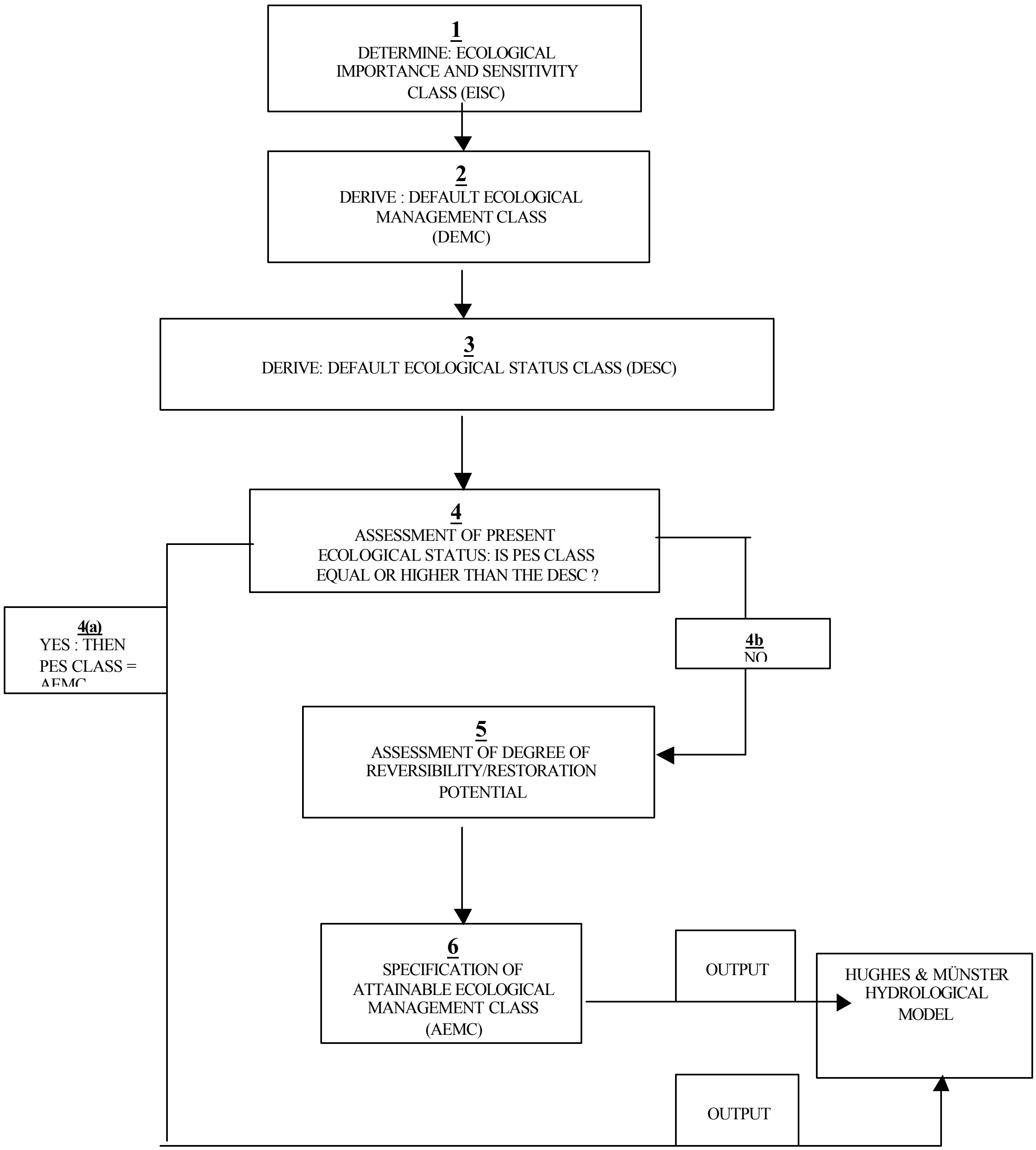


Figure 2.1: Flow diagram indicating the sequence of steps proposed for the determination of the Attainable Ecological Management Class.

- E10A, E10B
- E10C
- E10D, E10E, E10F, E10G, E10J
- E10K (gorge section and below)
- E21A, E21B, E21C, E21D
- E21E, E21F, E21G, E21H, E21J, E21K, E21L, E24A, E24B
- E22A, E22B, E22C, E22D, E22E, E22F, E23A, E23B, E23C, E23D, E23E, E23F, E23G, E23H, E23J, E23K, E24C, E24E, E24F, E24G, E24K
- E22G
- E24L, E24M, E24J, E24H
- E32A, E31B, E31C
- E33A, E33B, E33C, E33D, E31D, E31E, E31F, E31G, E31H, E32B, E32C, E32D, E32E
- E33F, E33G, E33H
- E40A, E40B
- E40C, E40D

- F60A, F60B, F60C, F60D, F60E, F40A, F40B, F40C, F40D, F40E, F40F, F40G, F40H, F50A, F50B, F50C, F50D, F50E, F50F, F50G

- G10A, G10B
- G10C
- G10D, G10F

- G10J (alone due to the presence of a downstream dam)
- G10E
- G10G
- G10L
- G10H
- G10K
- G10M (no rivers)
- G21A
- G21B
- G21D, G21C, G21E
- G21F
- G22A, G22B
- G22C, G22D
- G22E, G22G, G22H, G22J, G22K
- G22F
- G30B, G30C, G30D, G10H
- G30E, G30F, G30A
- G30G
- G30H (no rivers)
- G40A, G40B, G40D
- G40C

- G40E, G40F, G40G
- G40H, G40J, G40K, G40L
- G40M, G50A, G50B, G50C, G50D, G50E, G50F
- G50G, G50H, G50K
- G50J (no rivers)

- H10A, H10B, H10C
- H10D
- H10F, H10G
- H10E
- H10J, H10K
- H10L, H10H, H40C, H40D, H40E (mainstem of Breede River, before and after Hex River)
- H20A, H20B, H20C, H20D, H20E, H20F, H20G, H20H
- H30A, H30B
- H30E
- H40A, H40B, H30C, H30D
- H40F, H40G, H40H, H40J, H40K, H40L
- H50A, H50B, H70A
- H60A, H60B, H60C
- H60D, H60E, H60F, H60G, H60H
- H60J, H60K, H60L

- H70B, H70C, H70D, H70E, H70F
- H70G, H70H, H70J, H70K
- H80A, H80B, H80C, H90A, H90B, H90C
- H80D, H80E, H80F

- J11A, J11B, J11C, J11D, J11E, J11F, J11G, J11H, J11K, J12A, J12B, J12C, J12D, J12E, J12F, J12G, J12H, J12J, J12K, J12L, J12M, J13A, J13B, J13C (no data available for EI&SC)
- J11J
- J22A, J22B, J22C, J22D, J22E, J22F, J22G, J22H, J22J, J22K, J21A, J21B, J21C, J21D, J21E, J24A, J24B, J24C, J24D, J24E, J24F, J23A, J23B, J23C, J23D, J23E, J23F, J23G, J23H, J32A, J32B, J32C, J32D, J32E, J31A, J31B, J31C, J31D
- J23J, J25A, J25B, J25C, J25D (possibly B/ A due to pristine nature of tributaries and rugged terrain)
- J25E, J35A, J35B, J35C, J35D, J35E, J35F, J33A, J33B, J33C, J33D, J33E, J33F
- J34A, J34B, J34C, J34D, J34E, J34F
- J40A, J40B, J40C, J40D, J40E

- K10A, K10B, K10C, K10D, K10E, K10F, K20A, K30A, K30B, K30C
- K30D, K40A, K40B, K40C, K40D, K40E, K50A, K50B, K60A, K60B, K60C, K60D, K60E, K60F, K60G, K70A, K70B

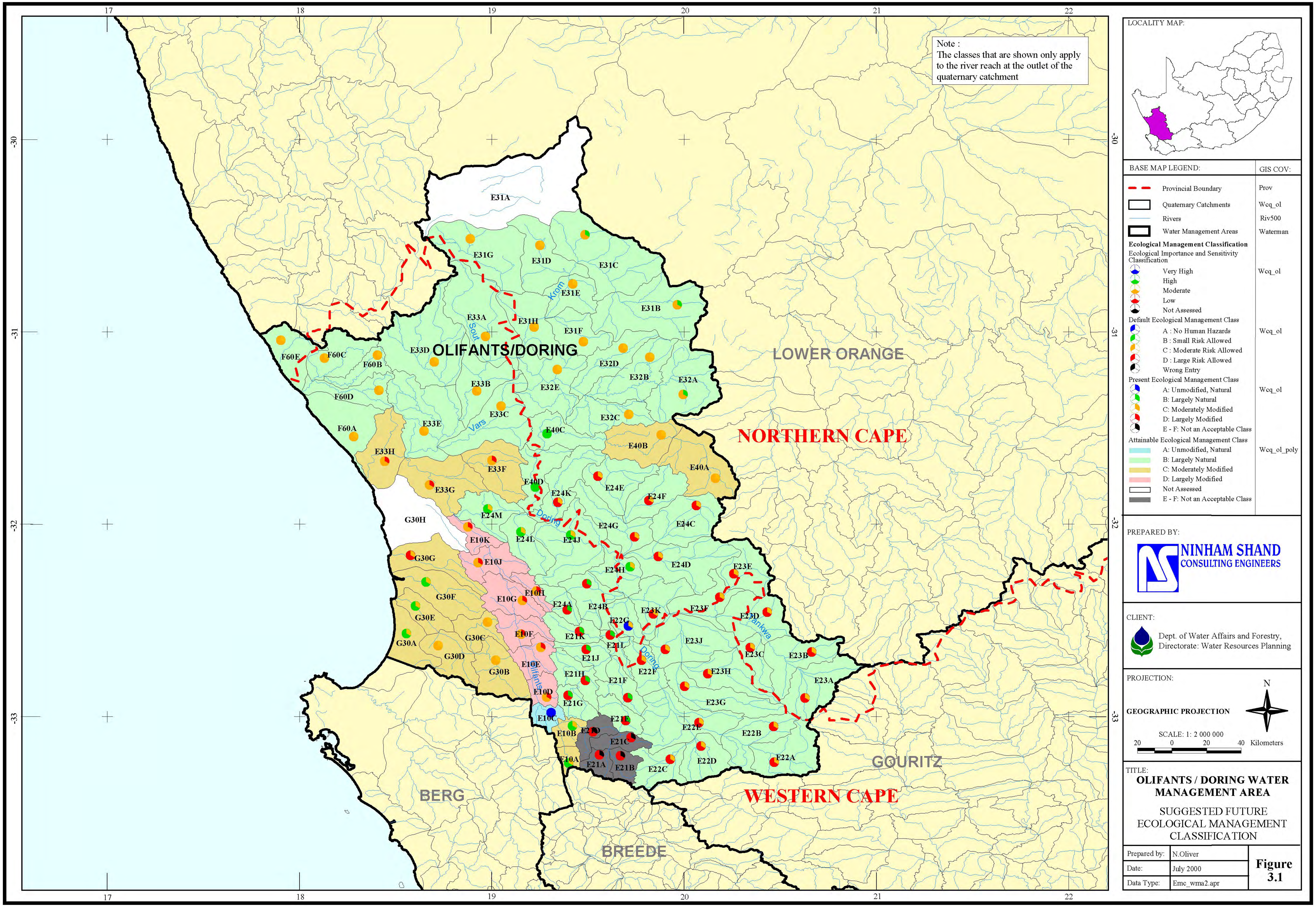
CHAPTER 3: RESULTS OF THE WORKSHOP

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 Western Cape.

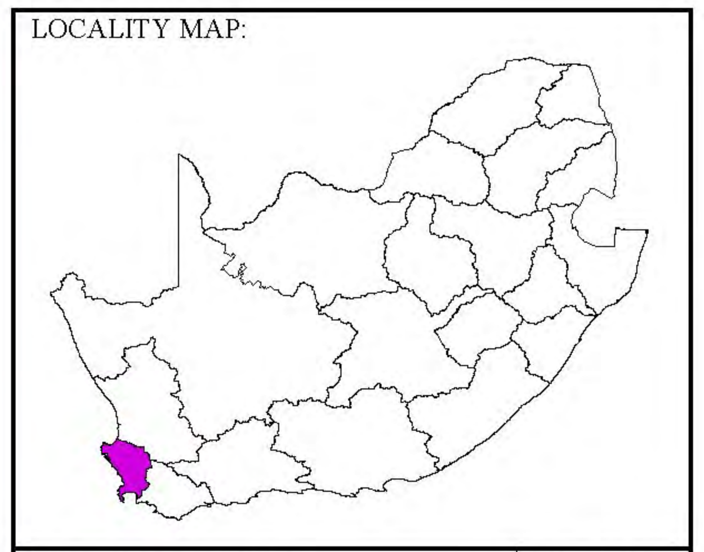
3.2 MANAGEMENT CLASSES

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 3.4) and the data entered in the Ecoinfo programme on CD Rom (see Annexure B).



Note : The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
OLIFANTS/DORING
LOWER ORANGE
NORTHERN CAPE
WESTERN CAPE
GOURITZ
BERG
BREEDE
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary Prov
Quaternary Catchments Wcq_ol
Rivers Riv500
Water Management Areas Waterman
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Very High Wcq_ol
High
Moderate
Low
Not Assessed
Default Ecological Management Class
A : No Human Hazards Wcq_ol
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
A: Unmodified, Natural Wcq_ol
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
A: Unmodified, Natural Wcq_ol_poly
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:
OLIFANTS / DORING WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Emc_wma2.apr
Figure 3.1

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	Wcqpnt1_berg_geo
Very High	
High	
Moderate	
Low	
Not Assessed	
Default Ecological Management Class	Wcqpnt1_berg_geo
A : No Human Hazards	
B : Small Risk Allowed	
C : Moderate Risk Allowed	
D : Large Risk Allowed	
Wrong Entry	
Present Ecological Status Class	Wcqpnt1_berg_geo
A: Unmodified, Natural	
B: Largely Natural	
C: Moderately Modified	
D: Largely Modified	
E - F: Not an Acceptable Class	
Attainable Ecological Management Class	Wcqberg_sass_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:

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION:

GEOGRAPHIC PROJECTION

N

SCALE: 1: 1 000 000

10 0 10 20 Kilometers

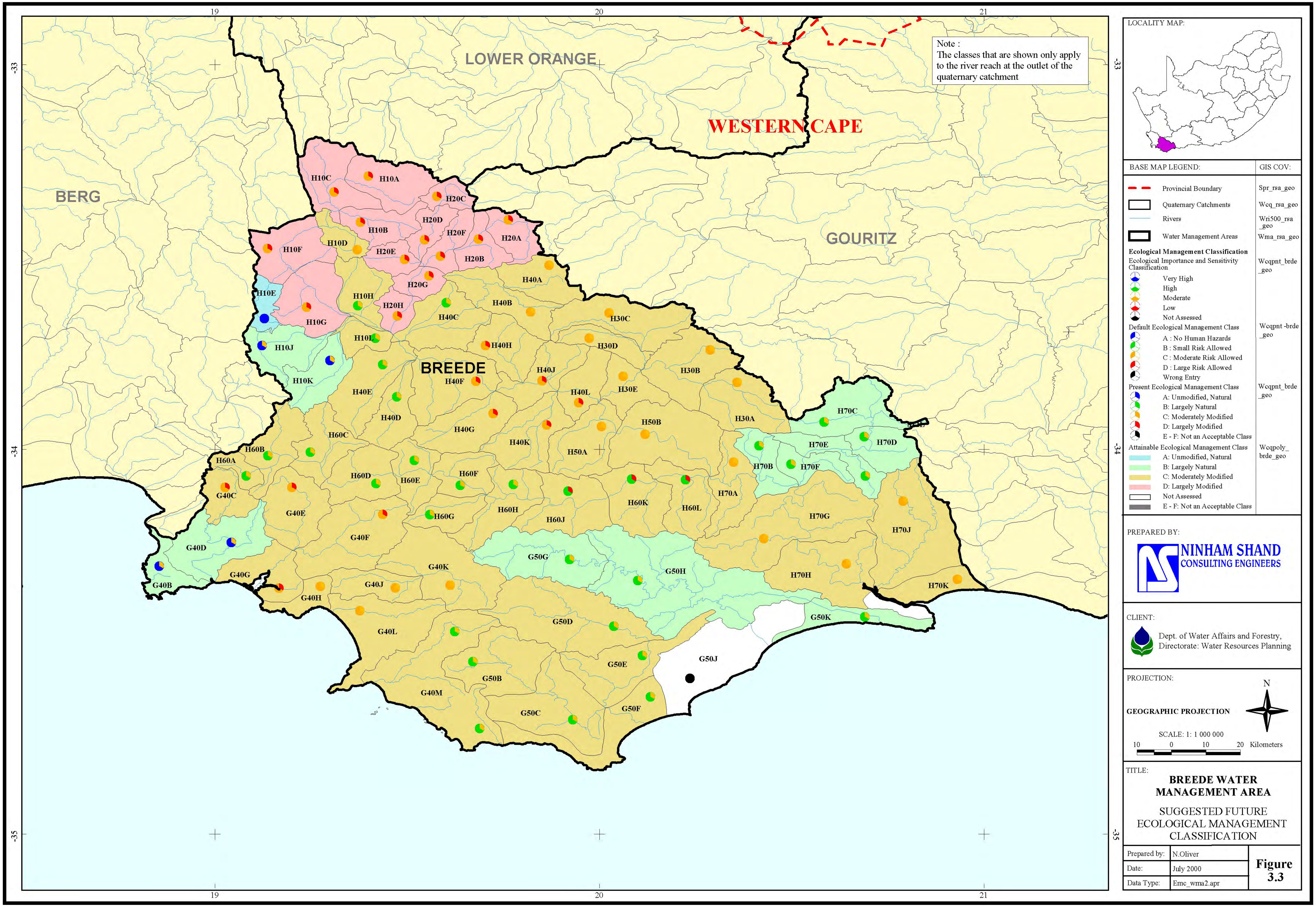
TITLE:

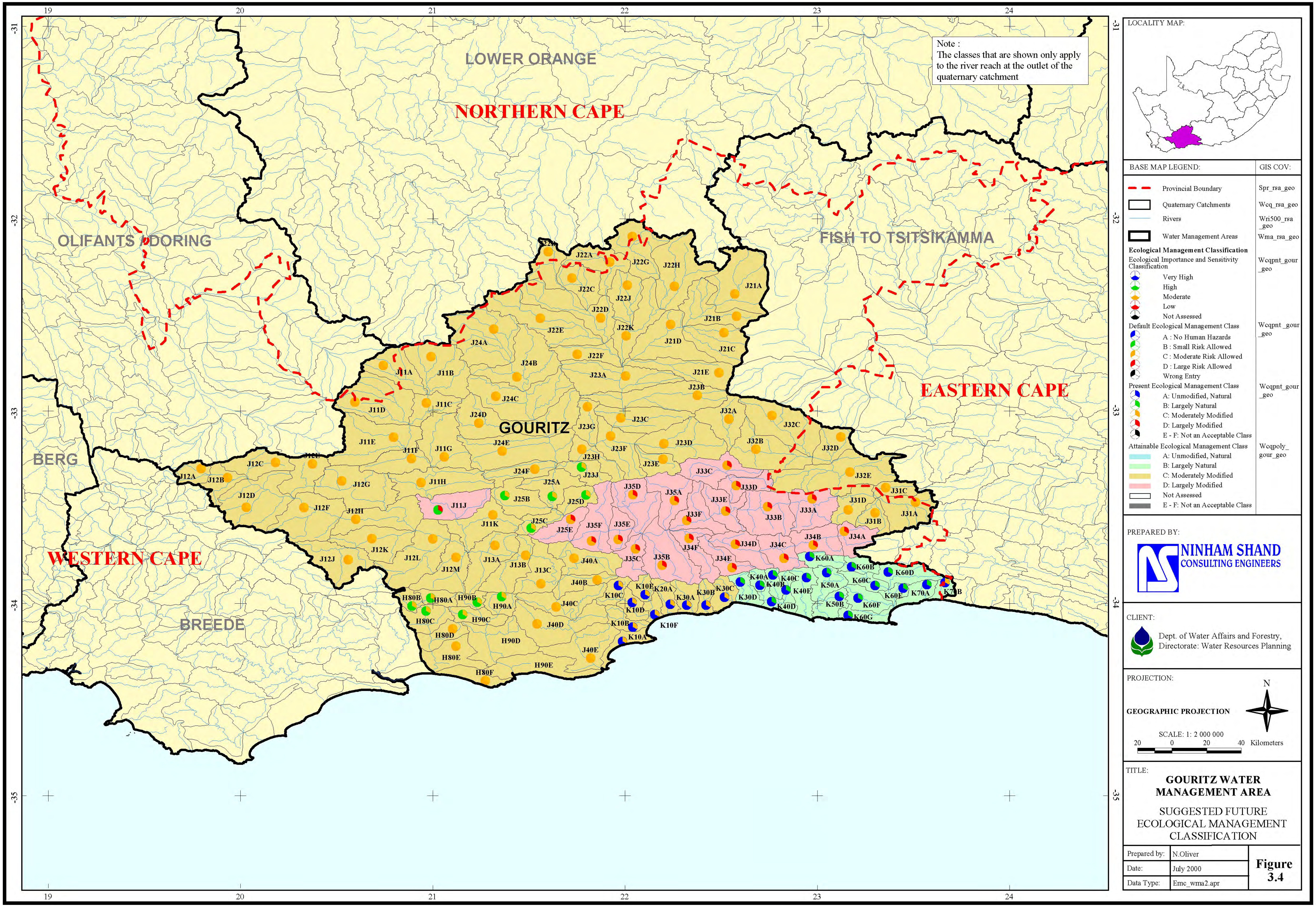
BERG WATER MANAGEMENT AREA

SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION

Prepared by:	N.Oliver
Date:	July 2000
Data Type:	Environmental.apr

Figure 3.2


LOWER ORANGE
WESTERN CAPE
BERG
GOURITZ
BREEDE
Note : The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
H10A H10B H10C H10D H10E H10F H10G H10H H10J H10K H10L
H20A H20B H20C H20D H20E H20F H20G H20H
H30A H30B H30C H30D H30E
H40A H40B H40C H40D H40E H40F H40G H40H H40J H40K H40L
H50A H50B
H60A H60B H60C H60D H60E H60F H60G H60H H60J H60K H60L
H70A H70B H70C H70D H70E H70F H70G H70H H70J H70K
G40B G40C G40D G40E G40F G40G G40H G40J G40K G40L G40M
G50B G50C G50D G50E G50F G50G G50H G50J G50K
19
20
21
-33
-34
-35
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_brde_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class — Wcqpnt -brde_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class — Wcqpnt_brde_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class — Wcqpoly_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: 1 000 000
10 0 10 20 Kilometers
TITLE:
BREEDE WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Eme_wma2.apr
Figure 3.3



Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
LOWER ORANGE
NORTHERN CAPE
OLIFANTS / DORING
FISH TO TSITSIKAMMA
EASTERN CAPE
GOURITZ
BERG
WESTERN CAPE
BREEDE
J11A J11B J11C J11D J11E J11F J11G J11H J11J J11K
J12A J12B J12C J12D J12E J12F J12G J12H J12J J12K J12L J12M
J13A J13B J13C
J21A J21B J21C J21D J21E
J22A J22C J22D J22E J22F J22G J22H J22J J22K
J23A J23B J23C J23D J23E J23F J23G J23H J23J
J24A J24B J24C J24D J24E J24F
J25A J25B J25C J25D J25E
J31A J31B J31C J31D
J32A J32B J32C J32D J32E
J33A J33B J33C J33D J33E J33F
J34A J34B J34C J34D J34E J34F
J35A J35B J35C J35D J35E J35F
J40A J40B J40C J40D J40E
H80A H80B H80C H80D H80E H80F
H90A H90B H90C H90D H90E
K10A K10B K10C K10D K10E K10F
K20A K30A K30B K30C K30D
K40A K40B K40C K40D K40E
K50A K50B
K60A K60B K60C K60D K60E K60F K60G
K70A K70B
19 20 21 22 23 24
-31 -32 -33 -34 -35
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 3.4

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 Western Cape rivers.

- Accuracy of assessments was facilitated by the diverse number of experts involved in the decision-making process. However, it was viewed by some that in most cases only one expert per field was present which makes it difficult to verify the results obtained.

- A lack of knowledge of inland and middle-eastern (e.g. the Klein Karoo) areas as well as the Gouritz area has made it difficult to assess these areas accurately. The concern is that this will affect the overall accuracy of the results obtained. An in-depth study of the unfamiliar areas is necessary to improve the data. Areas rated with a confidence level of “1" or “2" are those quaternaries where there is a lack of information.

- A request by participants is that the information contained in the water quality database, as well as other information regarding the issues concerned, be expanded and made available for detailed research.

- The scoring system is regarded as being easy to use and general consensus regarding areas discussed was reached within a short time frame. However, greater clarification regarding the confidence scoring system is necessary in order to facilitate evaluation.

- The upgrading of rivers to a higher class is decided by the possible improvement of flow modification. This leaves doubt as to how the other criteria should be addressed. It was felt that by removing invasive vegetation and reducing bulldozing of river beds flow would improve, yet these options were not addressed. Very few rivers have the potential to be upgraded over the specified five-year period as the majority require upgrading over ten years or more.

- Groupings of various catchments are too big, thus a very broad assessment was made resulting in inaccuracies. A number of quaternaries are linked together but only the main stem river was taken into account. This could result in the inaccurate scoring of the tributaries.

- The format of the methodology paper should be made clearer and user-friendly tables should be included, especially for EI&SC and DEMC. Furthermore, if the GIS layout of the results from the previous workshop had been available it would have aided the process greatly.

- The confidence levels need to be attached to all classes and a confidence level common denominator given.

- Ideally, rivers should be grouped according to ecotones rather than quaternary hydrological catchments as they are ecologically inappropriate, but it is acknowledged that this would not meet the requirements of the water balance model.

- The results should be reviewed by participants on a GIS database before the data is used for the national water balance.

- 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. *Western 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

BREEDE WATER MANAGEMENT AREA

APPENDIX F.7

ASSUMD RURAL DOMESTIC PER CAPITA WATER REQUIREMENTS PER QUATERNARY

Quaternary	PER CAPITA PER DAY RURAL USAGE					Average Consumption l/c/d
	30	30	30	100	l/c/d	
	Rural %	Advanced Rural %	Developing Urban %	Farming %	Comments	
G40B	0	0	100	0	Rooi-els, Pringle Bay	30
G40C	0	0	0	100	0	100
G40D	0	0	0	100	0	100
G40E	0	0	0	100	0	100
G40F	0	0	0	100	0	100
G40G	0	0	80	20	Hawston	44
G40H	0	0	0	100	0	100
G40J	0	80	0	20	Tesselaarsdal	44
G40K	0	0	0	100	0	100
G40L	0	0	0	100	0	100
G40M	0	30	0	70	Baardskeerdersbos, Uilenkraal	79
G50A	0	10	0	90	Viljoenshof	93
G50B	0	80	0	20	Elim	44
G50C	0	0	0	100	0	100
G50D	0	0	0	100	0	100
G50E	0	0	0	100	0	100
G50F	0	0	0	100	0	100
G50G	0	30	0	70	Klipdale	79
G50H	0	30	0	70	Protem, Wydgelee	79
G50J	0	0	0	100	0	100
G50K	0	0	0	100	0	100
H10A	0	0	0	100	0	100
H10B	0	0	0	100	0	100
H10C	0	0	0	100	0	100
H10D	0	0	0	0	No farming	0
H10E	0	0	0	0	No farming	0
H10F	0	0	0	100	0	100
H10G	0	10	0	90	Goudiniweg	93
H10H	0	0	0	100	0	100
H10J	0	0	0	100	0	100
H10K	0	0	0	100	0	100
H10L	0	0	70	30	Voorsorg prison	51
H20A	0	0	0	100	0	100
H20B	0	0	0	100	0	100
H20C	0	0	0	100	0	100
H20D	0	0	0	0	No farming	0
H20E	0	0	0	100	0	100
H20F	0	0	0	100	0	100
H20G	0	0	50	50	De Wet	65
H20H	0	0	0	100	0	100
H30A	0	0	0	100	0	100
H30B	0	0	0	100	0	100
H30C	0	0	0	100	0	100

Quaternary	PER CAPITA PER DAY RURAL USAGE					Average Consumption l/c/d
	30	30	30	100	l/c/d	
	Rural %	Advanced Rural %	Developing Urban %	Farming %	Comments	
H30D	0	0	0	100	0	100
H30E	0	0	0	100	0	100
H40A	0	0	0	100	0	100
H40B	0	0	0	100	0	100
H40C	0	0	0	100	0	100
H40D	0	0	0	100	0	100
H40E	0	0	0	100	0	100
H40F	0	0	0	100	0	100
H40G	0	0	0	100	0	100
H40H	0	0	0	100	0	100
H40J	0	0	0	100	0	100
H40K	0	0	0	100	0	100
H40L	0	0	0	100	0	100
H50A	0	0	0	100	0	100
H50B	0	0	20	80	Merwespont, Drew	86
H60A	0	0	0	100	0	100
H60B	0	0	0	100	0	100
H60C	0	0	20	80	Dennehof	86
H60D	0	0	50	50	Helderstroom	65
H60E	0	0	0	100	0	100
H60F	0	0	0	100	0	100
H60G	0	0	0	100	0	100
H60H	0	0	0	100	0	100
H60J	0	0	0	100	0	100
H60K	0	0	0	100	0	100
H60L	0	0	0	100	0	100
H70A	0	0	0	100	0	100
H70B	0	0	0	100	0	100
H70C	0	0	0	100	0	100
H70D	0	0	0	100	0	100
H70E	0	0	0	100	0	100
H70F	0	0	60	40	Buffeljagsrivier	58
H70G	0	0	0	100	0	100
H70H	0	30	0	70	Malgas	79
H70J	0	0	0	100	0	100
H70K	0	0	0	100	0	100

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.1

HYDROLOGICAL DATA PER QUATERNARY CATCHMENT

Quaternary catchment	aMTCi	eMRTo	oMAEi	oMAPi	oMARi
	Catchment Area	Natural mean annual runoff (accumulative)	Mean annual evaporation	Mean annual precipitation	Natural mean annual runoff (incremental)
	km^2	Mm^3/a	mm/a	mm/a	Mm^3/a
G40B	122.00	49.20	1410.00	937.00	49.20
G40C	145.00	109.70	1410.00	1367.00	109.70
G40D	327.00	252.60	1418.00	984.00	142.90
G40E	278.00	37.22	1415.00	722.00	37.22
G40F	422.00	21.65	1400.00	515.00	21.65
G40G	220.00	88.54	1415.00	724.00	29.67
G40H	96.00	11.71	1410.00	698.00	11.71
G40J	169.00	14.58	1440.00	613.00	14.58
G40K	429.00	33.89	1430.00	496.00	19.31
G40L	385.00	55.39	1440.00	569.00	21.50
G40M	393.00	22.55	1440.00	574.00	22.55
G50A	243.00	11.88	1440.00	545.00	11.88
G50B	339.00	15.26	1445.00	531.00	15.26
G50C	421.00	29.95	1440.00	489.00	14.69
G50D	572.00	15.46	1465.00	431.00	15.46
G50E	313.00	24.96	1465.00	448.00	9.50
G50F	290.00	62.85	1440.00	453.00	7.94
G50G	380.00	6.62	1430.00	371.00	6.62
G50H	890.00	21.97	1470.00	371.00	15.35
G50J	517.00	8.58	1430.00	365.00	8.58
G50K	163.00	26.17	1420.00	441.00	4.20
H10A	234.00	39.32	1670.00	512.00	39.32
H10B	162.00	46.64	1650.00	708.00	46.64
H10C	260.00	155.09	1650.00	674.00	69.13
H10D	97.00	205.49	1640.00	1019.00	50.40
H10E	85.00	90.35	1605.00	1850.00	90.35
H10F	248.00	382.45	1625.00	784.00	86.61
H10G	270.00	477.86	1610.00	788.00	95.41
H10H	187.00	556.84	1620.00	886.00	78.98
H10J	214.00	183.80	1570.00	1595.00	183.80
H10K	194.00	111.20	1545.00	1225.00	111.20
H10L	96.00	860.89	1605.00	476.00	9.05
H20A	140.00	4.74	1680.00	357.00	4.74
H20B	124.00	8.80	1660.00	590.00	4.06
H20C	81.00	8.84	1675.00	643.00	8.84
H20D	101.00	36.88	1660.00	696.00	28.04
H20E	95.00	40.15	1645.00	906.00	40.15
H20F	117.00	97.15	1660.00	797.00	11.32
H20G	85.00	101.90	1640.00	680.00	4.75
H20H	89.00	104.45	1620.00	300.00	2.55
H30A	284.00	16.33	1530.00	443.00	16.33
H30B	315.00	27.31	1600.00	374.00	10.98
H30C	327.00	23.26	1650.00	480.00	23.26

Quaternary catchment	aMTCi Catchment Area km ^{2}	eMRTo Natural mean annual runoff (accumulative) Mm ^{3}/a	oMAEi Mean annual evaporation mm/a	oMAPi Mean annual precipitation mm/a	oMARi Natural mean annual runoff (incremental) Mm ^{3}/a
H30D	127.00	28.08	1615.00	385.00	4.82
H30E	154.00	64.30	1550.00	441.00	8.91
H40A	184.00	6.51	1660.00	426.00	6.51
H40B	241.00	10.22	1645.00	578.00	3.71
H40C	272.00	989.74	1620.00	375.00	14.18
H40D	182.00	24.79	1500.00	557.00	24.79
H40E	285.00	1025.70	1545.00	539.00	35.96
H40F	340.00	1059.64	1560.00	293.00	9.15
H40G	263.00	17.47	1495.00	464.00	17.47
H40H	208.00	18.18	1605.00	461.00	18.18
H40J	204.00	1105.88	1560.00	424.00	10.59
H40K	271.00	12.46	1490.00	406.00	12.46
H40L	159.00	1124.43	1555.00	381.00	6.09
H50A	265.00	1195.65	1480.00	335.00	6.92
H50B	431.00	1212.31	1485.00	389.00	16.66
H60A	73.00	88.44	1440.00	1895.00	88.44
H60B	210.00	206.94	1465.00	1127.00	118.50
H60C	217.00	290.73	1470.00	891.00	83.79
H60D	227.00	332.43	1450.00	652.00	41.70
H60E	170.00	361.99	1455.00	640.00	29.56
H60F	165.00	385.28	1450.00	582.00	23.29
H60G	141.00	11.67	1420.00	475.00	11.67
H60H	253.00	416.70	1420.00	464.00	19.75
H60J	293.00	438.72	1415.00	457.00	22.02
H60K	262.00	450.33	1410.00	371.00	11.61
H60L	230.00	459.81	1405.00	361.00	9.48
H70A	224.00	1685.36	1415.00	414.00	13.24
H70B	153.00	1726.56	1450.00	694.00	41.20
H70C	287.00	13.97	1520.00	373.00	13.97
H70D	170.00	52.88	1440.00	635.00	38.91
H70E	157.00	100.50	1445.00	741.00	47.62
H70F	121.00	123.35	1440.00	573.00	22.85
H70G	652.00	1859.57	1420.00	366.00	9.66
H70H	400.00	1866.98	1440.00	395.00	7.41
H70J	551.00	9.41	1400.00	383.00	9.41
H70K	207.00	1882.39	1410.00	458.00	6.00
TOTALS	**19668.00**	**--**	**--**	**--**	**2471.86**

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

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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 of 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).

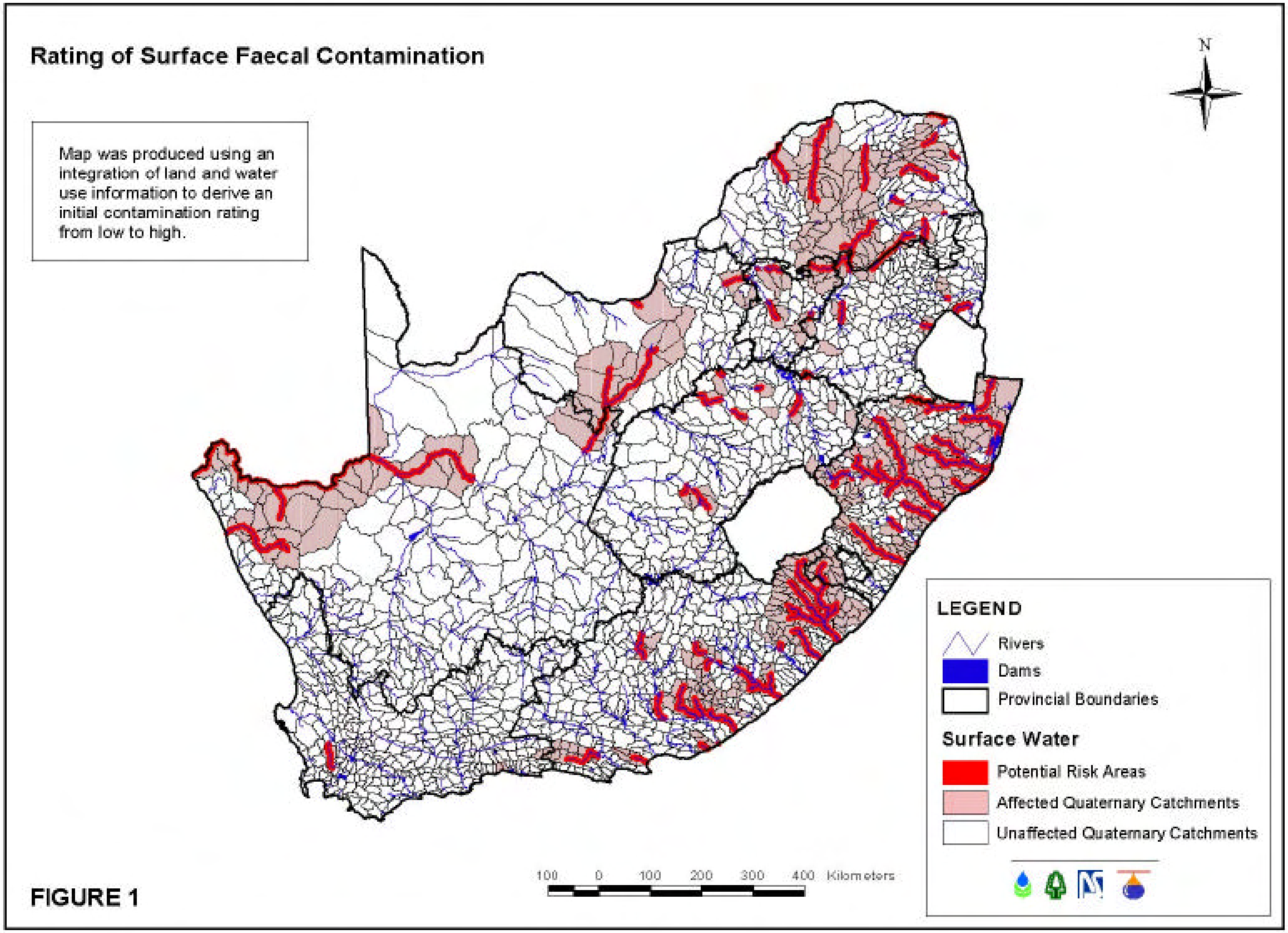
$$OR = 0.4\ TLU + 0.6\ TWU \qquad \text{........ (1)}$$

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
Map was produced using an integration of land and water use information to derive an initial contamination rating from low to high.
N
LEGEND
Rivers
Dams
Provincial Boundaries
Surface Water
Potential Risk Areas
Affected Quaternary Catchments
Unaffected Quaternary Catchments
100 0 100 200 300 400 Kilometers
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).

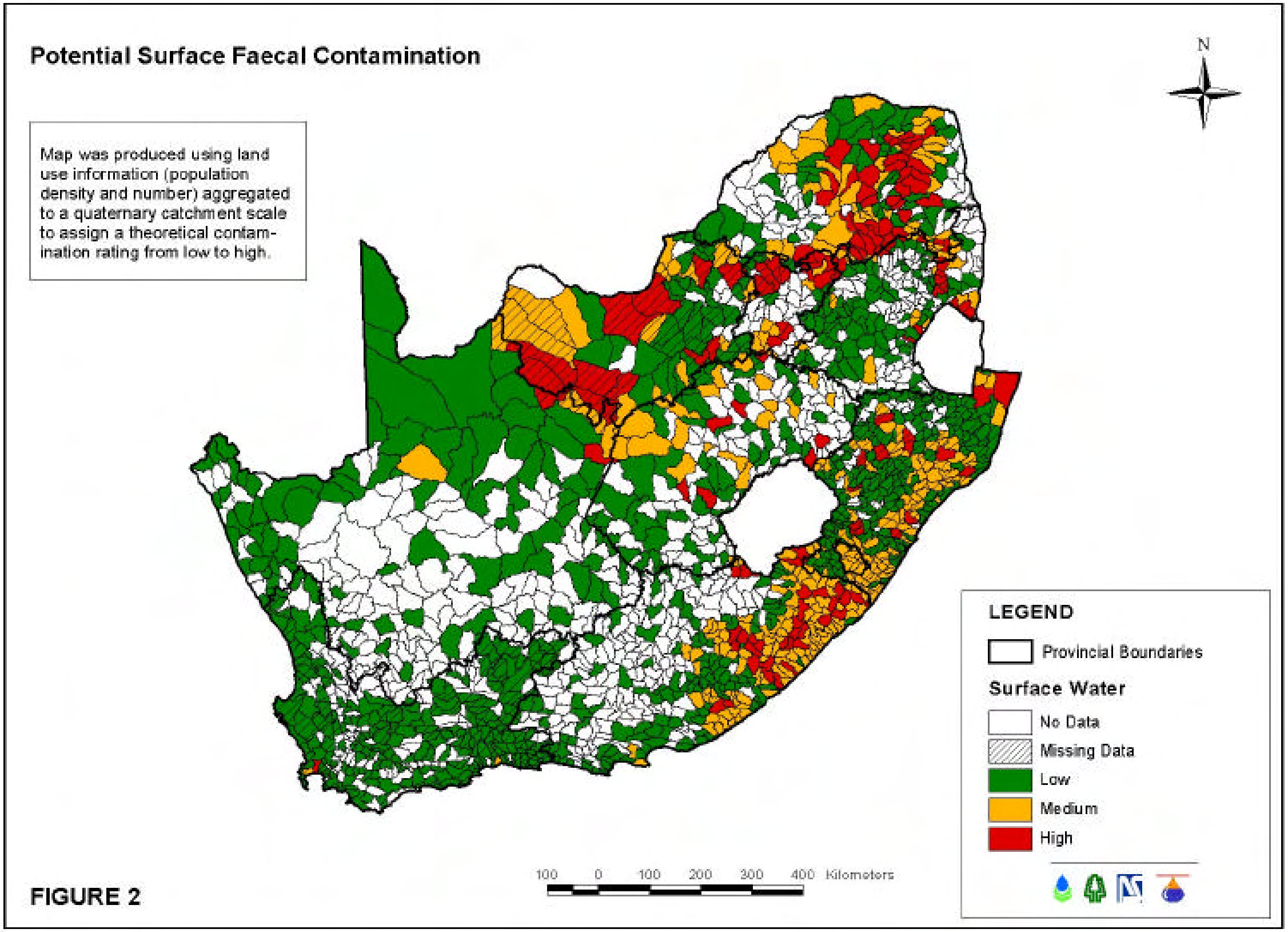

Potential Surface Faecal Contamination
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
N
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
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.

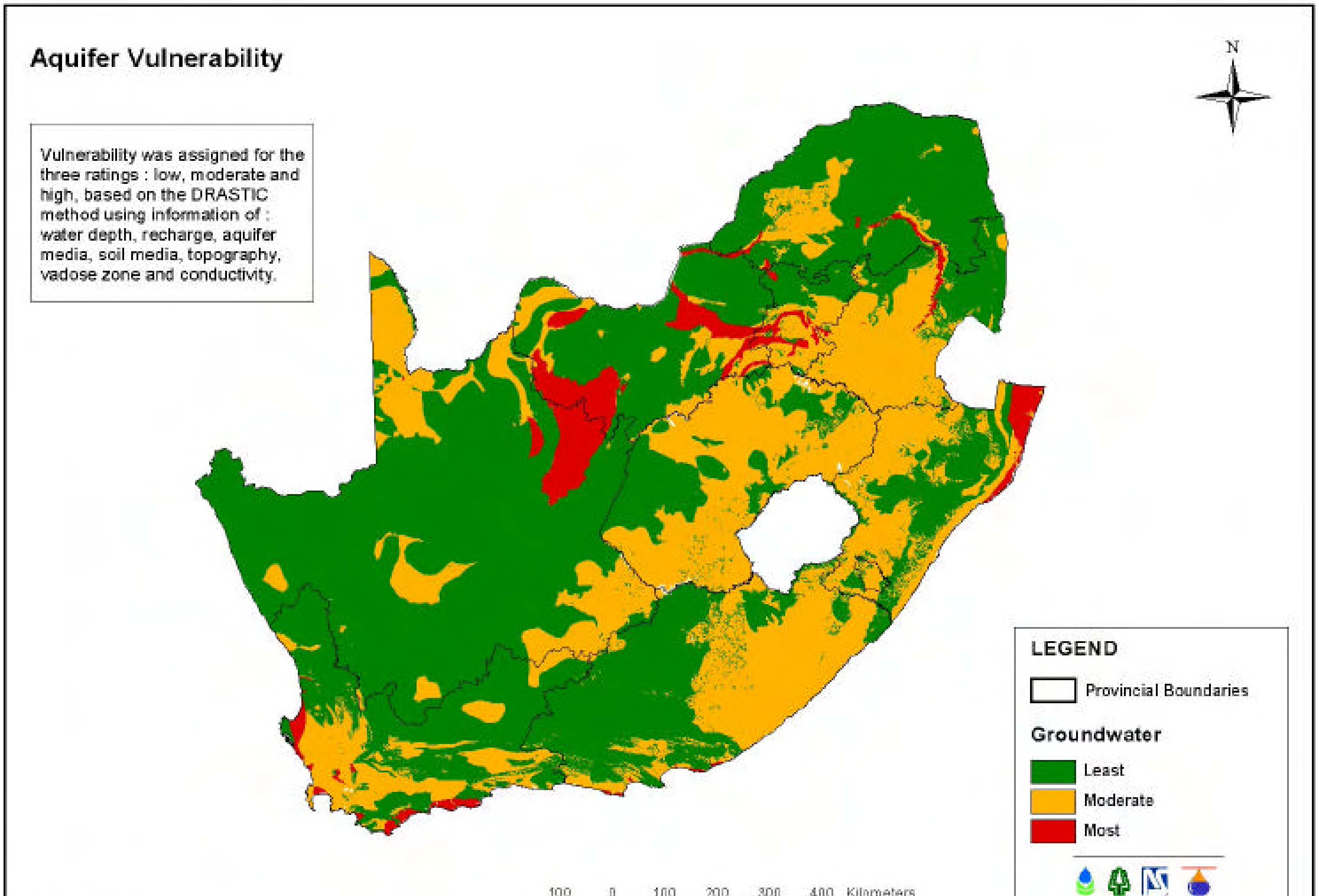

Aquifer Vulnerability
Vulnerability was assigned for the three ratings : low, moderate and high, based on the DRASTIC method using information of : water depth, recharge, aquifer media, soil media, topography, vadose zone and conductivity.
N
100 0 100 200 300 400 Kilometers
LEGEND
Provincial Boundaries
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:

$$I = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad \text{........(7)}$$

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,

$$\text{Index} = 5\ D_R + 5\ S_R + 4\ I_R \qquad \text{......... (8)}$$

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.

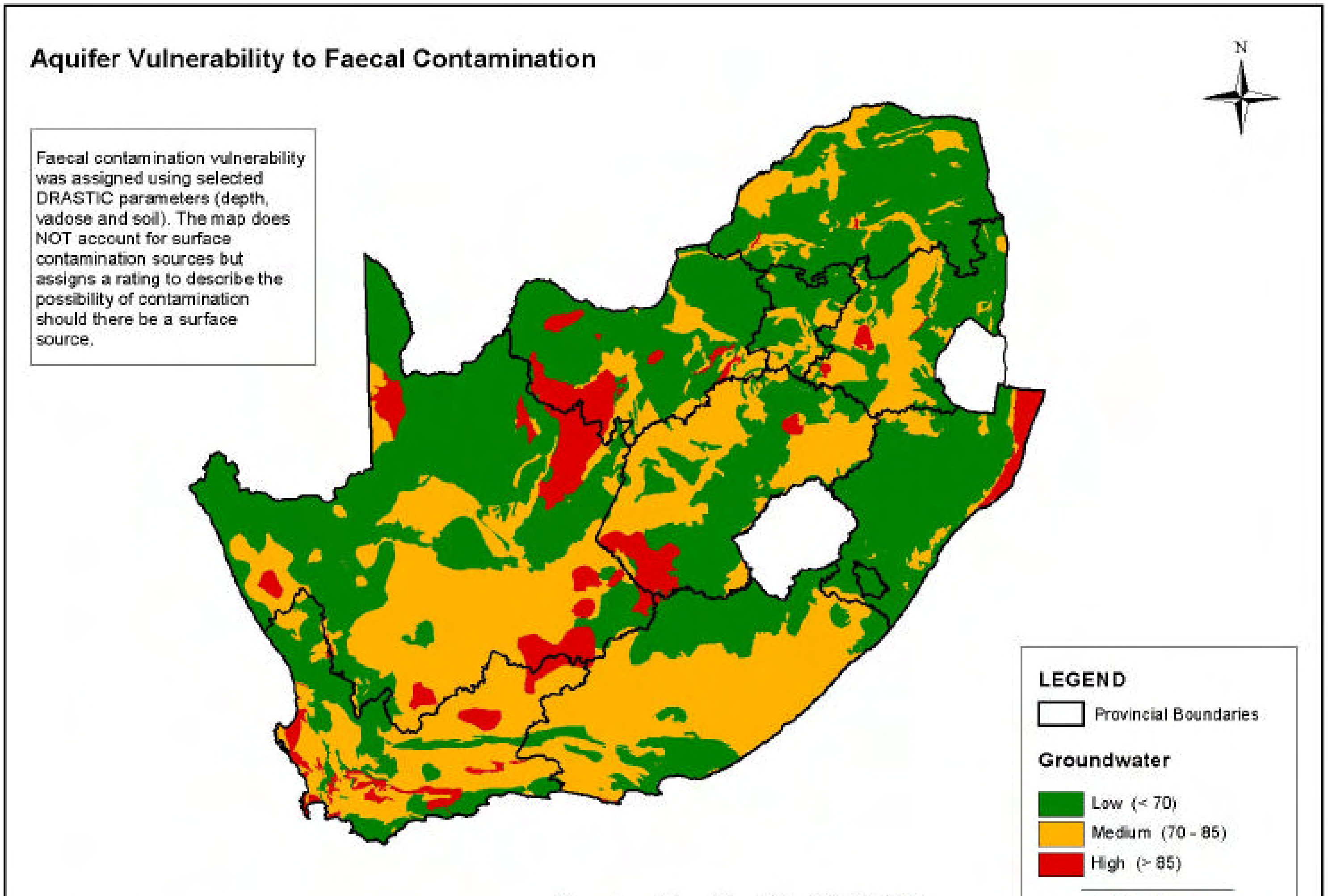

Aquifer Vulnerability to Faecal Contamination
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
N
LEGEND
Provincial Boundaries
Groundwater
Low (< 70)
Medium (70 - 85)
High (> 85)
100 0 100 200 300 400 Kilometers

FIGURE 4

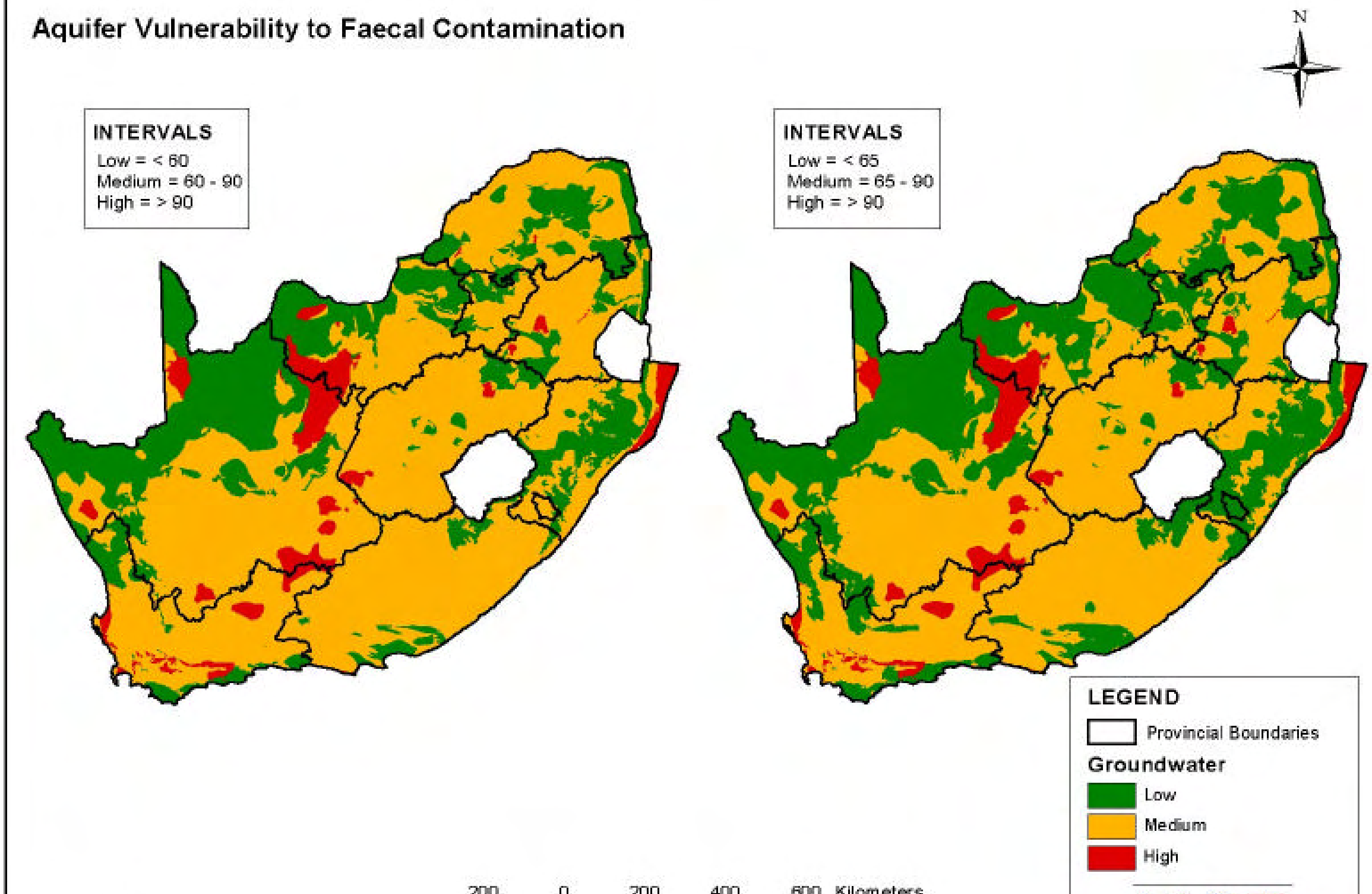

Aquifer Vulnerability to Faecal Contamination
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
N
LEGEND
Provincial Boundaries
Groundwater
Low
Medium
High
200 0 200 400 600 Kilometers

FIGURE 5

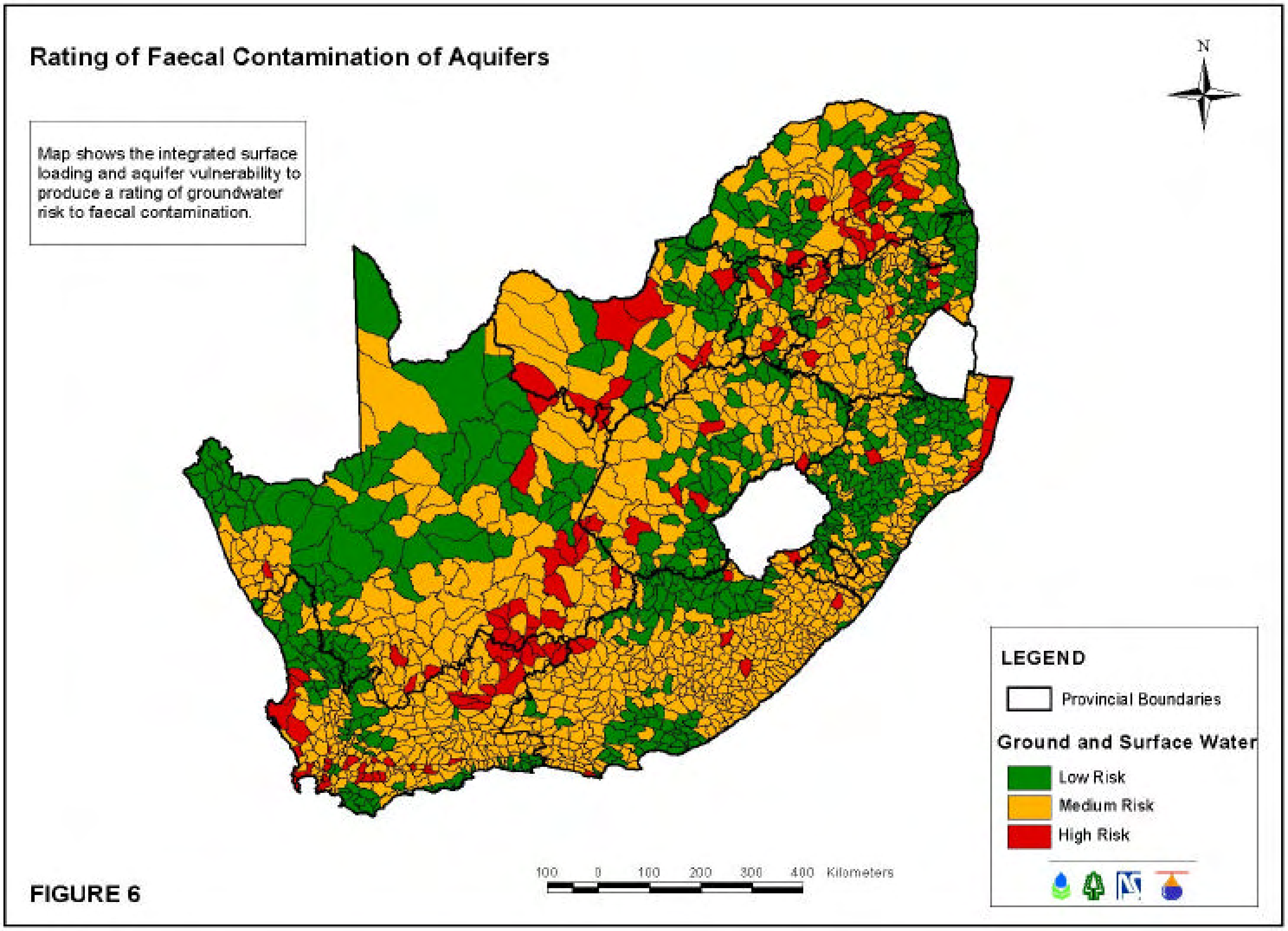

Rating of Faecal Contamination of Aquifers
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
N
LEGEND
Provincial Boundaries
Ground and Surface Water
Low Risk
Medium Risk
High Risk
100 0 100 200 300 400 Kilometers

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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BREEDE WATER MANAGEMENT AREA

APPENDIX G.3

SEDIMENTATION DATA PER QUATERNARY CATCHMENT

Quaternary Catchment	Area	Yield	25 year sediment Volume
	km^2	tonnes/a	m^3
G40B	122	1000	27269
G40C	145	2000	54538
G40D	327	8000	218152
G40E	278	6000	163614
G40F	422	14000	381766
G40G	220	2000	54538
G40H	96	1000	27269
G40J	169	4000	109076
G40K	429	15000	409035
G40L	385	3000	81807
G40M	393	6000	163614
G50A	243	8000	218152
G50B	339	7000	190883
G50C	421	15000	409035
G50D	572	19000	518111
G50E	313	8000	218152
G50F	290	9000	245421
G50G	380	13000	354497
G50H	890	29000	790801
G50J	517	5000	136345
G50K	163	1000	27269
H10A	234	8000	218152
H10B	162	2000	54538
H10C	260	4000	109076
H10D	97	1000	27269
H10E	85	1000	27269
H10F	248	5000	136345
H10G	270	4000	109076
H10H	187	4000	109076
H10J	214	2000	54538
H10K	194	2000	54538
H10L	96	1000	27269
H20A	140	4000	109076
H20B	124	3000	81807
H20C	81	1000	27269
H20D	101	1000	27269
H20E	95	1000	27269
H20F	117	2000	54538
H20G	85	1000	27269
H20H	89	3000	81807
H30A	284	7000	190883
H30B	315	9000	245421
H30C	327	11000	299959
H30D	127	2000	54538
H30E	154	4000	109076

Quaternary Catchment	Area	Yield	25 year sediment Volume
	km^2	tonnes/a	m^3
H40A	184	5000	136345
H40B	241	4000	109076
H40C	272	8000	218152
H40D	182	2000	54538
H40E	285	5000	136345
H40F	340	8000	218152
H40G	263	4000	109076
H40H	208	6000	163614
H40J	204	6000	163614
H40K	271	5000	136345
H40L	159	5000	136345
H50A	265	8000	218152
H50B	431	13000	354497
H60A	73	1000	27269
H60B	210	4000	109076
H60C	217	4000	109076
H60D	227	4000	109076
H60E	170	4000	109076
H60F	165	4000	109076
H60G	141	5000	136345
H60H	253	7000	190883
H60J	293	8000	218152
H60K	262	8000	218152
H60L	230	7000	190883
H70A	224	7000	190883
H70B	153	4000	109076
H70C	287	8000	218152
H70D	170	3000	81807
H70E	157	3000	81807
H70F	121	4000	109076
H70G	652	23000	627187
H70H	400	13000	354497
H70J	551	19000	518111
H70K	207	3000	81807
TOTALS	**19668**	**--**	**13116389**

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 (20th 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 ?/s	0.7
1.5 - 3.0 ?/s	0.6
0.7 - 1.5 ?/s	0.5
0.3 - 0.7 ?/s	0.4
<0.3 ?/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 ?/capita/day.

- Livestock use

  The number of equivalent large livestock units per quaternary catchment was taken from the WSAM and multiplied by 45 ?/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 ?/s) have been found in the Malmani Dolomites. Other high borehole yielding (> 10 ?/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 ?/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/?. The higher rainfall eastern parts have the best water quality, TDS < 100 mg/?. 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.

GROUNDWATER USE PER QUATERNARY CATCHMENT

QUATERNARY	AREA (km^2)	HARVEST POTENTIAL (m^3/km^2/a)	HARVEST POTENTIAL (mm)	oGHPi HARVEST POTENTIAL (x10^6 m^3/a)	AVERAGE YIELD BOREHOLES (□/s, 8hrs/day)	oGBYi AVERAGE YIELD BOREHOLES (□/s, 24hrs/day)	fGECi EXPLOITA-TION FACTOR	EXPLOITA-TION POTENTIAL (m^3/km^2/a)	EXPLOITA-TION POTENTIAL (mm)	oGEPo EXPLOITATION POTENTIAL (x10^6 m^3/a)	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (□/s)	SUM OF BOREHOLE YIELDS (x10^6 m^3/a)	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE (X10^6 m^3/a)	RURAL USE (x10^6 m^3/a)	LIVESTOCK USE (x10^6 m^3/a)	IRRIGATION USE (x10^6 m^3/a)	TOTAL USE FACTOR	oGWSo TOTAL USE (x10^6 m^3/a)	TOTAL USE (mm/a)
G40B	122	104631	104.6	12.76	2.00	0.67	0.6	62779	62.8	7.66	0	0.00	0.00	0	0.0000	0.0000	0.0014	0.0000	4.0000	0.0056	0.0
G40C	145	116731	116.7	16.93	3.68	1.23	0.7	81711	81.7	11.85	23	84.60	0.89	0	0.0000	0.0000	0.0014	0.0000	4.0000	0.0056	0.0
G40D	327	118792	118.8	38.85	3.57	1.19	0.7	83155	83.2	27.19	80	285.81	3.00	0	0.0000	0.0000	0.0020	0.0000	4.0000	0.0080	0.0
G40E	278	68373	68.4	19.01	5.53	1.84	0.7	47861	47.9	13.31	82	453.77	4.77	14	0.2050	0.0000	0.0047	0.0000	4.0000	0.8388	3.0
G40F	422	22306	22.3	9.41	2.76	0.92	0.6	13383	13.4	5.65	50	138.05	1.45	1	0.0000	0.0000	0.0060	0.0000	4.0000	0.0240	0.1
G40G	220	81658	81.7	17.96	2.56	0.85	0.6	48995	49.0	10.78	6	15.35	0.16	1	0.0050	0.0000	0.0026	0.0000	4.0000	0.0304	0.1
G40H	96	77185	77.2	7.41	1.73	0.58	0.6	46311	46.3	4.45	5	8.63	0.09	110	0.4000	0.0000	0.0006	0.0000	5.0000	2.0030	20.9
G40J	169	66461	66.5	11.23	3.24	1.08	0.7	46522	46.5	7.86	11	35.64	0.37	0	0.0000	0.0000	0.0011	0.0000	4.0000	0.0044	0.0
G40K	429	19507	19.5	8.37	4.84	1.61	0.7	13655	13.7	5.86	27	130.57	1.37	1	0.0000	0.0000	0.0071	0.0000	4.0000	0.0284	0.1
G40L	385	73837	73.8	28.43	3.87	1.29	0.7	51686	51.7	19.90	70	271.00	2.85	0	0.0000	0.0000	0.0022	0.0000	4.0000	0.0088	0.0
G40M	393	58977	59.0	23.18	8.80	2.93	0.7	41284	41.3	16.22	1	8.80	0.09	0	0.0000	0.0000	0.0028	0.0000	4.0000	0.0112	0.0
G50A	243	55620	55.6	13.52	2.00	0.67	0.6	33372	33.4	8.11	0	0.00	0.00	0	0.0000	0.0000	0.0000	0.0000	1.2000	0.0000	0.0
G50B	339	46890	46.9	15.90	3.70	1.23	0.7	32823	32.8	11.13	1	3.70	0.04	0	0.0000	0.0000	0.0048	0.0000	1.2000	0.0058	0.0
G50C	421	34066	34.1	14.34	0.71	0.24	0.5	17033	17.0	7.17	4	2.84	0.03	1	0.0000	0.0000	0.0068	0.0000	1.2000	0.0082	0.0
G50D	572	21971	22.0	12.57	1.52	0.51	0.6	13182	13.2	7.54	15	22.73	0.24	19	0.2422	0.0000	0.0075	0.0000	1.2000	0.2996	0.5
G50E	313	45087	45.1	14.11	6.39	2.13	0.7	31561	31.6	9.88	11	70.30	0.74	9	0.5000	0.0000	0.0049	0.0000	1.2000	0.6059	1.9
G50F	290	56221	56.2	16.30	1.53	0.51	0.6	33733	33.7	9.78	2	3.05	0.03	30	0.4000	0.0000	0.0047	0.0000	1.2000	0.4856	1.7
G50G	380	11642	11.6	4.42	0.20	0.07	0.3	3493	3.5	1.33	0	0.00	0.00	4	0.0000	0.0000	0.0067	0.0000	1.2000	0.0080	0.0
G50H	890	19162	19.2	17.05	0.25	0.08	0.3	5749	5.7	5.12	46	11.59	0.12	6	0.0000	0.0000	0.0140	0.0000	1.2000	0.0168	0.0
G50J	517	52710	52.7	27.25	0.35	0.12	0.4	21084	21.1	10.90	7	2.47	0.03	3	0.0000	0.0000	0.0082	0.0000	1.2000	0.0098	0.0
G50K	163	56439	56.4	9.20	1.00	0.33	0.5	28220	28.2	4.60	0	0.00	0.00	0	0.0000	0.0000	0.0018	0.0000	1.2000	0.0022	0.0
H10A	234	13936	13.9	3.26	7.14	2.38	0.7	9755	9.8	2.28	10	71.44	0.75	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H10B	162	82641	82.6	13.39	7.45	2.48	0.7	57849	57.8	9.37	14	104.26	1.10	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H10C	260	60071	60.1	15.62	10.25	3.42	0.7	42050	42.0	10.93	103	1055.75	11.10	262	0.6560	0.0000	0.0001	13.6644	1.9750	28.2830	108.8
H10D	97	58281	58.3	5.65	2.00	0.67	0.6	34969	35.0	3.39	0	0.00	0.00	5	0.0000	0.0000	0.0000	0.0517	2.0000	0.1034	1.1
H10E	85	177404	177.4	15.08	2.00	0.67	0.6	106442	106.4	9.05	0	0.00	0.00	0	0.0000	0.0000	0.0015	0.0000	2.0000	0.0030	0.0
H10F	248	125552	125.6	31.14	2.18	0.73	0.6	75331	75.3	18.68	6	13.09	0.14	831	0.0000	0.0000	0.0205	9.5054	2.0000	19.0518	76.8
H10G	270	92521	92.5	24.98	5.52	1.84	0.7	64764	64.8	17.49	11	60.70	0.64	198	0.0000	0.0000	0.0035	5.7530	2.0000	11.5130	42.6
H10H	187	64086	64.1	11.98	4.96	1.65	0.7	44860	44.9	8.39	8	39.67	0.42	48	0.0000	0.0000	0.0014	1.2380	2.0000	2.4788	13.3

QUATERNARY	AREA	HARVEST POTENTIAL	HARVEST POTENTIAL	oGHPi HARVEST POTENTIAL	AVERAGE YIELD BOREHOLES	oGBYi AVERAGE YIELD BOREHOLES	fGECi EXPLOITA-TION FACTOR	EXPLOITA-TION POTENTIAL	EXPLOITA-TION POTENTIAL	oGEPo EXPLOITATION POTENTIAL	NO OF BORES WITH YIELD DATA	SUM OF YIELDS	SUM OF BOREHOLE YIELDS	oGBNi THEORETICAL NO OF PRODUCTION	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)	(□/s, 8hrs/day)	(□/s, 24hrs/day)		($m^3/km^2/a$)	(mm)	($x10^6$ m^3/a)		(□/s)	($x10^6$ m^3/a)	BOREHOLES	($X10^6$ 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)
H10J	214	102666	102.7	21.97	8.24	2.75	0.7	71866	71.9	15.38	3	24.73	0.26	7	0.0000	0.0000	0.0047	0.3190	2.0000	0.6474	3.0
H10K	194	142256	142.3	27.60	4.12	1.37	0.7	99579	99.6	19.32	5	20.59	0.22	10	0.0000	0.0000	0.0035	0.2228	2.0000	0.4526	2.3
H10L	96	49971	50.0	4.80	2.19	0.73	0.6	29983	30.0	2.88	9	19.71	0.21	163	0.0870	0.0000	0.0013	1.7860	2.0000	3.7486	39.0
H20A	140	24645	24.6	3.45	6.84	2.28	0.7	17251	17.3	2.42	19	130.04	1.37	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H20B	124	56554	56.6	7.01	3.65	1.22	0.7	39588	39.6	4.91	56	204.17	2.15	3	0.0500	0.0000	0.0000	0.0000	2.0000	0.1000	0.8
H20C	81	75094	75.1	6.08	8.15	2.72	0.7	52566	52.6	4.26	2	16.30	0.17	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H20D	101	82687	82.7	8.35	0.90	0.30	0.5	41343	41.3	4.18	2	1.80	0.02	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H20E	95	95598	95.6	9.08	2.00	0.67	0.6	57359	57.4	5.45	1	2.00	0.02	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H20F	117	67005	67.0	7.84	4.55	1.52	0.7	46904	46.9	5.49	21	95.49	1.00	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H20G	85	60382	60.4	5.13	6.11	2.04	0.7	42268	42.3	3.59	5	30.53	0.32	10	0.0000	0.0000	0.0001	0.3103	2.0000	0.6208	7.3
H20H	89	29313	29.3	2.61	3.97	1.32	0.7	20519	20.5	1.83	15	59.50	0.63	24	0.0000	0.0000	0.0012	0.4962	2.0000	0.9948	11.2
H30A	284	35982	36.0	10.22	5.64	1.88	0.7	25187	25.2	7.15	22	124.16	1.31	20	0.0000	0.0000	0.0001	0.5905	2.0000	1.1812	4.2
H30B	315	33946	33.9	10.69	6.30	2.10	0.7	23762	23.8	7.48	12	75.59	0.79	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H30C	327	47552	47.6	15.55	4.28	1.43	0.7	33286	33.3	10.88	17	72.77	0.76	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H30D	127	46325	46.3	5.88	3.10	1.03	0.7	32428	32.4	4.12	2	6.20	0.07	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H30E	154	30315	30.3	4.67	4.40	1.47	0.7	21220	21.2	3.27	1	4.40	0.05	29	0.0000	0.0000	0.0029	0.6700	2.0000	1.3458	8.7
H40A	184	33846	33.8	6.23	6.82	2.27	0.7	23692	23.7	4.36	8	54.52	0.57	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H40B	241	85350	85.3	20.57	6.22	2.07	0.7	59745	59.7	14.40	5	31.11	0.33	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H40C	272	35927	35.9	9.77	3.76	1.25	0.7	25149	25.1	6.84	25	94.03	0.99	196	0.0000	0.0000	0.0032	3.8620	2.0000	7.7304	28.4
H40D	182	54500	54.5	9.92	6.67	2.22	0.7	38150	38.2	6.94	13	86.66	0.91	40	0.0000	0.0000	0.0025	1.4100	2.0000	2.8250	15.5
H40E	285	46805	46.8	13.34	7.90	2.63	0.7	32763	32.8	9.34	45	355.60	3.74	37	0.0000	0.0000	0.0038	1.5430	2.0000	3.0936	10.9
H40F	340	15477	15.5	5.26	9.49	3.16	0.7	10834	10.8	3.68	2	18.98	0.20	48	0.0000	0.0000	0.0052	2.4120	2.0000	4.8344	14.2
H40G	263	31293	31.3	8.23	5.71	1.90	0.7	21905	21.9	5.76	65	371.46	3.90	45	0.0000	0.0000	0.0058	1.3340	2.0000	2.6796	10.2
H40H	208	31698	31.7	6.59	5.19	1.73	0.7	22188	22.2	4.62	35	181.61	1.91	25	0.0000	0.0000	0.0052	0.6742	2.0000	1.3588	6.5
H40J	204	37419	37.4	7.63	4.30	1.43	0.7	26193	26.2	5.34	19	81.63	0.86	0	0.0000	0.0000	0.0060	0.0000	2.0000	0.0120	0.1
H40K	271	56177	56.2	15.22	8.15	2.72	0.7	39324	39.3	10.66	30	244.51	2.57	0	0.0001	0.0000	0.0010	0.0000	2.0000	0.0022	0.0
H40L	159	36458	36.5	5.80	1.02	0.34	0.5	18229	18.2	2.90	29	29.53	0.31	1	0.0000	0.0000	0.0049	0.0000	2.0000	0.0098	0.1
H50A	265	29804	29.8	7.90	2.50	0.83	0.6	17882	17.9	4.74	1	2.50	0.03	0	0.0000	0.0000	0.0009	0.0000	2.0000	0.0018	0.0
H50B	431	23465	23.5	10.11	3.19	1.06	0.7	16425	16.4	7.08	12	38.22	0.40	116	0.0000	0.0000	0.0029	1.9385	2.0000	3.8828	9.0
H60A	73	144678	144.7	10.56	9.95	3.32	0.7	101275	101.3	7.39	43	427.72	4.50	0	0.0000	0.0000	0.0003	0.0000	1.0000	0.0003	0.0
H60B	210	54517	54.5	11.45	8.71	2.90	0.7	38162	38.2	8.01	49	426.95	4.49	1	0.0000	0.0000	0.0022	0.1108	1.0000	0.1130	0.5

QUATERNARY	AREA (km^2)	HARVEST POTENTIAL ($m^3/km^2/a$)	HARVEST POTENTIAL (mm)	oGHPi HARVEST POTENTIAL ($x10^6$ m^3/a)	AVERAGE YIELD BOREHOLES (□/s, 8hrs/day)	oGBYi AVERAGE YIELD BOREHOLES (□/s, 24hrs/day)	fGECi EXPLOITA-TION FACTOR	EXPLOITA-TION POTENTIAL ($m^3/km^2/a$)	EXPLOITA-TION POTENTIAL (mm)	oGEPo EXPLOITATION POTENTIAL ($x10^6$ m^3/a)	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (□/s)	SUM OF BOREHOLE YIELDS ($x10^6$ m^3/a)	oGBNi THEORETICAL NO OF PRODUCTION BOREHOLES	MUNICIPAL USE ($X10^6$ m^3/a)	RURAL USE ($x10^6$ m^3/a)	LIVESTOCK USE ($x10^6$ m^3/a)	IRRIGATION USE ($x10^6$ m^3/a)	TOTAL USE FACTOR	oGWSo TOTAL USE ($x10^6$ m^3/a)	TOTAL USE (mm/a)
H60C	217	91309	91.3	19.81	6.75	2.25	0.7	63916	63.9	13.87	29	195.74	2.06	34	0.0000	0.0000	0.0030	2.3740	1.0000	2.3770	11.0
H60D	227	58523	58.5	13.28	1.36	0.45	0.5	29261	29.3	6.64	19	25.81	0.27	77	0.0000	0.0000	0.0034	1.0900	1.0000	1.0934	4.8
H60E	170	46896	46.9	7.97	1.57	0.52	0.6	28137	28.1	4.78	6	9.39	0.10	19	0.0000	0.0000	0.0028	0.3158	1.0000	0.3186	1.9
H60F	165	49972	50.0	8.25	2.00	0.67	0.6	29983	30.0	4.95	0	0.00	0.00	0	0.0000	0.0000	0.0023	0.0000	1.0000	0.0023	0.0
H60G	141	17700	17.7	2.50	1.73	0.58	0.6	10620	10.6	1.50	17	29.49	0.31	0	0.0000	0.0000	0.0028	0.0000	1.0000	0.0028	0.0
H60H	253	30593	30.6	7.74	1.17	0.39	0.5	15296	15.3	3.87	19	22.22	0.23	0	0.0000	0.0000	0.0050	0.0000	1.0000	0.0050	0.0
H60J	293	26359	26.4	7.72	0.20	0.07	0.3	7908	7.9	2.32	0	0.00	0.00	49	0.0000	0.0000	0.0042	0.0988	1.0000	0.1030	0.4
H60K	262	14856	14.9	3.89	0.16	0.05	0.3	4457	4.5	1.17	11	1.79	0.02	57	0.0000	0.0000	0.0036	0.0935	1.0000	0.0971	0.4
H60L	230	13054	13.1	3.00	0.27	0.09	0.3	3916	3.9	0.90	15	4.00	0.04	79	0.0000	0.0000	0.0030	0.2180	1.0000	0.2210	1.0
H70A	224	17433	17.4	3.91	0.24	0.08	0.3	5230	5.2	1.17	5	1.20	0.01	113	0.0000	0.0000	0.0030	0.1401	2.0000	0.2862	1.3
H70B	153	36732	36.7	5.62	3.30	1.10	0.7	25712	25.7	3.93	1	3.30	0.03	19	0.0000	0.0000	0.0019	0.3357	2.0000	0.6752	4.4
H70C	287	26981	27.0	7.74	8.42	2.81	0.7	18886	18.9	5.42	99	833.56	8.76	13	0.0000	0.0000	0.0026	0.5575	2.0000	1.1202	3.9
H70D	170	71489	71.5	12.15	1.00	0.33	0.5	35745	35.7	6.08	0	0.00	0.00	33	0.0000	0.0000	0.0004	0.1755	2.0000	0.3518	2.1
H70E	157	56510	56.5	8.87	1.00	0.33	0.5	28255	28.3	4.44	0	0.00	0.00	6	0.0000	0.0000	0.0017	0.0275	2.0000	0.0584	0.4
H70F	121	18047	18.0	2.18	0.50	0.17	0.4	7219	7.2	0.87	0	0.00	0.00	177	0.0000	0.0000	0.0016	0.4634	2.0000	0.9300	7.7
H70G	652	11886	11.9	7.75	0.14	0.05	0.3	3566	3.6	2.32	23	3.18	0.03	284	0.0000	0.0000	0.0084	0.1977	2.0000	0.4122	0.6
H70H	400	16023	16.0	6.41	0.11	0.04	0.3	4807	4.8	1.92	7	0.74	0.01	104	0.0000	0.0000	0.0032	0.0545	2.0000	0.1154	0.3
H70J	551	16782	16.8	9.25	0.14	0.05	0.3	5035	5.0	2.77	17	2.34	0.02	0	0.0000	0.0000	0.0000	0.0000	2.0000	0.0000	0.0
H70K	207	39356	39.4	8.15	0.05	0.02	0.3	11807	11.8	2.44	2	0.10	0.00	157	0.0400	0.0000	0.0012	0.0000	2.0000	0.0824	0.4

GROUNDWATER CONTRIBUTION TO BASEFLOW PER QUATERNARY CATCHMENT

QUATERNARY	vMARi MEAN ANNUAL RUNOFF	BASEFLOW SCHULTZ	BASEFLOW PITTMAN	BASEFLOW HUGHES	oGBFi BASEFLOW SCHULTZ	BASEFLOW FACTOR	fGBDo CORRECTED BASEFLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	fGPQi PORTION POTABLE	oGWMo MAX UTILISABLE GROUND WATER
	($x10^6$ m^3/a)	(mm/a)	(mm/a)	(mm/a)	($x10^6$ m^3/a)						($x10^6$ m^3/a)
G40B	49.20	31.70	59.70	157.19	3.87	0.30	0.30	UNDER - UTILISED	MODERATE	0.95	7.28
G40C	109.70	60.83	108.10	291.05	8.82	0.52	0.52	UNDER - UTILISED	MODERATE	0.95	11.26
G40D	142.95	34.10	64.80	171.63	11.15	0.29	0.29	UNDER - UTILISED	LOW	0.95	25.83
G40E	37.22	3.13	13.60	41.05	0.87	0.05	0.05	UNDER - UTILISED	LOW	0.40	5.32
G40F	21.65	1.28	5.40	16.43	0.54	0.06	0.06	UNDER - UTILISED	LOW	0.30	1.69
G40G	29.67	2.99	13.70	41.50	0.66	0.04	0.04	UNDER - UTILISED	LOW	0.50	5.39
G40H	11.71	3.11	12.50	35.45	0.30	0.04	0.04	UNDER - UTILISED	LOW	0.70	3.11
G40J	14.58	1.94	8.90	25.96	0.33	0.03	0.03	UNDER - UTILISED	LOW	0.70	5.50
G40K	19.31	1.12	4.90	14.23	0.48	0.06	0.06	UNDER - UTILISED	LOW	0.30	1.76
G40L	21.50	1.94	7.20	18.64	0.75	0.03	0.03	UNDER - UTILISED	LOW	0.85	16.91
G40M	22.55	1.98	7.30	19.01	0.78	0.03	0.03	UNDER - UTILISED	LOW	0.70	11.36
G50A	11.88	1.73	6.20	0.00	0.42	0.03	0.03	UNDER - UTILISED	LOW	0.50	4.05
G50B	15.26	1.59	5.70	15.01	0.54	0.03	0.03	UNDER - UTILISED	LOW	0.50	5.56
G50C	14.69	1.29	4.70	11.71	0.54	0.04	0.04	UNDER - UTILISED	LOW	0.40	2.87
G50D	15.46	0.94	3.40	9.13	0.54	0.04	0.04	UNDER - UTILISED	LOW	0.30	2.26
G50E	9.50	1.06	3.70	10.05	0.33	0.02	0.02	UNDER - UTILISED	LOW	0.30	2.96
G50F	7.94	1.03	3.80	9.16	0.30	0.02	0.02	UNDER - UTILISED	LOW	0.30	2.93
G50G	6.62	0.63	2.20	5.60	0.24	0.05	0.05	UNDER - UTILISED	LOW	0.30	0.40
G50H	15.35	0.61	2.20	5.71	0.54	0.03	0.03	UNDER - UTILISED	LOW	0.25	1.28
G50J	8.58	0.64	2.10	5.45	0.33	0.01	0.01	UNDER - UTILISED	LOW	0.50	5.45
G50K	4.20	1.47	3.60	8.69	0.24	0.03	0.03	UNDER - UTILISED	LOW	0.30	1.38
H10A	39.32	3.58	20.70	50.43	0.84	0.26	0.26	UNDER - UTILISED	LOW	0.82	1.87
H10B	46.64	6.65	36.70	87.98	1.08	0.08	0.08	UNDER - UTILISED	LOW	0.75	7.03
H10C	69.13	5.98	33.60	81.97	1.56	0.10	0.10	HEAVILY-UTILISED	LOW	0.95	10.41
H10D	50.40	11.69	65.30	162.69	1.13	0.20	0.20	UNDER - UTILISED	LOW	0.85	2.88
H10E	90.35	53.57	149.70	374.80	4.55	0.30	0.30	UNDER - UTILISED	MODERATE	0.95	8.60
H10F	86.61	7.75	43.80	109.06	1.92	0.06	0.06	UNDER - UTILISED	LOW	0.80	14.95
H10G	95.41	7.95	44.20	110.68	2.15	0.09	0.09	UNDER - UTILISED	LOW	0.97	16.91
H10H	78.98	9.50	53.00	133.11	1.78	0.15	0.15	UNDER - UTILISED	LOW	0.61	5.14

QUATERNARY	vMARi MEAN ANNUAL RUNOFF	BASEFLOW SCHULTZ	BASEFLOW PITTMAN	BASEFLOW HUGHES	oGBFi BASEFLOW SCHULTZ	BASEFLOW FACTOR	fGBDo CORRECTED BASEFLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	fGPQi PORTION POTABLE	oGWMo MAX UTILISABLE GROUND WATER
	(x10^6 m^3/a)	(mm/a)	(mm/a)	(mm/a)	(x10^6 m^3/a)						(x10^6 m^3/a)
H10J	183.84	43.55	119.90	302.19	9.32	0.42	0.42	UNDER - UTILISED	MODERATE	1.00	15.38
H10K	111.17	31.98	82.40	202.15	6.20	0.22	0.22	UNDER - UTILISED	LOW	0.95	18.35
H10L	9.05	0.00	0.00	9.17	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.87	2.49
H20A	4.74	0.00	0.00	0.00	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.96	2.31
H20B	4.06	0.97	3.80	9.54	0.12	0.02	0.02	UNDER - UTILISED	LOW	0.92	4.50
H20C	8.84	3.60	4.80	12.68	0.29	0.05	0.05	UNDER - UTILISED	LOW	0.85	3.62
H20D	28.04	9.83	35.50	86.52	0.99	0.12	0.12	UNDER - UTILISED	LOW	0.85	3.55
H20E	40.15	15.47	54.80	136.00	1.47	0.16	0.16	UNDER - UTILISED	LOW	0.85	4.63
H20F	11.32	2.06	8.30	28.74	0.24	0.03	0.03	UNDER - UTILISED	LOW	0.99	5.42
H20G	4.75	1.41	5.60	15.61	0.12	0.02	0.02	UNDER - UTILISED	LOW	0.85	3.05
H20H	2.55	0.00	0.00	0.27	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.40	0.73
H30A	16.33	0.00	0.00	6.51	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	1.00	7.15
H30B	10.98	0.00	0.00	2.56	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.63	4.68
H30C	23.26	0.09	0.00	9.62	0.03	0.00	0.00	UNDER - UTILISED	LOW	1.00	10.88
H30D	4.82	0.00	0.00	1.86	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	1.00	4.12
H30E	8.91	0.59	0.00	10.29	0.09	0.02	0.02	UNDER - UTILISED	LOW	0.40	1.31
H40A	6.51	0.00	0.00	2.49	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.85	3.71
H40B	3.71	1.74	3.60	6.28	0.42	0.02	0.02	UNDER - UTILISED	LOW	0.70	10.08
H40C	14.18	0.00	0.00	4.65	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.40	2.74
H40D	24.79	0.00	0.00	18.09	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.50	3.47
H40E	35.96	0.00	0.00	17.30	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.40	3.74
H40F	9.15	0.00	0.00	1.49	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.94	3.47
H40G	17.47	0.80	0.00	12.81	0.21	0.03	0.03	UNDER - UTILISED	LOW	0.40	2.30
H40H	18.18	0.00	0.00	9.80	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.70	3.23
H40J	10.59	0.44	0.00	9.13	0.09	0.01	0.01	UNDER - UTILISED	LOW	0.80	4.27
H40K	12.46	0.44	0.00	8.01	0.12	0.01	0.01	UNDER - UTILISED	LOW	0.70	7.46
H40L	6.09	0.18	0.00	5.53	0.03	0.01	0.01	UNDER - UTILISED	LOW	0.20	0.58
H50A	6.92	0.11	0.00	3.55	0.03	0.00	0.00	UNDER - UTILISED	LOW	0.40	1.90
H50B	16.66	0.28	0.00	6.58	0.12	0.01	0.01	UNDER - UTILISED	LOW	0.30	2.12
H60A	88.44	47.61	161.80	416.16	3.48	0.33	0.33	UNDER - UTILISED	MODERATE	0.85	6.28

QUATERNARY	vMARi MEAN ANNUAL RUNOFF	BASEFLOW SCHULTZ	BASEFLOW PITTMAN	BASEFLOW HUGHES	oGBFi BASEFLOW SCHULTZ	BASEFLOW FACTOR	fGBDo CORRECTED BASEFLOW FACTOR	ESTIMATED EXTENT OF GROUNDWATER UTILISATION	IMPACT OF GROUNDWATER ABSRTACTION ON SURFACE WATER	fGPQi PORTION POTABLE	$_{o}GWM_{o}$ MAX UTILISABLE GROUND WATER
	($x10^6$ m^3/a)	(mm/a)	(mm/a)	(mm/a)	($x10^6$ m^3/a)						($x10^6$ m^3/a)
H60B	118.53	20.15	72.10	188.06	4.23	0.37	0.37	UNDER - UTILISED	MODERATE	0.85	6.81
H60C	83.79	14.13	51.50	128.90	3.07	0.15	0.15	UNDER - UTILISED	LOW	0.70	9.71
H60D	41.70	6.06	22.70	58.77	1.38	0.10	0.10	UNDER - UTILISED	LOW	0.40	2.66
H60E	29.56	5.48	21.90	55.33	0.93	0.12	0.12	UNDER - UTILISED	LOW	0.40	1.91
H60F	23.29	3.98	17.50	44.08	0.66	0.08	0.08	UNDER - UTILISED	LOW	0.40	1.98
H60G	11.67	3.63	10.50	27.14	0.51	0.20	0.20	UNDER - UTILISED	LOW	0.30	0.45
H60H	19.75	3.44	9.80	25.65	0.87	0.11	0.11	UNDER - UTILISED	LOW	0.30	1.16
H60J	22.02	3.38	9.50	24.85	0.99	0.13	0.13	UNDER - UTILISED	LOW	0.30	0.70
H60K	11.61	1.71	5.30	13.95	0.45	0.12	0.12	UNDER - UTILISED	LOW	0.30	0.35
H60L	9.48	1.57	4.90	13.06	0.36	0.12	0.12	UNDER - UTILISED	LOW	0.30	0.27
H70A	13.24	2.27	7.20	18.96	0.51	0.13	0.13	UNDER - UTILISED	LOW	0.30	0.35
H70B	41.20	57.68	41.30	147.65	8.83	1.57	1.00	UNDER - UTILISED	HIGH	0.40	1.57
H70C	13.97	0.00	0.00	2.92	0.00	0.00	0.00	UNDER - UTILISED	NEGLIGABLE	0.30	1.63
H70D	38.91	46.97	35.20	123.60	7.98	0.66	0.66	UNDER - UTILISED	MODERATE	0.40	2.43
H70E	47.62	67.43	46.70	166.66	10.59	1.19	1.00	UNDER - UTILISED	HIGH	0.40	1.77
H70F	22.85	37.45	29.30	101.40	4.53	2.07	1.00	UNDER - UTILISED	HIGH	0.30	0.26
H70G	9.66	0.83	2.20	5.42	0.54	0.07	0.07	UNDER - UTILISED	LOW	0.00	0.00
H70H	7.41	1.05	2.70	6.60	0.42	0.07	0.07	UNDER - UTILISED	LOW	0.00	0.00
H70J	9.41	0.98	2.50	6.27	0.54	0.06	0.06	UNDER - UTILISED	LOW	0.00	0.00
H70K	6.00	1.74	4.00	10.08	0.36	0.04	0.04	UNDER - UTILISED	LOW	0.30	0.73

APPENDIX G.5 : WATER QUALITY INFORMATION

Quaternary	Station no	Mean (mg/l)	Maximum (mg/l)	Mean colour	Maximum colour	Overall colour
G40A	G4R001Q01	50	82	Blue	Blue	Blue
G40B	NO					
G40C	G4R002Q01	47	177	Blue	Blue	Blue
G40D	G4H007Q01	84	133	Blue	Blue	Blue
G40E	G4H014Q01	218	333	Blue	Green	Green
G40F	NO					
G40G	NO					
G40H	NO					
G40J	NO					
G40K	NO					
G40L	G4H006Q01	744	1500	Yellow	Yellow	Yellow
G40M	NO					
G50B	NO					
G50C	NO					
G50D	NO					
G50E	NO					
G50F	NO					
G50G	NO					
G50H	G5R001Q01	6015	8387	Purple	Purple	Purple
G50J	G5R001Q01	6015	8387	Purple	Purple	Purple
G50K	NO					
H10A	H1H013Q01	38	55	Blue	Blue	Blue
H10B	H1H003Q01	181	379	Blue	Green	Green
H10C	H1H013Q01	38	55	Blue	Blue	Blue
H10D	H1H006Q01	82	178	Blue	Blue	Blue
H10E	H1H007Q01	26	41	Blue	Blue	Blue
H10F	H1H006Q01	82	178	Blue	Blue	Blue
H10G	H1H006Q01	82	178	Blue	Blue	Blue
H10H	H1H015Q01	84	147	Blue	Blue	Blue
H10J	H1H018Q01	28	39	Blue	Blue	Blue
H10K	H1H015Q01	84	147	Blue	Blue	Blue
H10L	H1H015Q01	84	147	Blue	Blue	Blue
H20A	H2H014Q01	37	87	Blue	Blue	Blue
H20B	H2H014Q01	37	87	Blue	Blue	Blue
H20C	H2H016Q01	70	83	Blue	Blue	Blue
H20D	H2H005Q01	24	39	Blue	Blue	Blue
H20E	H2H006Q01	114	358	Blue	Green	Green
H20F	H2H014Q01	37	87	Blue	Blue	Blue
H20G	H2H006Q01	114	358	Blue	Green	Green
H20H	H2H010Q01	1692	2478	Yellow	Red	Red
H30A	H3H013Q01	361	472	Green	Green	Green
H30B	H3H011Q01	2168	3469	Red	Purple	Purple
H30C	H3H011Q01	2168	3469	Red	Purple	Purple
H30D	H3H011Q01	2168	3469	Red	Purple	Purple
H30E	H3H011Q01	2168	3469	Red	Purple	Purple
H40A	H4H033Q01	123	187	Blue	Blue	Blue
H40B	H4H033Q01	123	187	Blue	Blue	Blue
H40C	H4H020Q01	2690	4012	Red	Purple	Purple
H40D	H4H022Q01	72	176	Blue	Blue	Blue
H40E	H4H022Q01	72	176	Blue	Blue	Blue
H40F	H4H017Q01	158	304	Blue	Green	Green

H40G	H4H018Q01	3809	5199	Purple	Purple	Purple
H40H	H4H024Q01	173	312	Blue	Green	Green
H40J	H4H019Q01	1538	2475	Yellow	Red	Red
H40K	H4H015Q01	40	72	Blue	Blue	Blue
H40L	H5H006Q01	296	539	Green	Green	Green
H50A	H5H004Q01	614	1697	Yellow	Yellow	Yellow
H50B	H5H005Q01	643	1100	Yellow	Yellow	Yellow
H60A	H6H012Q01	72	147	Blue	Blue	Blue
H60B	H6H012Q01	72	147	Blue	Blue	Blue
H60C	H6H012Q01	72	147	Blue	Blue	Blue
H60D	H6H012Q01	72	147	Blue	Blue	Blue
H60E	H6H005Q01	47	70	Blue	Blue	Blue
H60F	H6H009Q01	158	430	Blue	Green	Green
H60G	H6H009Q01	158	430	Blue	Green	Green
H60H	H6H009Q01	158	430	Blue	Green	Green
H60J	H6H009Q01	158	430	Blue	Green	Green
H60K	H6H009Q01	158	430	Blue	Green	Green
H60L	H6H009Q01	158	430	Blue	Green	Green
H70A	H7H006Q01	354	855	Green	Yellow	Yellow
H70B	H7H005Q01	36	56	Blue	Blue	Blue
H70C	H7H004Q01	399	701	Green	Yellow	Yellow
H70D	NO					
H70E	NO					
H70F	NO					
H70G	NO					
H70H	NO					
H70J	NO					
H70K	NO					
H80A	NO					
H80B	NO					
H80C	NO					
H80D	NO					
H80E	NO					
H80F	NO					
H90A	H9H004Q01	57	87	Blue	Blue	Blue
H90B	H9R001Q01	68	106	Blue	Blue	Blue
H90C	NO					
H90D	NO					
H90E	NO					

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APPENDIX H

WATER BALANCE

APPENDIX H.1

DATA SOURCES

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

BREEDE WATER MANAGEMENT AREA

APPENDIX H.2

DATA DEFAULT VALUES USED IN THE WRSA REPORT

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

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**

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Witsand
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LEGEND
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:1 000 000
TITLE
BREEDE WMA
THE STUDY AREA
Figure 2.1.1


Northern Cape
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Endoreic Areas
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401 - 800
801 - 1200
1201 - 1600
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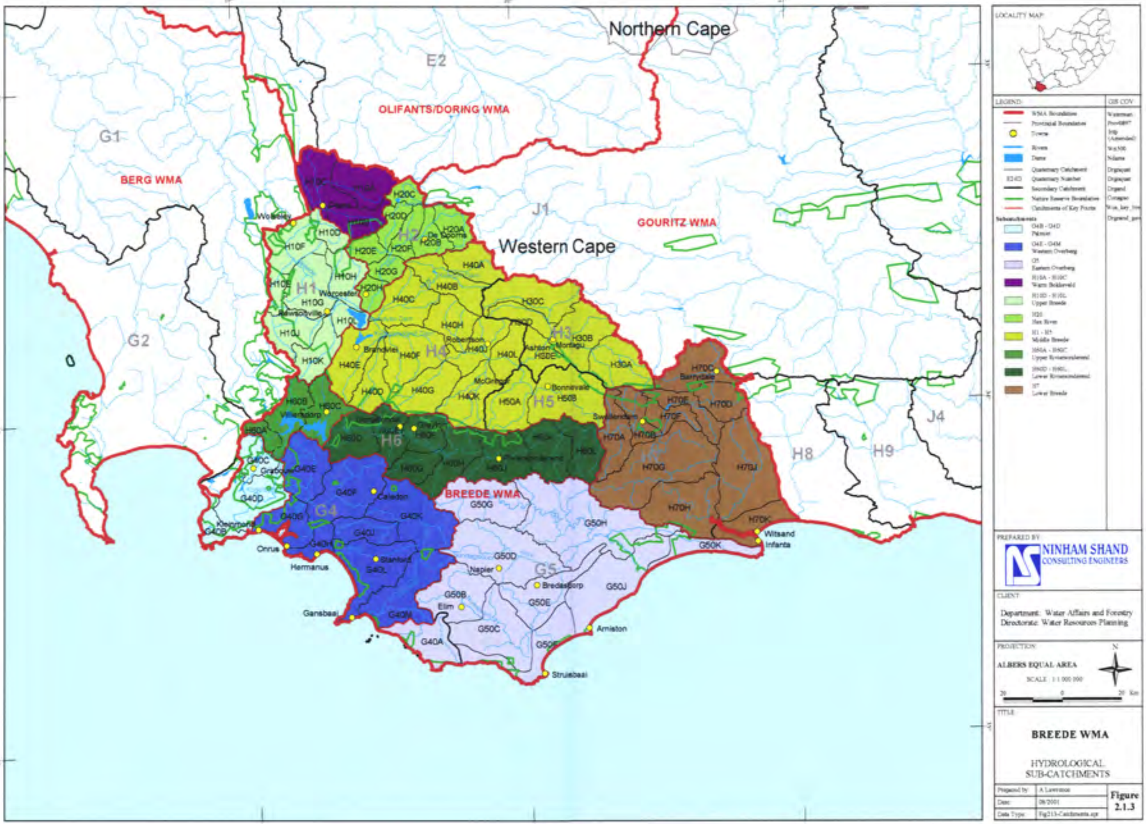
ALBERS EQUAL AREA
SCALE 1:1 000 000
N
TITLE
BREEDE WMA
TOPOGRAPHY AND
RIVER CATCHMENTS
Prepared by: A Lawrance
Figure
2.1.2


Northern Cape
E2
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G2
J1
GOURITZ WMA
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Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
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LOCALITY MAP:
LEGEND:
PREPARED BY:
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Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BREEDE WMA
HYDROLOGICAL
SUB-CATCHMENTS
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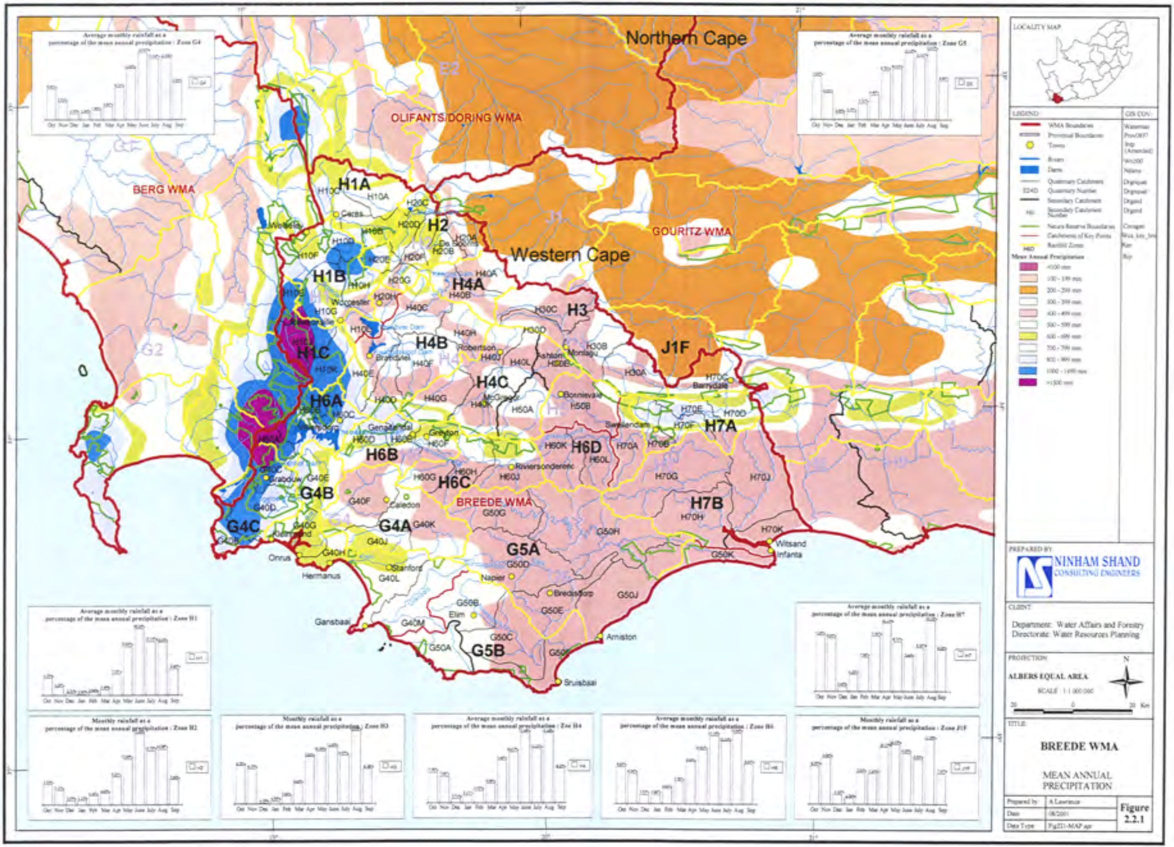
2.1.3


Northern Cape
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OLIFANTS/DORING WMA
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Bredasdorp
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Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
Mean Annual Precipitation
PREPARED BY:
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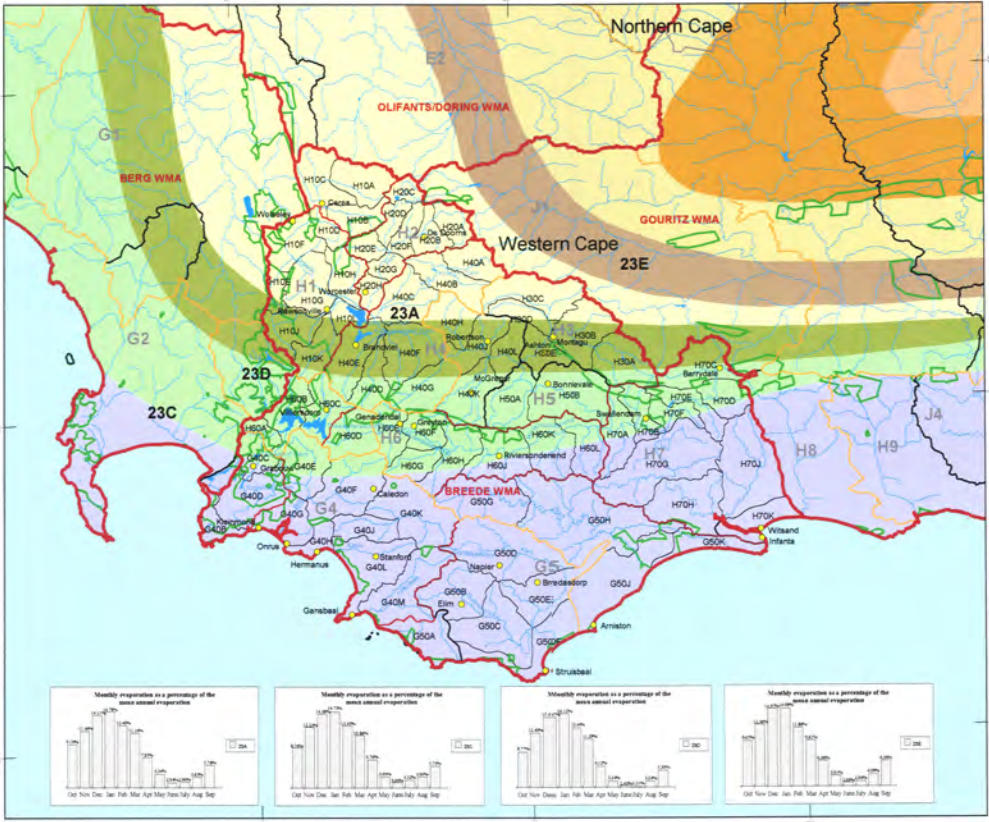
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
BREEDE WMA
MEAN ANNUAL PRECIPITATION
Figure 2.2.1



LOCALITY MAP

LEGEND:

Mean Annual Evaporation (S-Pan)

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PROJECTION:

ALBERS EQUAL AREA

SCALE 1:1 000 000

TITLE:

BREEDE WMA

SYMONS PAN MEAN ANNUAL EVAPORATION

Prepared by	A Lewinsohn	**Figure 2.2.2**
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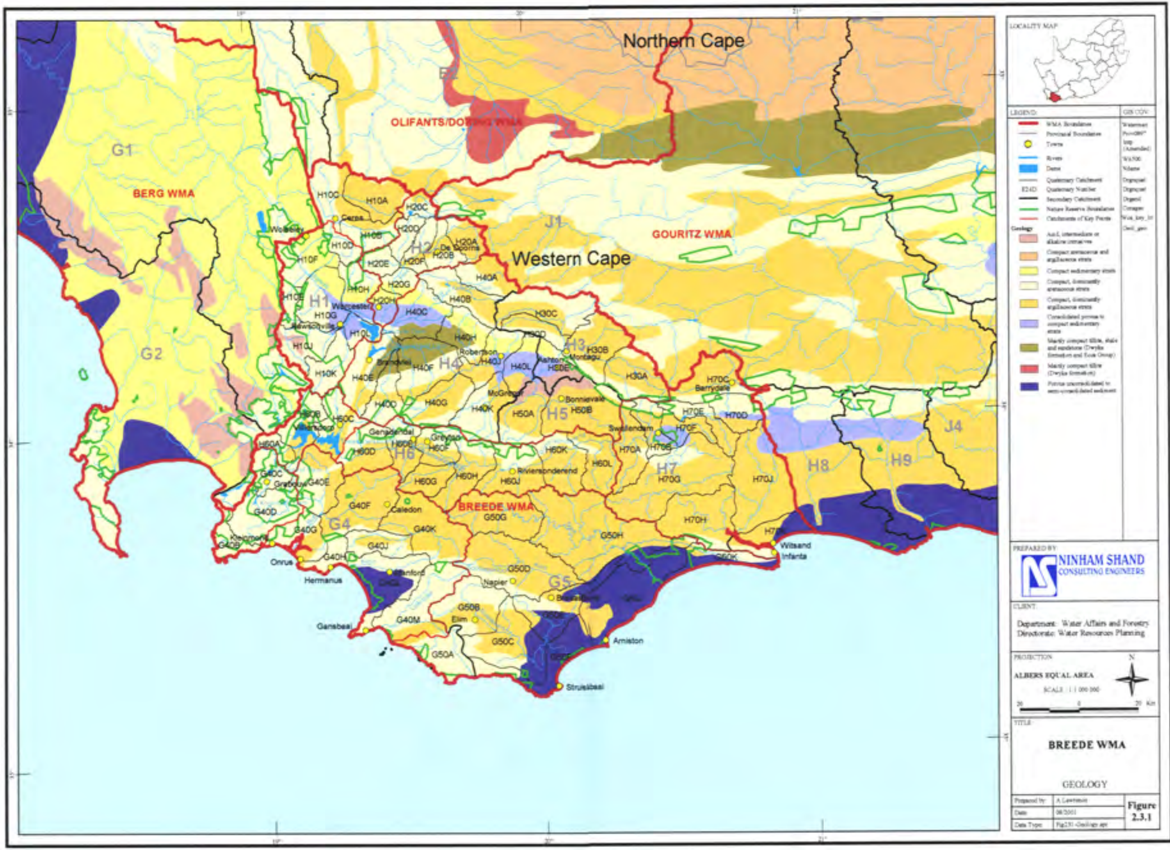
Northern Cape
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Napier
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WMA Boundaries
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Dams
Geology
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PROJECTION
ALBERS EQUAL AREA
N
TITLE:
BREEDE WMA
GEOLOGY
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Moderate to Deep
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Shallow
Sandy Loam
Undulating
Moderate to Deep
Sandy Soil
Undulating
GIS COV
PREPARED BY
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PROJECTION
ALBERS EQUAL AREA
N
BREEDE WMA
SOILS
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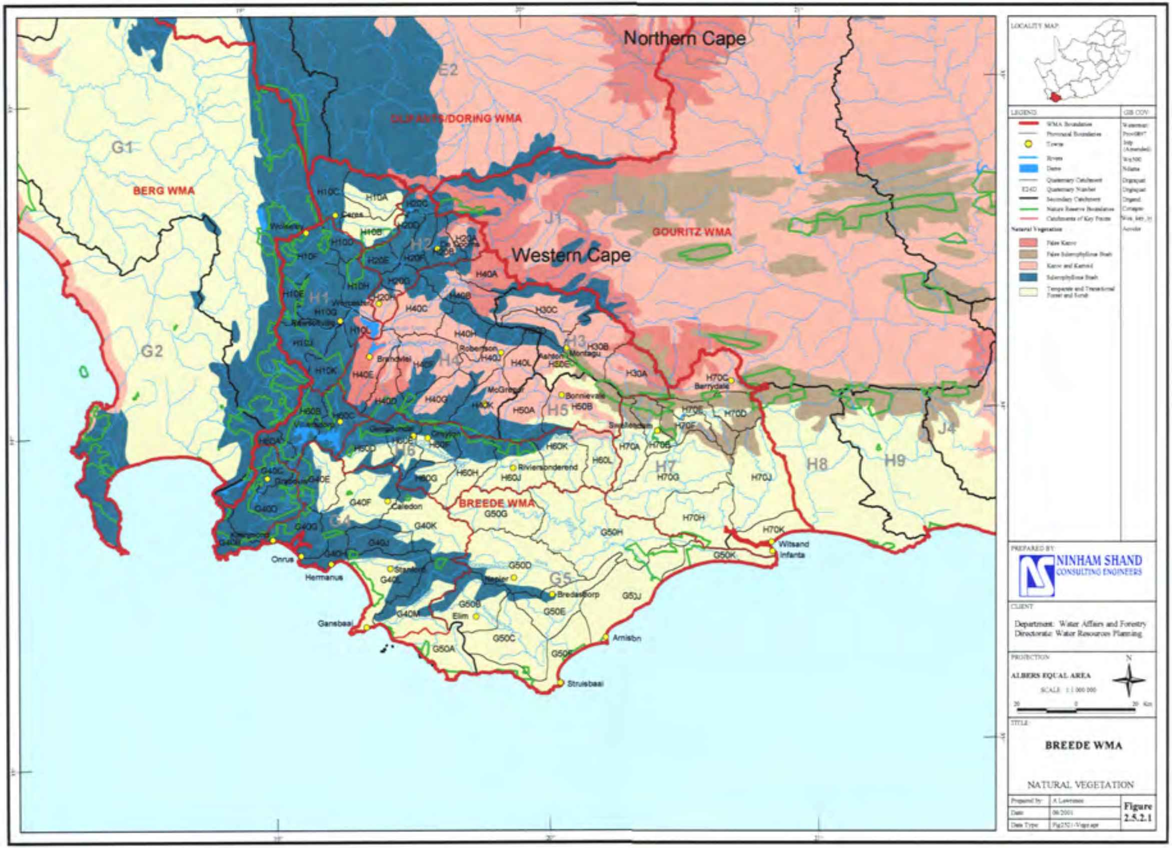
A Lawrence
Date
06/2001
Figure 2.4.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
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Catchments of Key Points
Natural Vegetation
False Karoo
False Sclerophyllous Bush
Karoo and Karroid
Sclerophyllous Bush
Temperate and Transitional Forest and Scrub
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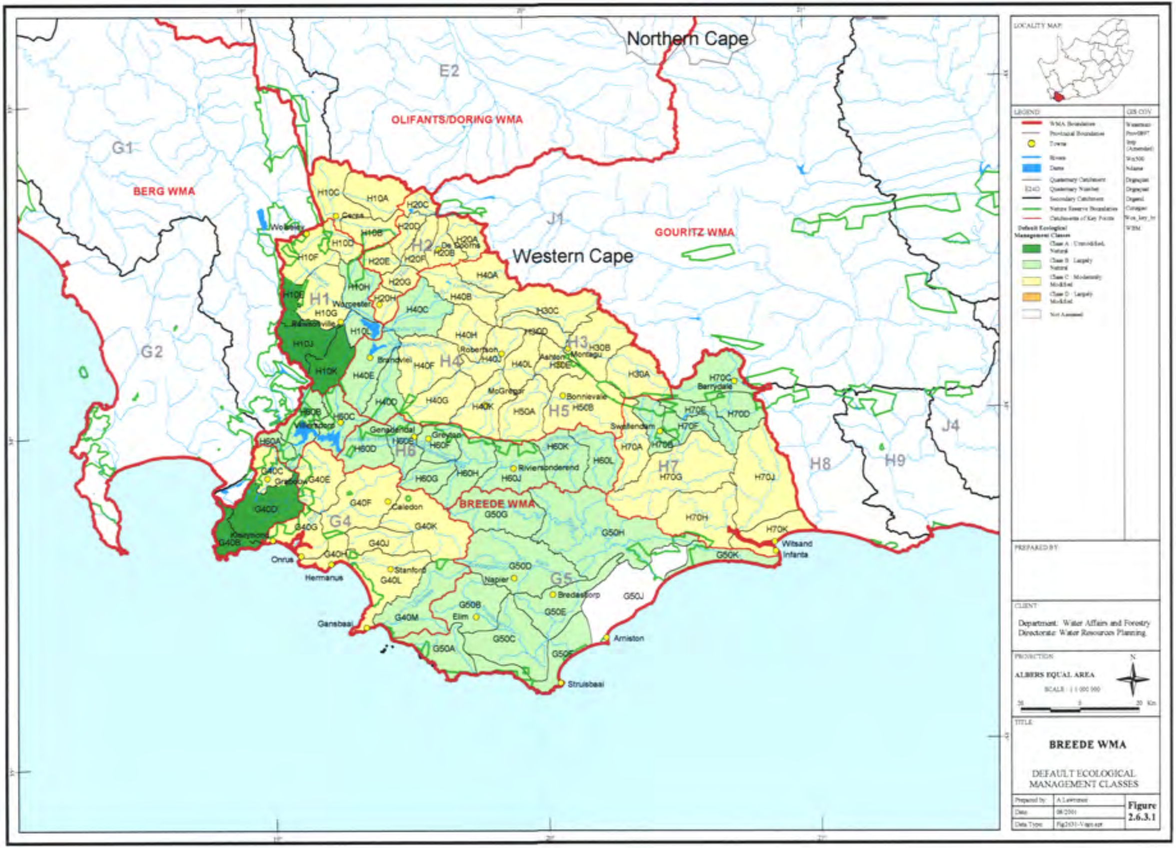
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
NATURAL VEGETATION
Prepared by: A Lawrance
Date 08/2001
Figure 2.5.2.1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Towns
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Default Ecological Management Classes
Class A : Unmodified, Natural
Class B : Largely Natural
Class C : Moderately Modified
Class D : Largely Modified
Not Assessed
PREPARED BY
CLIENT
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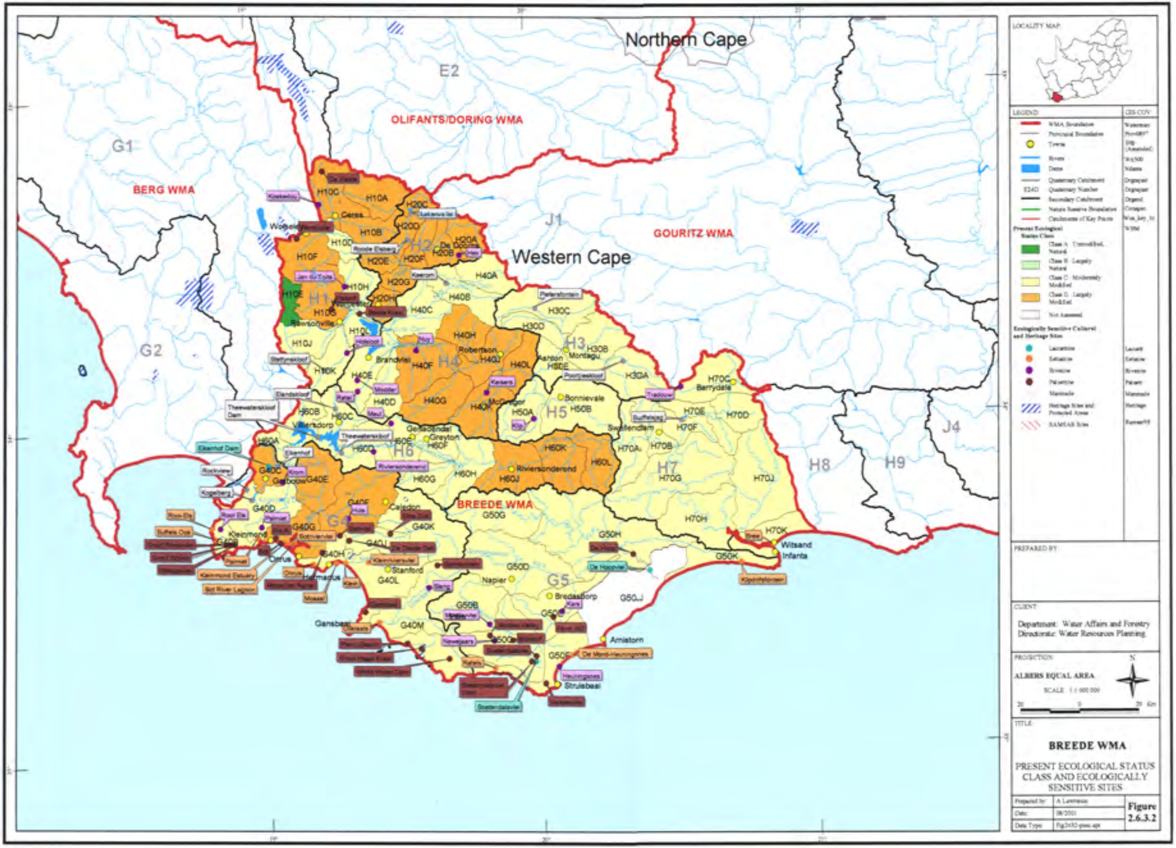
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Prepared by:
Date:
Data Type:
Figure 2.6.3.1


Northern Cape
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LOCALITY MAP
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PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
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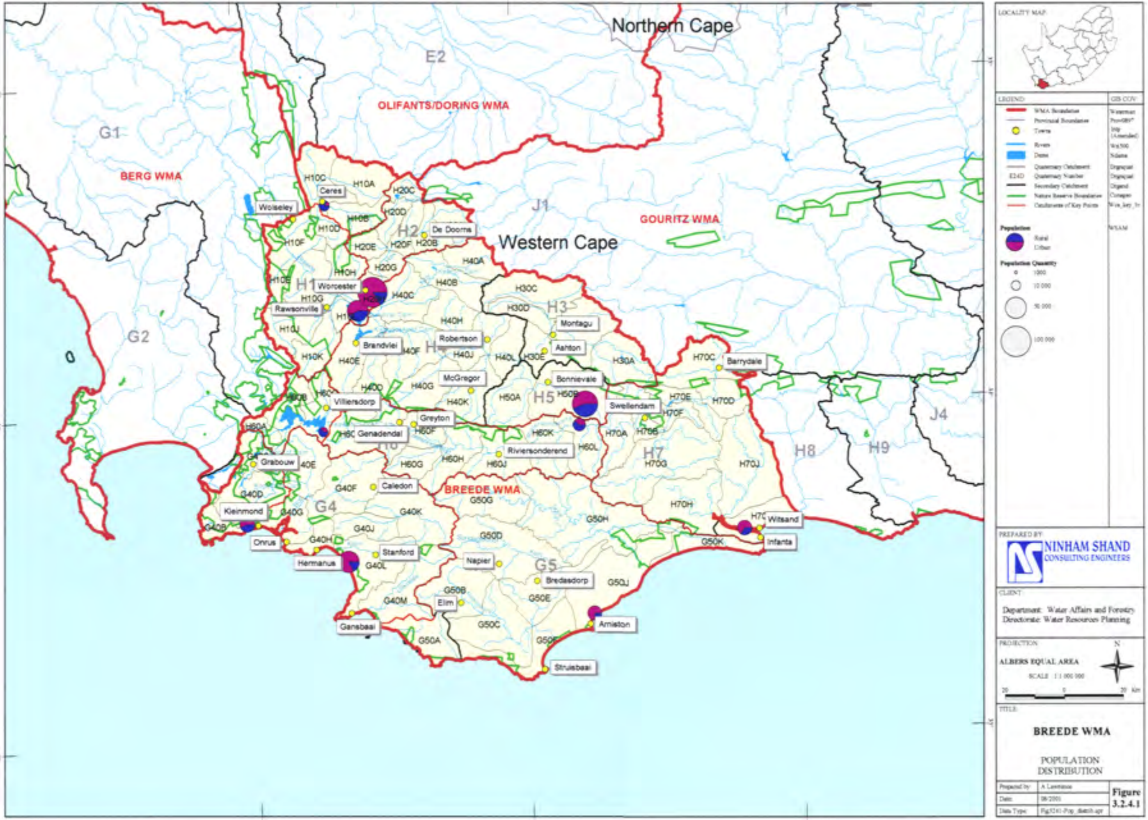
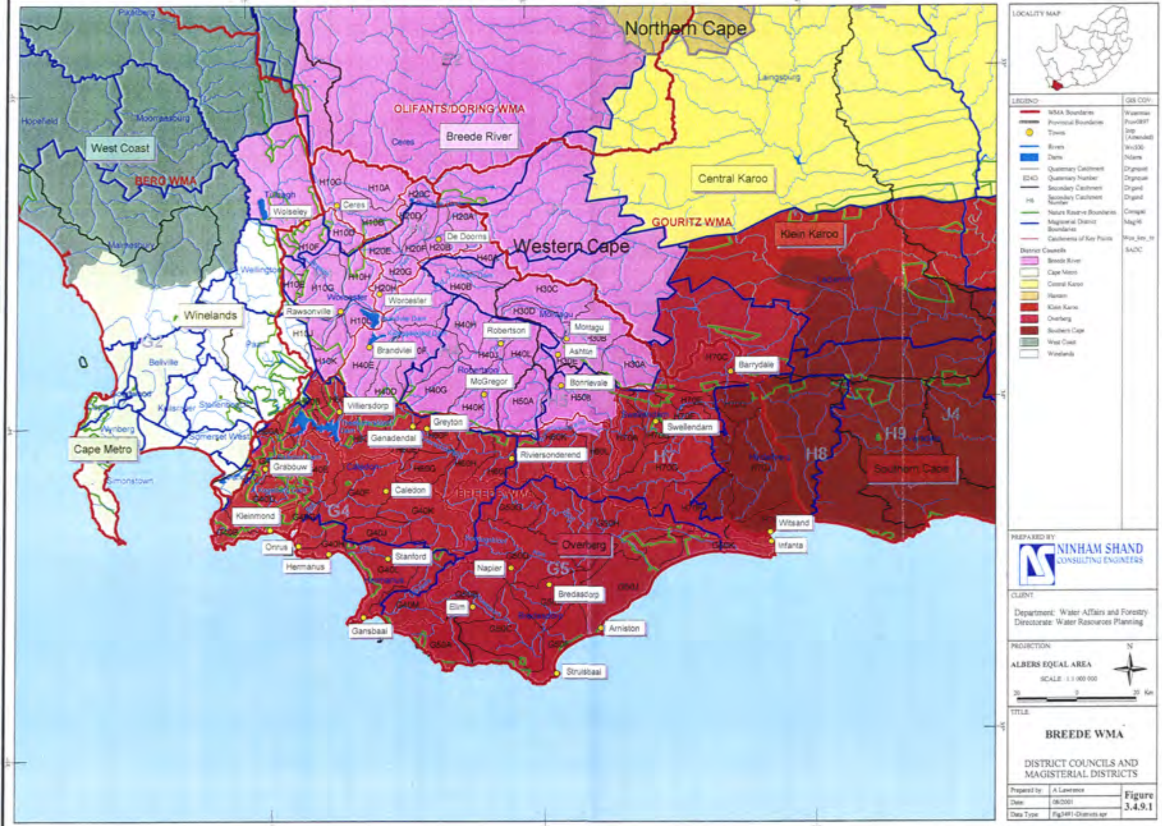
H2
H3
H4
H5
H6
H7
H8
H9
G4
G5
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Ashton
Montagu
McGregor
Bonnievale
Barrydale
Swellendam
Genadendal
Greyton
Riviersonderend
Villiersdorp
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
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
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BREEDE WMA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASS
Prepared by:
A Lawrence
Date:
08/2001
Figure 2.6.3.3


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
H1
H2
H3
H5
H7
H8
H9
J4
G2
G4
G5
BREEDE WMA
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
Barrydale
McGregor
Bonnievale
Swellendam
Villiersdorp
Greyton
Genadendal
Riviersonderend
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Napier
Bredasdorp
Witsand
Infanta
Elim
Gansbaai
Arniston
Struisbaai
H10A
H10B
H10C
H10D
H10E
H10F
H10G
H10H
H10J
H10K
H20B
H20C
H20D
H20E
H20F
H20G
H30A
H30C
H30D
H30E
H40A
H40B
H40C
H40D
H40E
H40G
H40H
H40J
H40K
H40L
H50A
H50B
H60A
H60F
H60G
H60H
H60J
H60K
H60L
H70A
H70B
H70C
H70D
H70E
H70F
H70G
H70H
H70J
G40D
G40E
G40F
G40G
G40H
G40J
G40K
G40L
G40M
G50A
G50B
G50C
G50D
G50E
G50G
G50H
G50J
G50K
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Population
Rural
Urban
Population Quantity
1000
10 000
50 000
100 000
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:1 000 000
N
20
0
20 Km
TITLE
BREEDE WMA
POPULATION DISTRIBUTION
Prepared by
A Lawrence
Date
Data Type
Figure 3.2.4.1

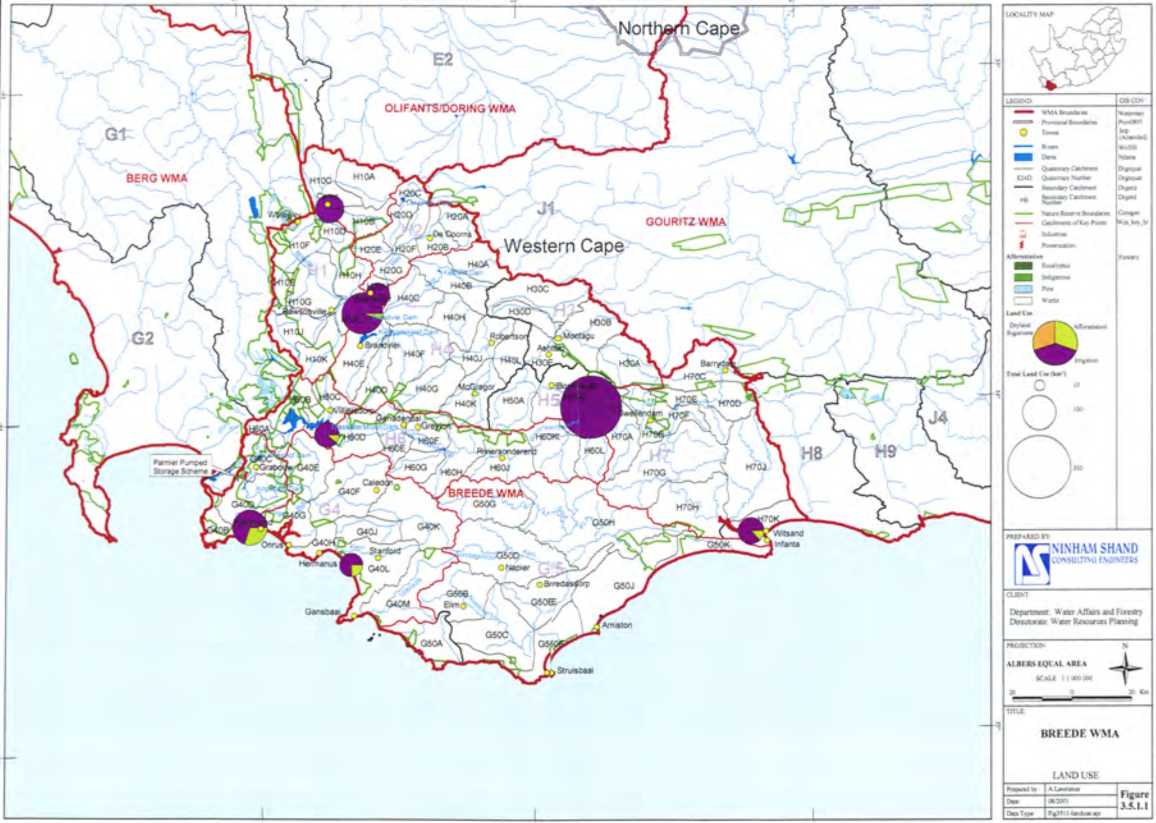


BREEDE WMA

DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS

Figure 3.4.9.1

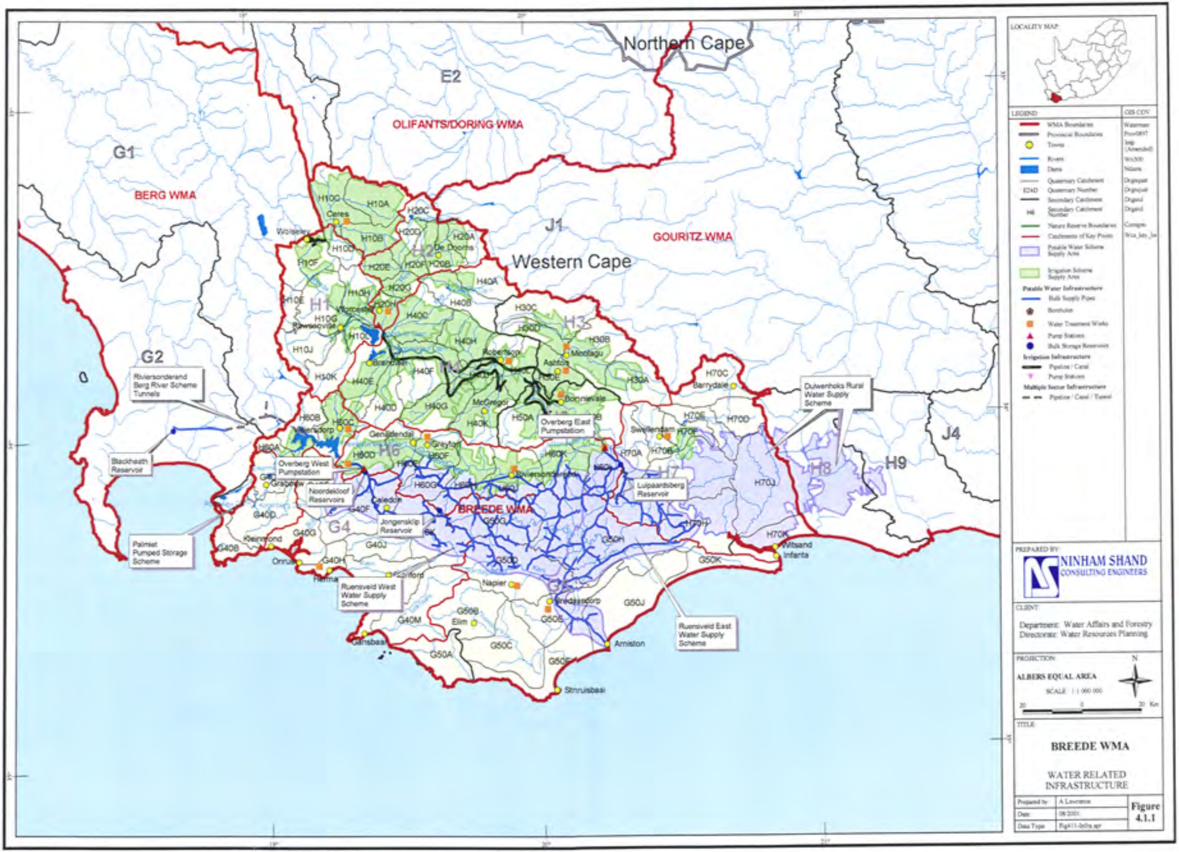

Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
Overberg
WITZENBERG
PRINCE ALFRED HAMLET
WOLSELEY
Wolseley
Ceres
CERES
DE DOORNS
De Doorns
WORCESTER
Worcester
Rawsonville
RAWSONVILLE
Brandvlei
ROBERTSON
Robertson
MONTAGU
Montagu
Ashton
ASHTON
MCGREGOR
McGregor
SWELLENDAM
Swellendam
BARRYDALE
Barrydale
Bonnievale
BONNIEVALE
FRANSCHHOEK
Villiersdorp
VILLIERSDORP
GREYTON
Greyton
Genadendal
GENADENDAL
RIVIERSONDEREND
Riviersonderend
SUURBRAK
SLANGRIVIER
CALEDON/MYDDLETON
Caledon
Grabouw
GRABOUW
BOTRIVIER
Kleinmond
HANGKLIP/ KLEINMOND
Onrus
HERMANUS
Hermanus
STANFORD
Stanford
NAPIER
Napier
BREDASDORP
Bredasdorp
Elim
Gansbaai
GANSBAAI
STRUISBAAI
Struisbaai
Arniston
INFANTA
Infanta
Witsand
LADISMITH
LANGEBERG
PAARL
LOCALITY MAP
LEGEND
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Secondary Catchment Number
Nature Reserve Boundaries
Waterboard Boundaries
Local/Regional Councils
Transitional Local Council
Transitional Regional Council
Waterboards
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE 1:1 000 000
N
TITLE:
BREEDE WMA
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Prepared by: A Lawrence
Date: 08/2001
Figure 3.4.9.2

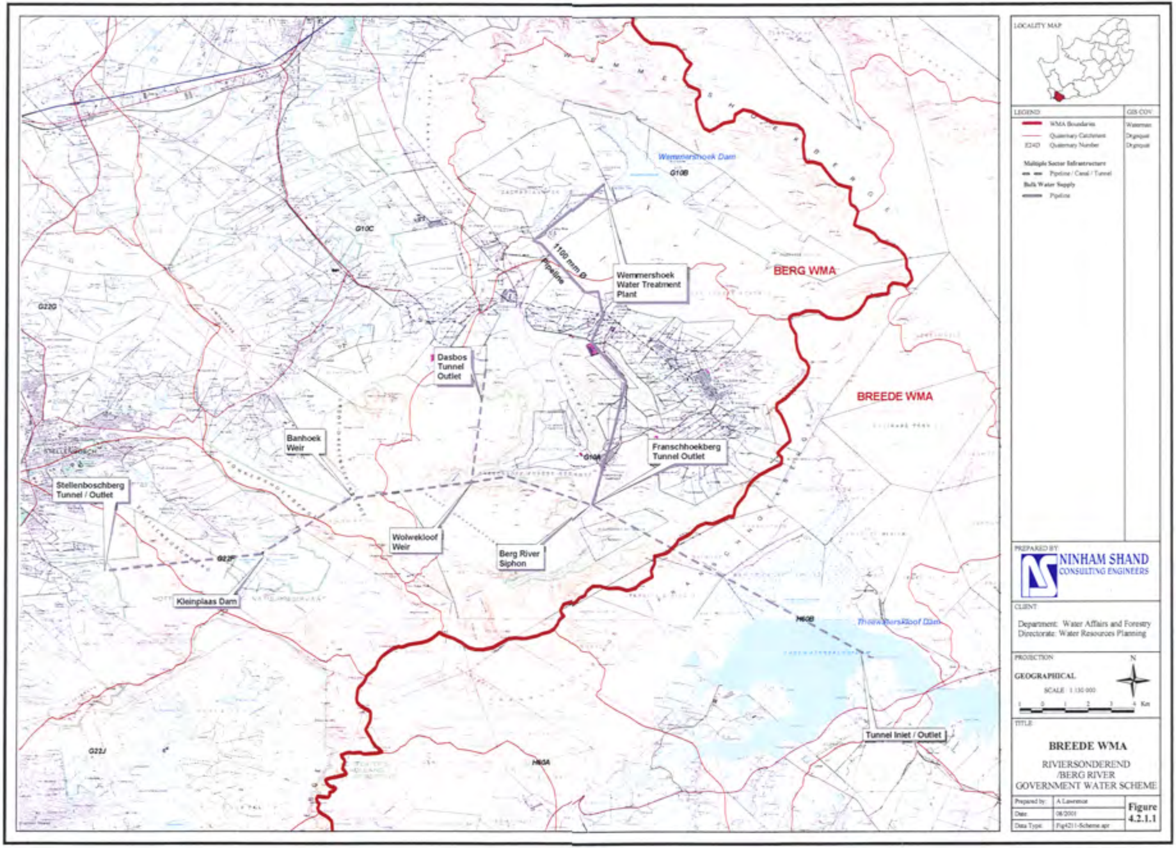


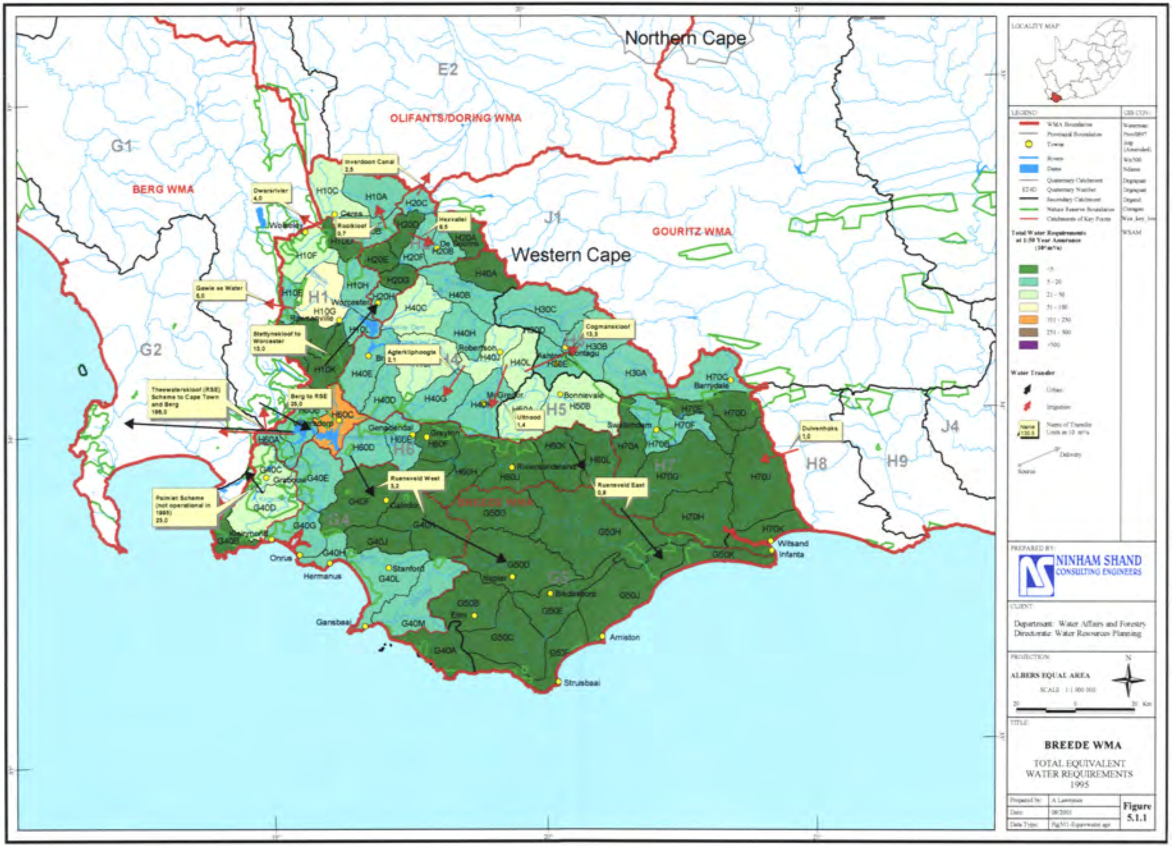
Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
E2
G1
G2
G4
J1
J4
H1
H2
H3
H4
H5
H6
H7
H8
H9
Palmiet Pumped Storage Scheme
Robertson
Montagu
Ashton
McGregor
Swellendam
Barrydale
Riviersonderend
Caledon
Grabouw
Villiersdorp
Genadendal
Greyton
Rawsonville
Brandvlei
De Doorns
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
Land Use
Total Land Use (km²)
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
SCALE: 1:1 000 000
TITLE:
BREEDE WMA
LAND USE
Figure 3.5.1.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
E2
G1
G2
J1
J4
H1
H2
H3
H4
H5
H6
H7
H8
H9
G4
G5
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
Bonnievale
McGregor
Villiersdorp
Genadendal
Greyton
Riviersonderend
Swellendam
Barrydale
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Napier
Bredasdorp
Elim
Gansbaai
Arniston
Struisbaal
Witsand
Infanta
LOCALITY MAP
LEGEND
Livestock
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
BREEDE WMA
LIVESTOCK AND GAME NUMBERS
Figure 3.5.4.1


Northern Cape
Western Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
J4
H8
H9
BREEDE WMA
H1
H2
H3
H4
H5
H6
H7
G4
G5
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
McGregor
Bonnievale
Swellendam
Barrydale
Genadendal
Greyton
Riviersonderend
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Elim
Bredasdorp
Arniston
Struisbaai
Witsand
Infanta
H10C
H10A
H20C
H20D
H10B
H10D
H10F
H20E
H20F
H20B
H20A
H10G
H10H
H20G
H40A
H10E
H20H
H40C
H40B
H30C
H10L
H30D
H10J
H40H
H30B
H30E
H40F
H40J
H40L
H10K
H40E
H30A
H70C
H40D
H40G
H50A
H50B
H60C
H40K
H70E
H70D
H70F
H60A
H60D
H60E
H60F
H60K
H70A
H70B
H60L
H60G
H60H
H60J
H70G
H70J
G40C
G40E
G40F
G40D
G50G
G40G
G40K
G50H
H70H
H70K
G40B
G40J
G50D
G50K
G40H
G40L
G50B
G50J
G40M
G50E
G50C
G50F
G50A
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
Condensed Area Of Alien Vegetation (Km²)
300
500
1100
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:1 000 000
N
20
0
20 Km
TITLE
BREEDE WMA
ALIEN VEGETATION INFESTATION
Prepared by
A Lawrence
Date
08/2001
Data Type
Fig3561-alienveg.apr
Figure 3.5.6.1

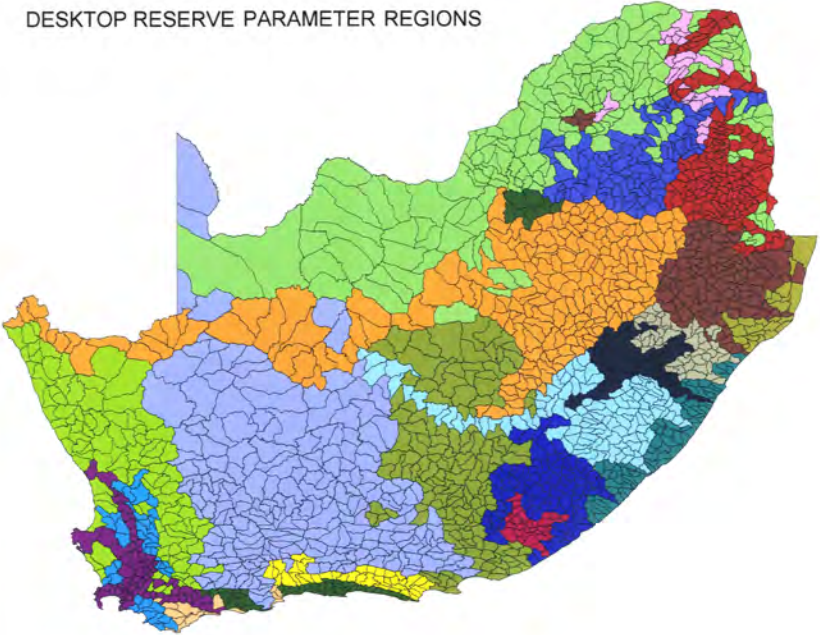

Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
Western Cape
GOURITZ WMA
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
Bonnievale
McGregor
Barrydale
Swellendam
Genadendal
Greyton
Villiersdorp
Riviersonderend
Caledon
Grabouw
Kleinmond
Onrus
Hermanus
Stanford
Napier
Bredasdorp
Elim
Gansbaai
Arniston
Struisbaai
Witsand
Infanta
Riviersonderend Berg River Scheme Tunnels
Blackheath Reservoir
Overberg West Pumpstation
Noordekloof Reservoirs
Jongensklip Reservoir
Palmiet Pumped Storage Scheme
Ruensveld West Water Supply Scheme
Ruensveld East Water Supply Scheme
Luipaardsberg Reservoir
Overberg East Pumpstation
Duiwenhoks Rural Water Supply Scheme
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
H6 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Potable Water Scheme Supply Area
Irrigation Scheme Supply Area
Potable Water Infrastructure
Bulk Supply Pipes
Boreholes
Water Treatment Works
Pump Stations
Bulk Storage Reservoirs
Irrigation Infrastructure
Pipeline / Canal
Pump Stations
Multiple Sector Infrastructure
Pipeline / Canal / Tunnel
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:1 000 000
N
TITLE:
BREEDE WMA
WATER RELATED INFRASTRUCTURE
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig411-Infra.apr
Figure 4.1.1


Wemmershoek Dam
G10B
G10C
1100 mm Ø Pipeline
Wemmershoek Water Treatment Plant
BERG WMA
BREEDE WMA
G22G
Dasbos Tunnel Outlet
Banhoek Weir
Franschhoekberg Tunnel Outlet
G10A
Stellenboschberg Tunnel / Outlet
Wolwekloof Weir
Berg River Siphon
G22F
Kleinplaas Dam
H60B
Theewaterskloof Dam
Tunnel Inlet / Outlet
G22J
H60A
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Quaternary Catchment
E24D Quaternary Number
Waterman
Drgnquat
Drgnquat
Multiple Sector Infrastructure
Pipeline / Canal / Tunnel
Bulk Water Supply
Pipeline
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
GEOGRAPHICAL
SCALE 1:130 000
N
1 0 1 2 3 4 Km
TITLE
BREEDE WMA
RIVIERSONDEREND
/BERG RIVER
GOVERNMENT WATER SCHEME
Prepared by: A Lawrence
Date: 08/2001
Data Type: Fig4211-Scheme.apr
Figure 4.2.1.1


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
J4
H8
H9
BREEDE WMA
Inverdoorn Canal
2,5
Dwarsrivier
4,0
Rooikloof
0,7
Hexvallei
8,5
Gawie se Water
5,0
Stettynskloof to Worcester
13,0
Agterkliphoogte
2,1
Cogmanskloof
13,3
Theewaterskloof (RSE) Scheme to Cape Town and Berg
186,0
Berg to RSE
25,0
Uitnood
1,4
Duiwenhoks
1,0
Ruensveld West
3,2
Ruensveld East
0,8
Palmiet Scheme (not operational in 1995)
25,0
Ceres
Wolseley
Worcester
Rawsonville
Robertson
Montagu
Barrydale
Bonnievale
McGregor
Swellendam
Genadendal
Greyton
Riviersonderend
Caledon
Grabouw
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
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:
BREEDE WMA
TOTAL EQUIVALENT
WATER REQUIREMENTS
1995
Figure
5.1.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
E2
G1
G2
J1
J4
H1
H2
H3
H4
H5
H6
H7
H8
H9
G4
G5
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Ashton
Montagu
McGregor
Bonnievale
Swellendam
Barrydale
Genadendal
Greyton
Riviersonderend
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
Total Water Requirements for the WMA
LOCALITY MAP
LEGEND
Use Groups
Total Water Requirements
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
TITLE:
BREEDE WMA
WATER REQUIREMENTS
AT 1:50 YEAR ASSURANCE
PER USER SECTOR 1995
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

N

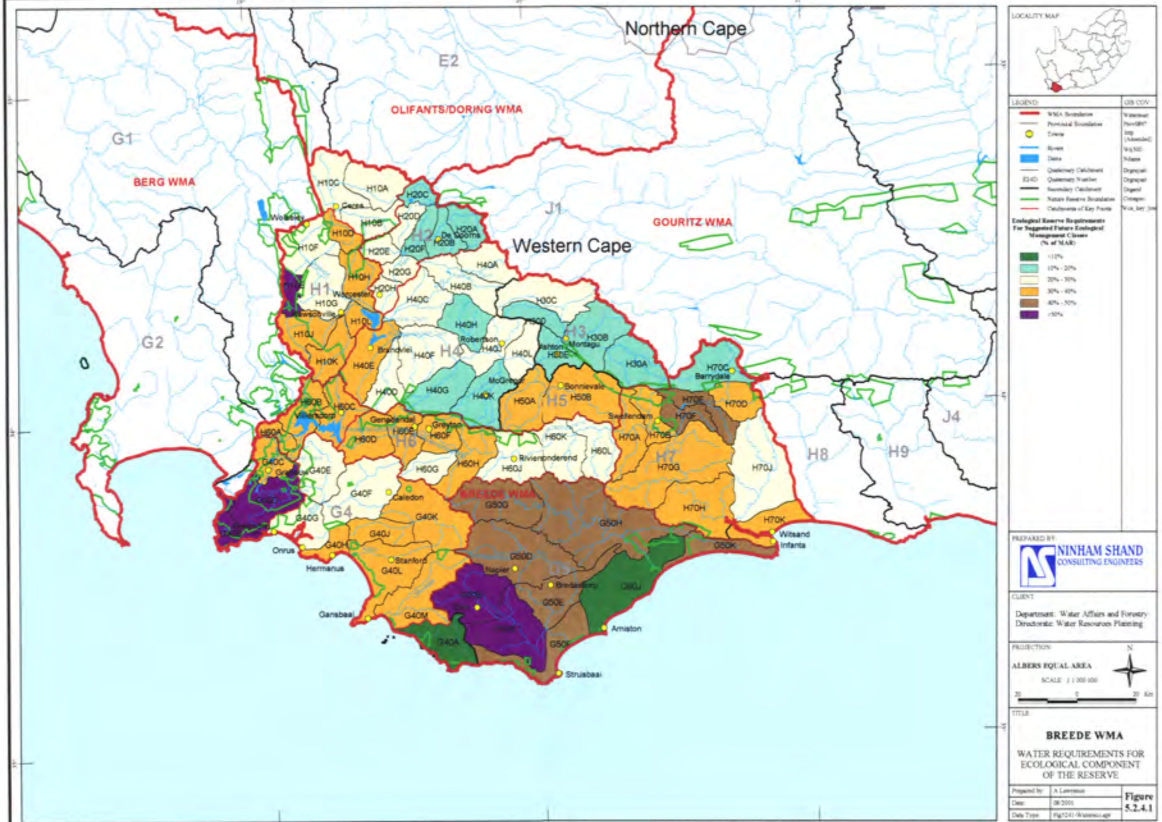
SCALE : N.T.S

TITLE

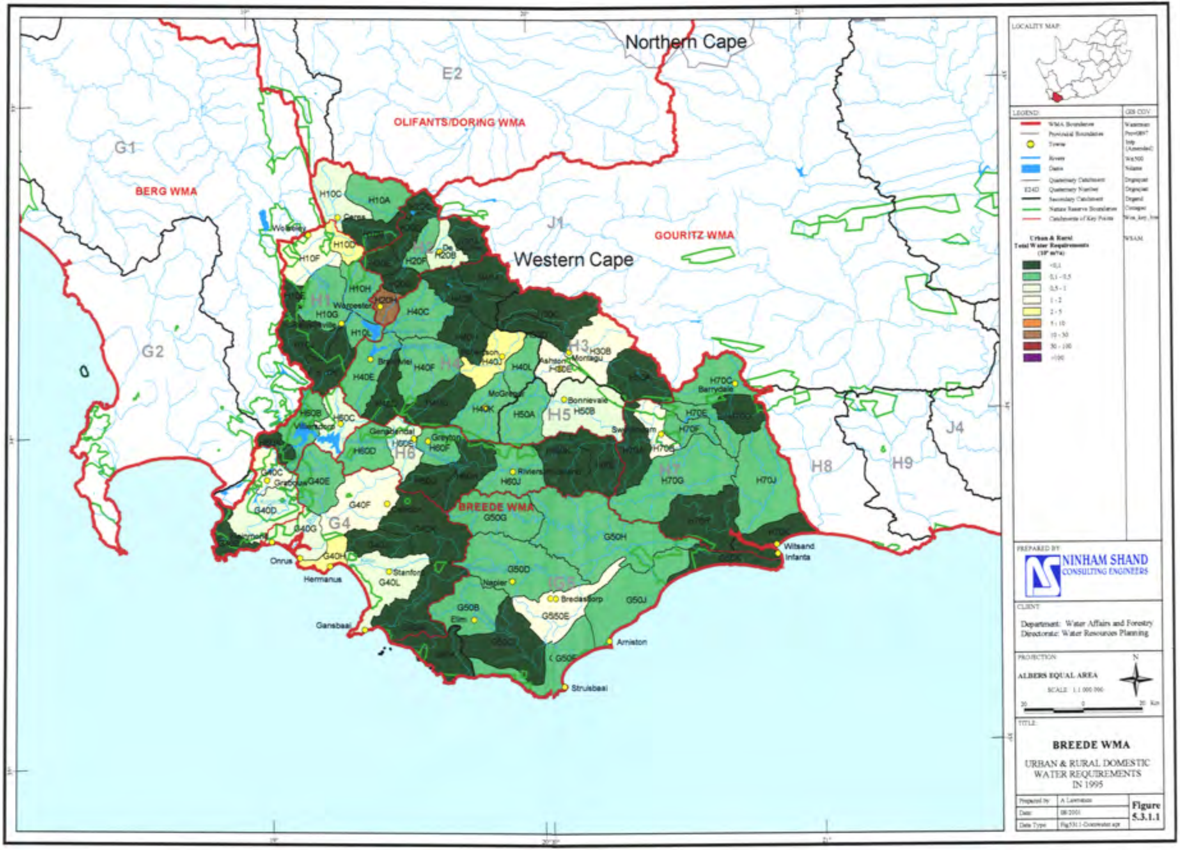
BREEDE WMA

DESKTOP RESERVE
PARAMETER REGIONS

Prepared by	A Lawrence	**Figure 5.2.1.1**
Date	08/2001	
Data Type	Fig5211-Model.apr	



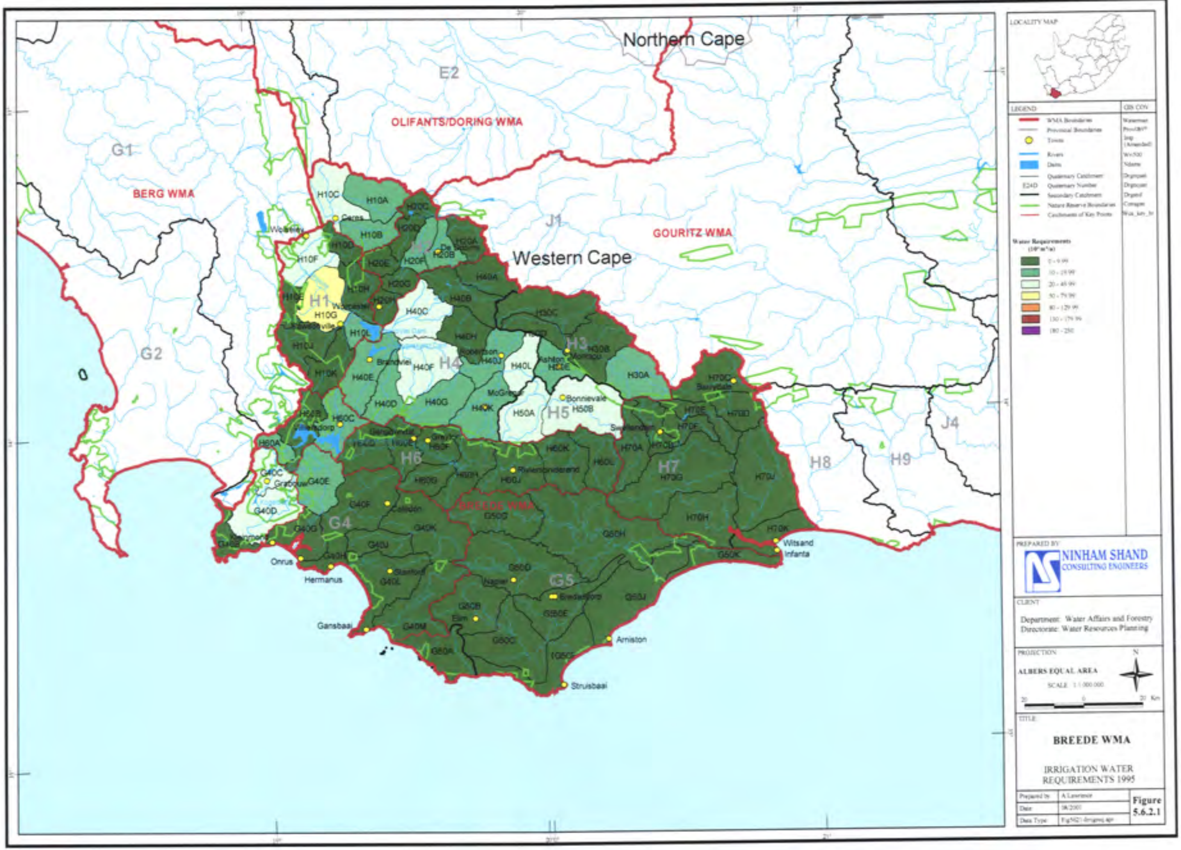
Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
BREEDE WMA
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
McGregor
Bonnievale
Barrydale
Swellendam
Villiersdorp
Genadendal
Greyton
Riviersonderend
Caledon
Stanford
Onrus
Hermanus
Gansbaai
Napier
Bredasdorp
Arniston
Struisbaai
Witsand
Infanta
Ecological Reserve Requirements For Suggested Future Ecological Management Classes (% of MAR)
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
BREEDE WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Figure 5.2.4.1



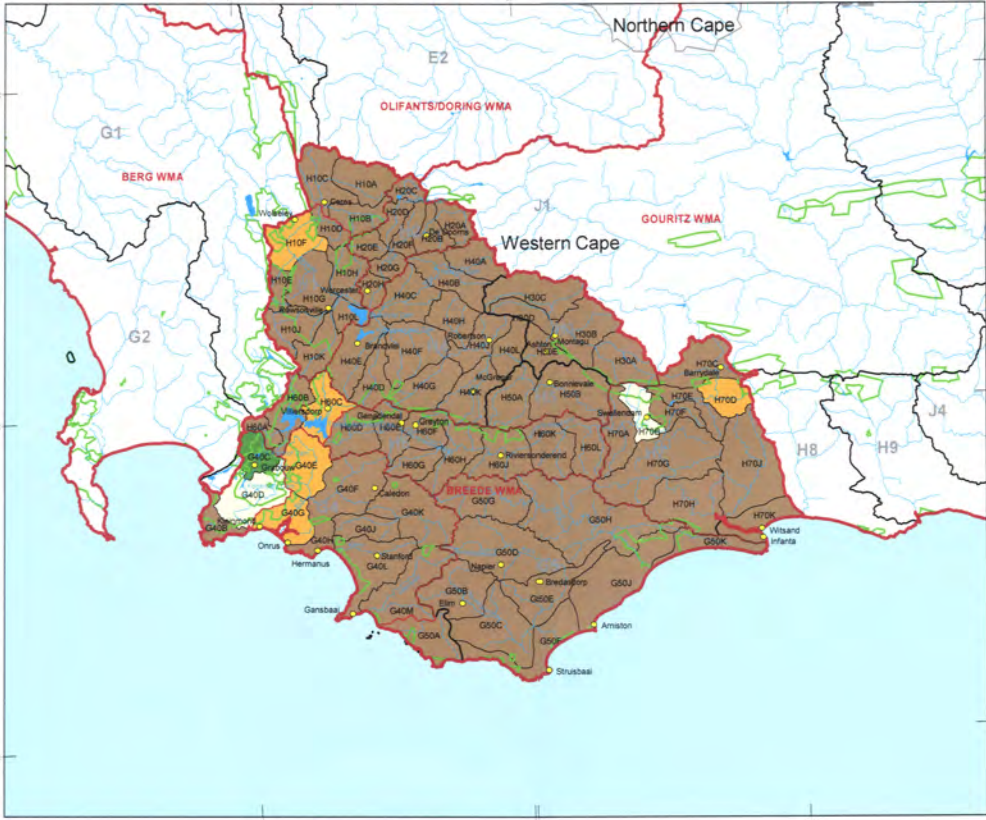
BREEDE WMA

URBAN & RURAL DOMESTIC WATER REQUIREMENTS IN 1995

Figure 5.3.1.1



Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
H1
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
Ceres
Wolseley
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
McGregor
Bonnievale
Swellendam
Barrydale
Villiersdorp
Genadendal
Greyton
Riviersonderend
Grabouw
Caledon
Stanford
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Gansbaai
Hermanus
Onrus
Witsand
Infanta
LOCALITY MAP
LEGEND
Water Requirements
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
IRRIGATION WATER
REQUIREMENTS 1995
Prepared by
Date
Data Type
Figure
5.6.2.1



LOCALITY MAP

LEGEND	GIS COV
WMA Boundaries	Watermas
Provincial Boundaries	Prov2017
Towns	Itop (Amended)
Rivers	Wr500
Dams	Ndams
Quaternary Catchment	Drgnquat
E24D Quaternary Number	Drgnquat
Secondary Catchment	Drgnsd
Nature Reserve Boundaries	Consagm
Catchments of Key Points	Wua_key_bt

Water Use by Afforestation (mm/a) — WSAM

- 0 - 1.99
- 2 - 5.99
- 6 - 13.99
- 14 - 25.99
- 26 - 40

PREPARED BY

NINHAM SHAND CONSULTING ENGINEERS

CLIENT

Department: Water Affairs and Forestry
Directorate: Water Resources Planning

PROJECTION

ALBERS EQUAL AREA

SCALE 1:1 000 000

20 0 20 Km

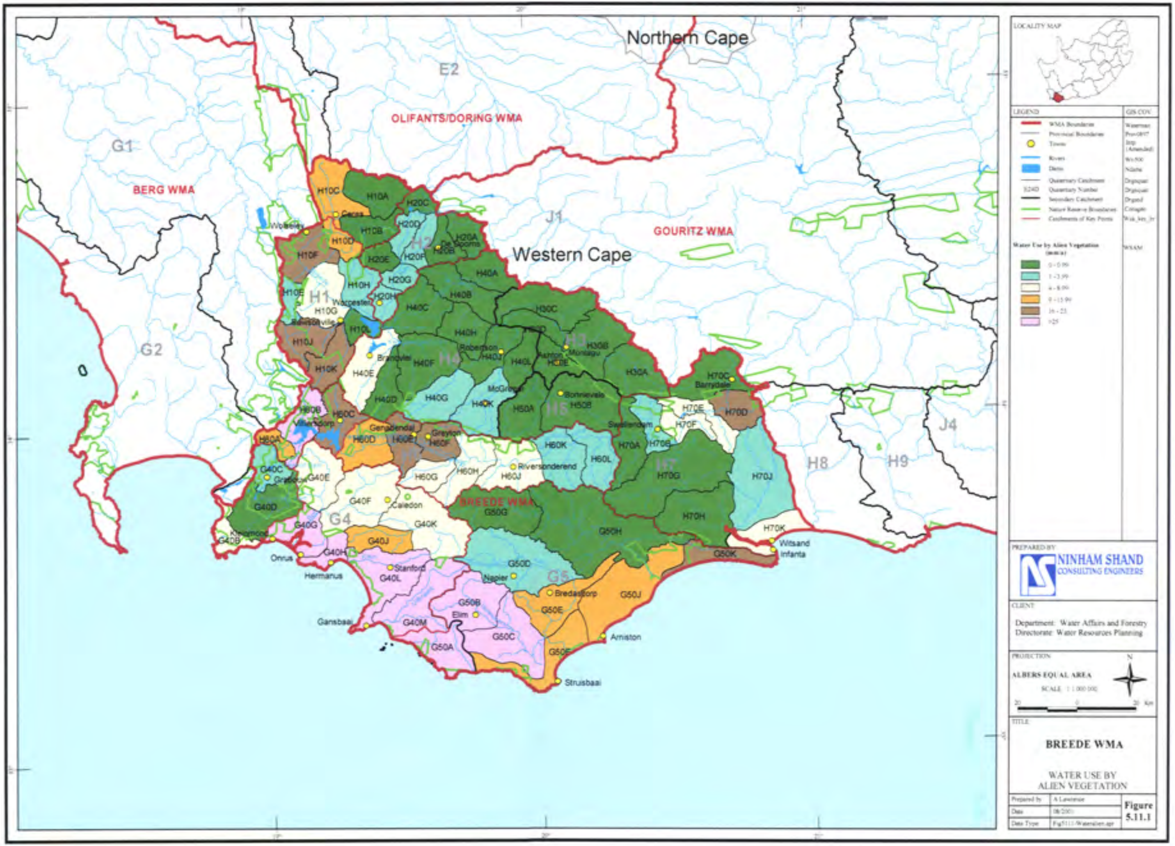
N

TITLE

BREEDE WMA

WATER USE BY AFFORESTATION IN 1995

Prepared by	A Lawrence	**Figure 5.9.1**
Date	08/2001	
Data Type	Fig591-Wateraffores.apr	



Northern Cape
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
Western Cape
LOCALITY MAP
LEGEND
Water Use by Alien Vegetation
PREPARED BY
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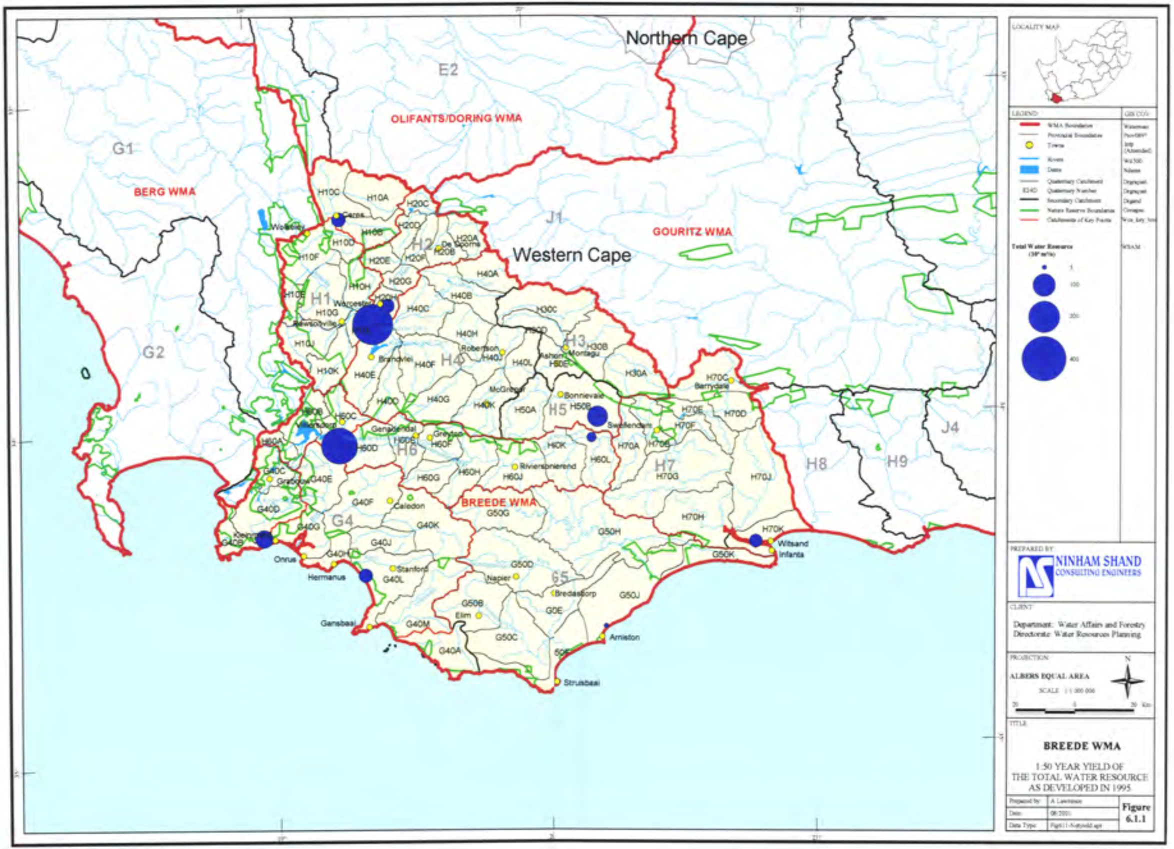
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
BREEDE WMA
WATER USE BY
ALIEN VEGETATION
Figure
5.11.1

Northern Cape
Western Cape
E2
G1
G2
J1
J4
H8
H9
OLIFANTS/DORING WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
H1
H4
H5
H6
H7
G4
Inverdoorn Canal 2,5
Dwarsrivier 4,0
Rooikloof 0,7
Hexvallei 6,5
Gawie se Water 5,0
Stettynskloof to Worcester 13,0
Agterkliphoogte 2,1
Cogmanskloof 13,3
Theewaterskloof (RSE) Scheme to Cape Town and Berg 186,0
Berg to RSE 25,0
Uitnood 1,4
Duivenhoks 1,0
Ruensveld West 3,2
Ruensveld East 0,9
Palmiet Scheme (not operational in 1995) 25,0
Worcester
Robertson
Montagu
Bonnievale
Swellendam
Barrydale
Genadendal
Greyton
Riviersonderend
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
De Doorns
Ceres
Wellington
Grabouw
LOCALITY MAP
LEGEND
Water Transfer
Irrigation
Urban
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BREEDE WMA
WATER TRANSFER SCHEMES
Figure 5.14.1


Northern Cape
Western Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
J4
H8
H9
BREEDE WMA
H1
H2
H3
H4
H5
H6
H7
G4
G5
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
McGregor
Bonnievale
Barrydale
Swellendam
Genadendal
Greyton
Riviersonderend
Villiersdorp
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
Total Water Resource
PREPARED BY
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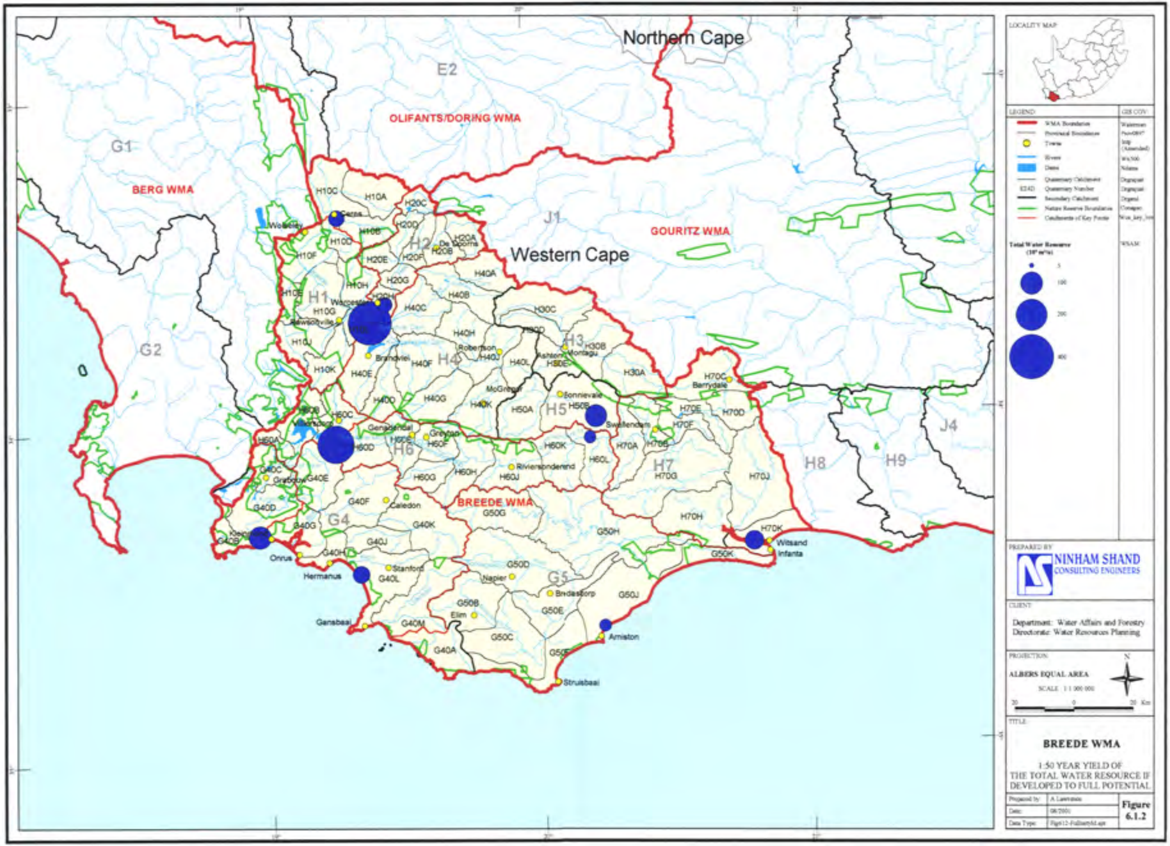
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
1:50 YEAR YIELD OF
THE TOTAL WATER RESOURCE
AS DEVELOPED IN 1995
Figure
6.1.1


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
Western Cape
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
Ceres
Wolseley
Worcester
Rawsonville
Brandvlei
De Doorns
Robertson
Ashton
Montagu
McGregor
Bonnievale
Swellendam
Barrydale
Genadendal
Greyton
Riviersonderend
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Catchments of Key Points
GIS COV
Total Water Resource
PREPARED BY
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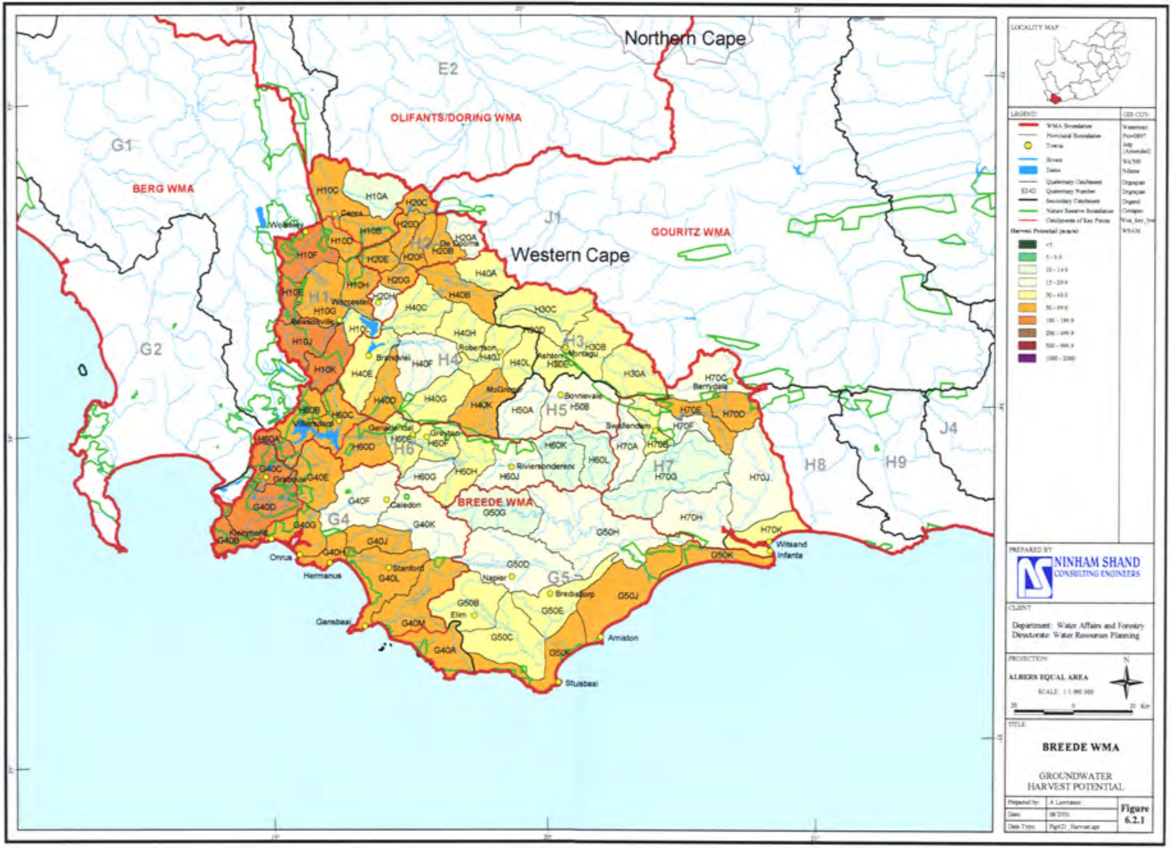
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE
BREEDE WMA
1:50 YEAR YIELD OF
THE TOTAL WATER RESOURCE IF
DEVELOPED TO FULL POTENTIAL
Prepared by
Date
Data Type
Figure
6.1.2



Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
H10A
H10B
H10C
H10D
H10E
H10F
H10G
H10H
H10J
H10K
H10L
H20A
H20B
H20C
H20D
H20E
H20F
H20G
H20H
H30A
H30B
H30C
H30D
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H40B
H40C
H40D
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H40F
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H40L
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G50K
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Ashton
Montagu
McGregor
Bonnievale
Barrydale
Swellendam
Villiersdorp
Genadendal
Greyton
Riviersonderend
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
Harvest Potential (m³/km²/a)
PREPARED BY
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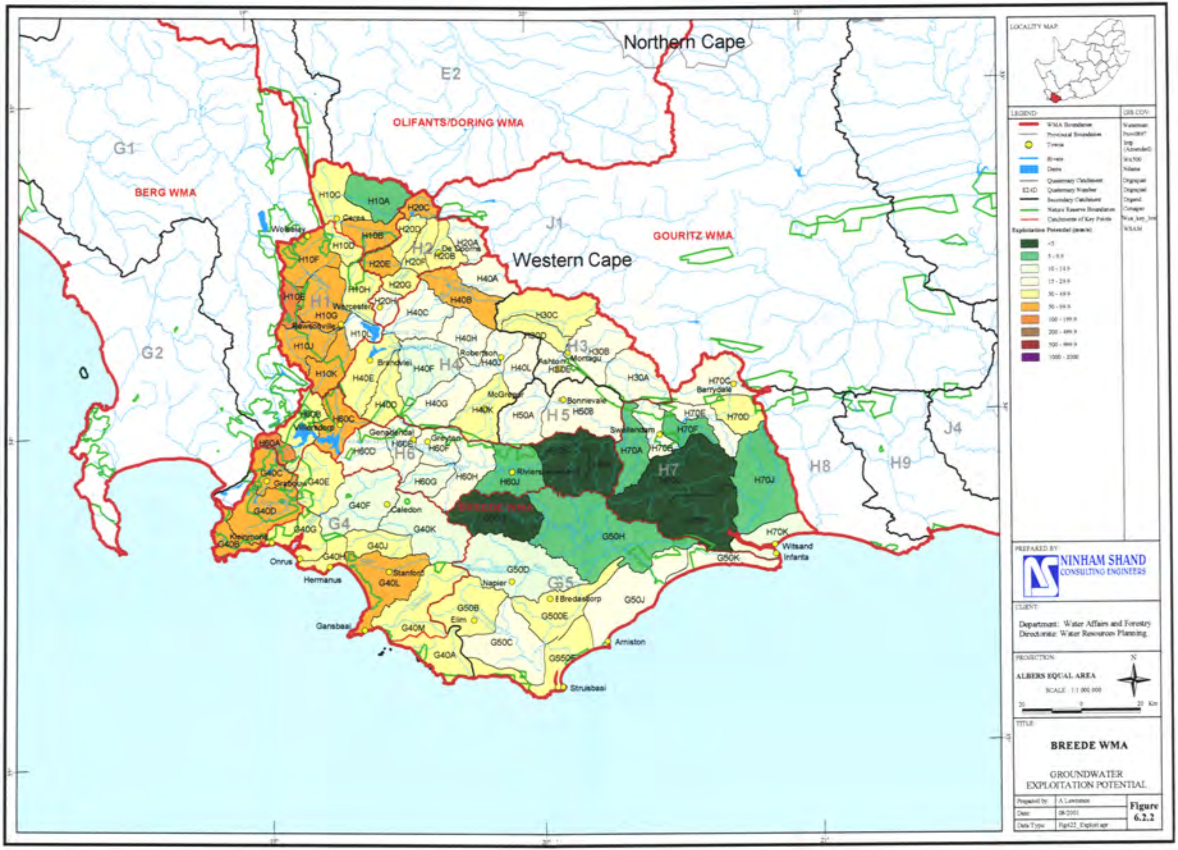
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
GROUNDWATER
HARVEST POTENTIAL
Prepared by:
A Lawrence
Date:
Figure
6.2.1


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
H10A
H10B
H10C
H10D
H10E
H10F
H10G
H10H
H10J
H10K
H10L
H20A
H20B
H20C
H20D
H20E
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H20H
H30A
H30B
H30C
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Wolseley
Ceres
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Ashton
Montagu
McGregor
Bonnievale
Barrydale
Swellendam
Villiersdorp
Genadendal
Greyton
Riviersonderend
Grabouw
Caledon
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
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 - 199.9
200 - 499.9
500 - 999.9
1000 - 2000
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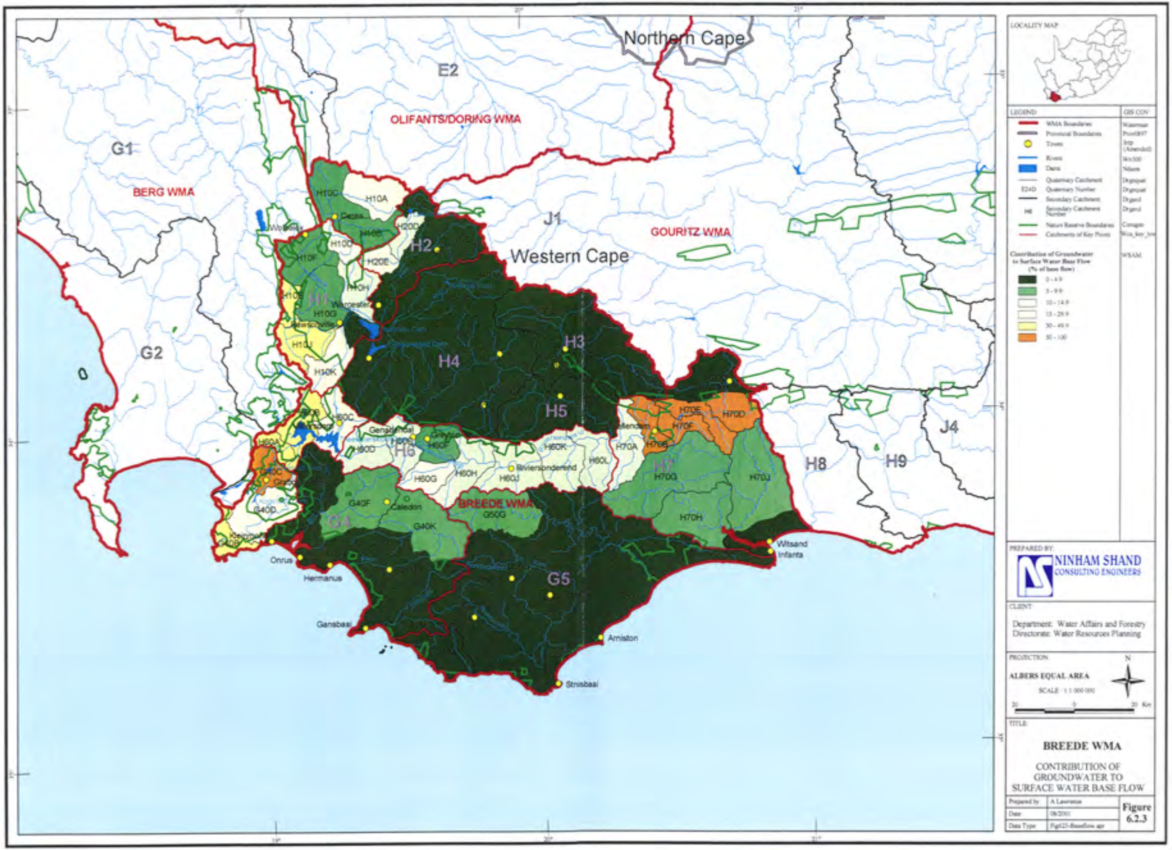
PROJECTION
ALBERS EQUAL AREA
SCALE : 1:1 000 000
N
TITLE
BREEDE WMA
GROUNDWATER
EXPLOITATION POTENTIAL
Prepared by
A Lawrence
Date
08/2001
Figure
6.2.2


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
H10A
H10C
H10B
H10D
H10F
H10E
H10G
H10J
H10K
H20D
H20E
H20H
H60A
H60B
H60C
H60D
H60F
H60G
H60H
H60J
H60K
H60L
H70A
H70B
H70D
H70E
H70F
H70G
H70H
H70J
G40D
G40F
G40K
G50G
Ceres
Wolseley
Worcester
Franschhoek
Caledon
Riviersonderend
Witsand
Infanta
Onrus
Hermanus
Gansbaai
Arniston
Struisbaai
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
H6 Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Contribution of Groundwater to Surface Water Base Flow (% of base flow)
0 - 4.9
5 - 9.9
10 - 14.9
15 - 29.9
30 - 49.9
50 - 100
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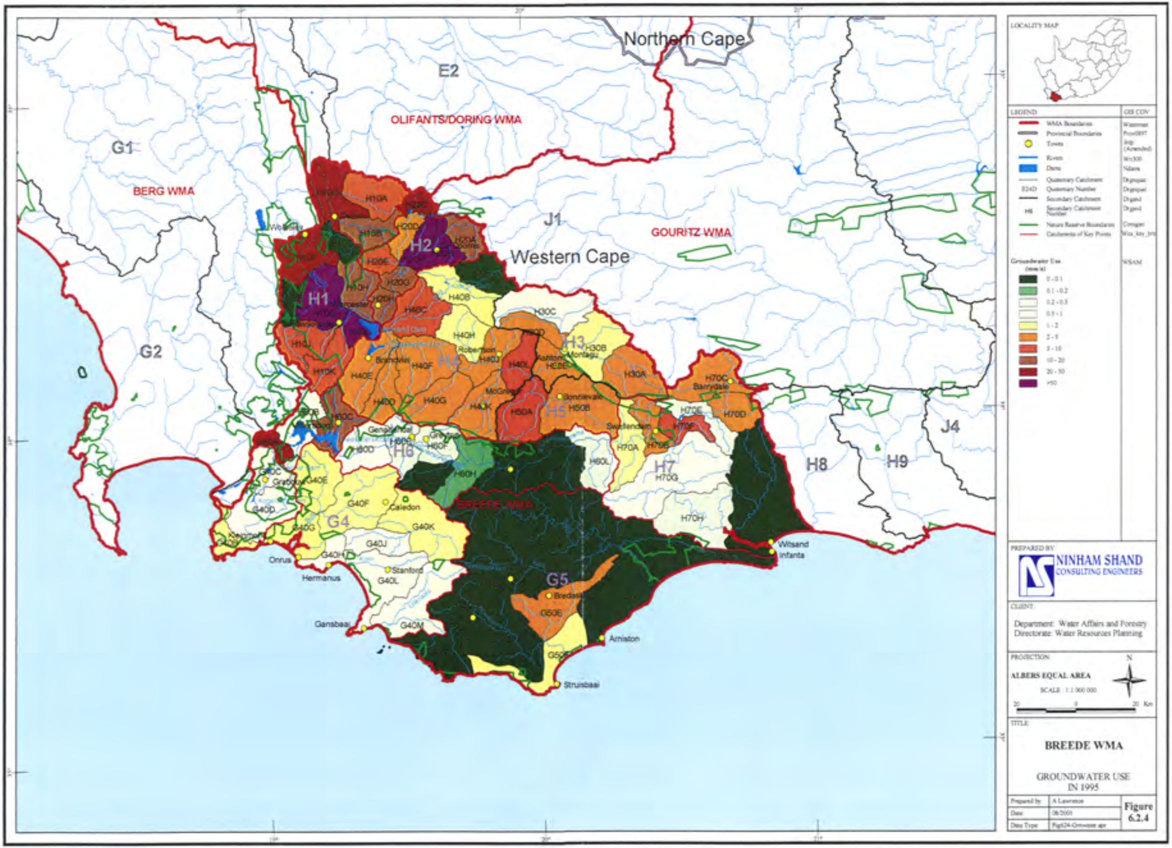
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BREEDE WMA
CONTRIBUTION OF GROUNDWATER TO SURFACE WATER BASE FLOW
Prepared by A Lawrence
Date 08/2001
Figure 6.2.3


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
Western Cape
GOURITZ WMA
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
Worcester
Robertson
Ashton
Montagu
Bonnievale
McGregor
Swellendam
Barrydale
Genadendal
Greyton
Caledon
Grabouw
Kleinmond
Onrus
Hermanus
Stanford
Gansbaai
Bredasdorp
Arniston
Struisbaai
Witsand
Infanta
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
Groundwater Use (mm/a)
0 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
>50
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Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
GROUNDWATER USE IN 1995
Prepared by
A Lawrence
Figure 6.2.4

Northern Cape
Western Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
BREEDE WMA
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
Ceres
Worcester
Rawsonville
Brandvlei
Robertson
Ashton
Montagu
McGregor
Bonnievale
Swellendam
Barrydale
Caledon
Riviersonderend
Grabouw
Onrus
Hermanus
Stanford
Gansbaai
Napier
Bredasdorp
Elim
Arniston
Struisbaai
Witsand
Infanta
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
Groundwater Utilisation
Over Utilised
Heavily Utilised
Moderately Utilised
Under Utilised
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Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
SCALE 1:1 000 000
N
TITLE
BREEDE WMA
EXTENT OF GROUNDWATER UTILISATION IN 1995
Prepared by
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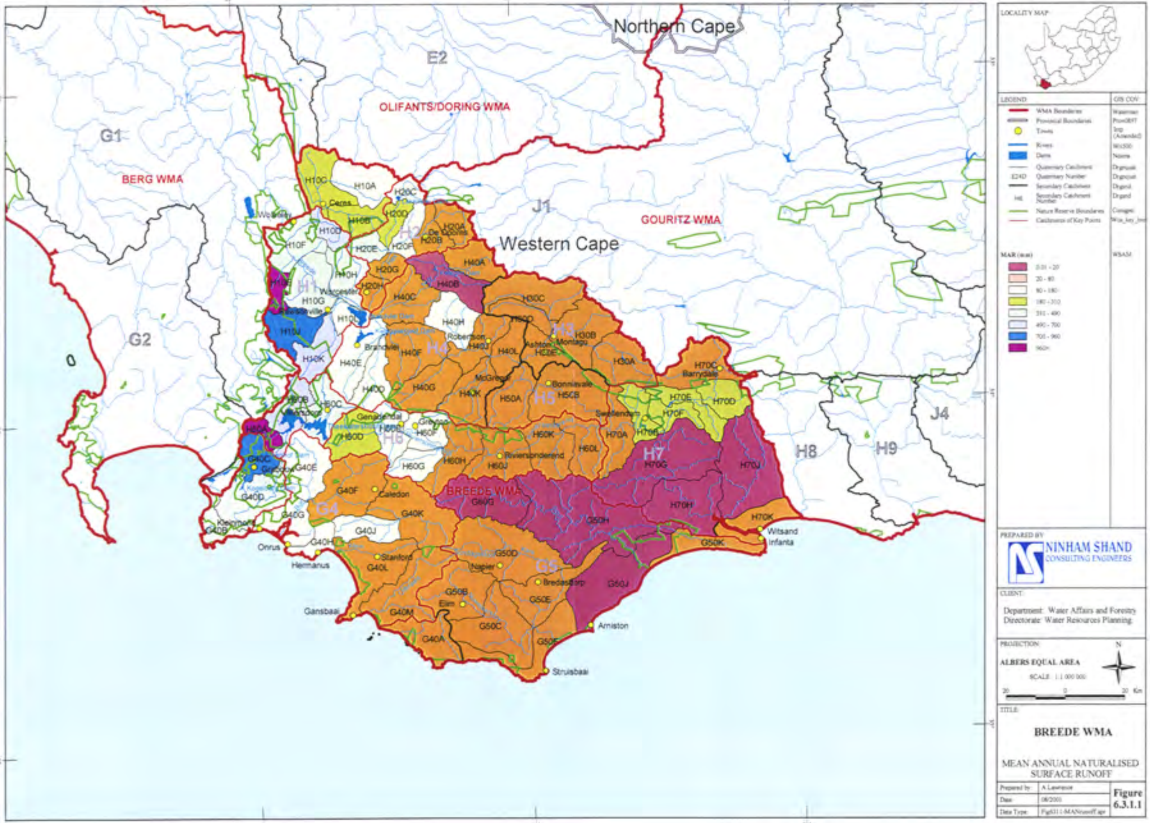
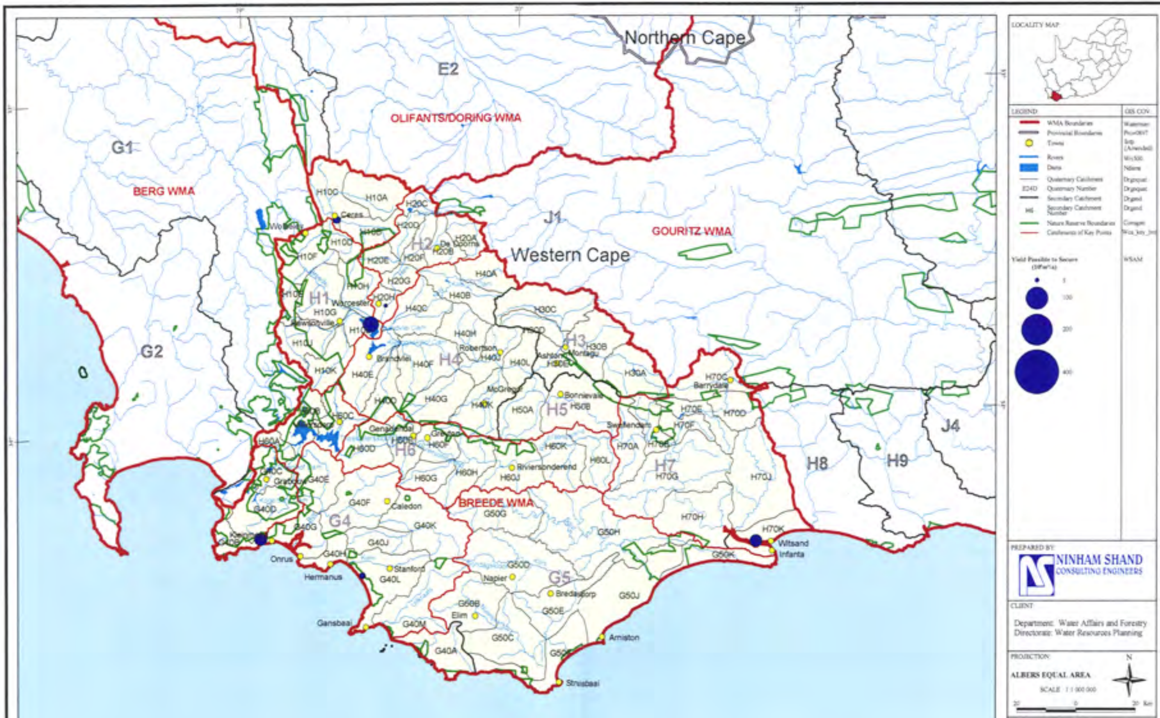
Date
08/2001
Figure 6.2.5



BREEDE WMA

MEAN ANNUAL NATURALISED SURFACE RUNOFF

Figure 6.3.1.1

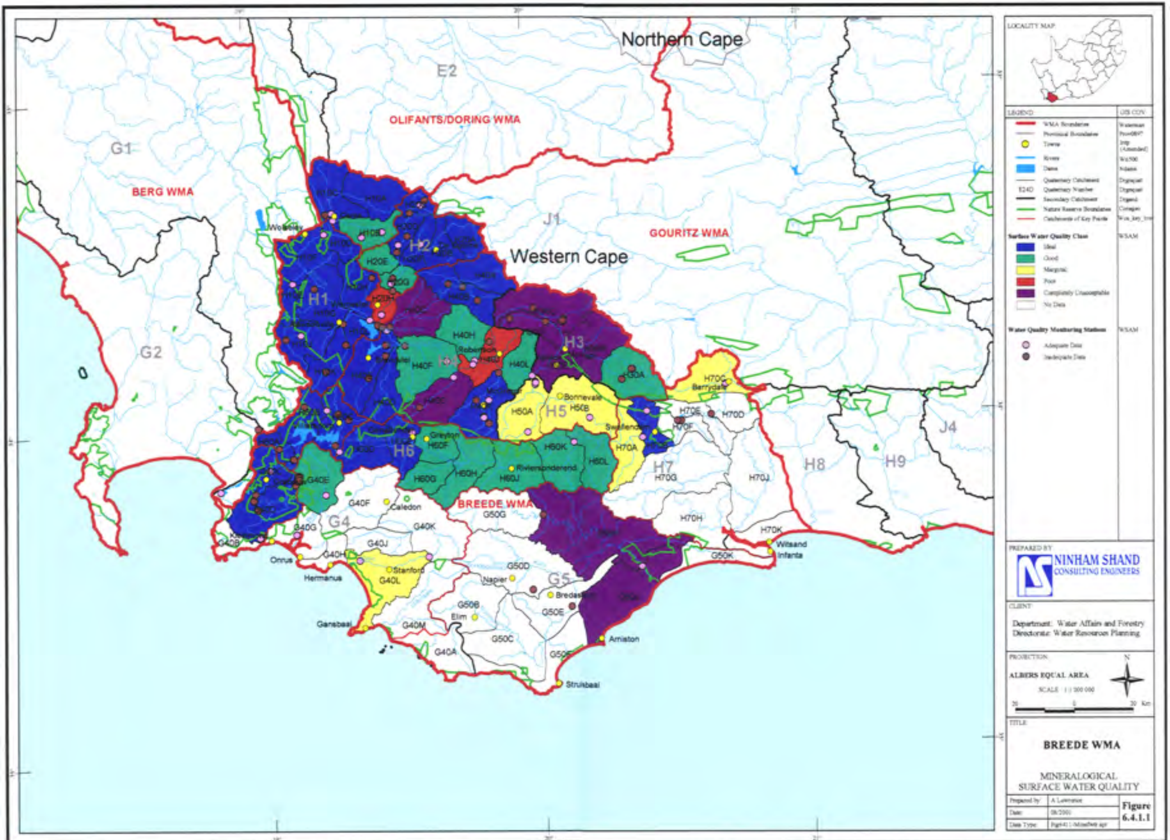


TITLE

BREEDE WMA

UNDEVELOPED POTENTIAL 1:50 YEAR SURFACE WATER YIELD

Prepared by	A Lawrence	Figure 6.3.2.1
Date	08/2001	
Data Type	Fig6321-Waterdev.apr	


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
Wolseley
J1
GOURITZ WMA
Western Cape
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G2
G4
G5
H10B
H20E
H20H
H40H
H40F
H40L
Robertson
H30A
H70C
Barrydale
H70E
H70D
H70F
Bonnievale
H50A
H50B
Swellendam
H70A
H70G
H70J
H70H
H70K
Greyton
H60F
H60K
H60L
H60G
H60H
H60J
Riviersonderend
G40E
G40F
Caledon
BREEDE WMA
G50G
G40G
G40K
G40J
G40H
G40B
Onrus
Hermanus
Stanford
G40L
G50D
Napier
Bredasdorp
G50B
Elim
G50E
G40M
G50C
G40A
G50F
Gansbaai
Arniston
Struisbaai
Witsand
Infanta
G50K
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Catchments of Key Points
Surface Water Quality Class
WSAM
Ideal
Good
Marginal
Poor
Completely Unacceptable
No Data
Water Quality Monitoring Stations
WSAM
Adequate Data
Inadequate Data
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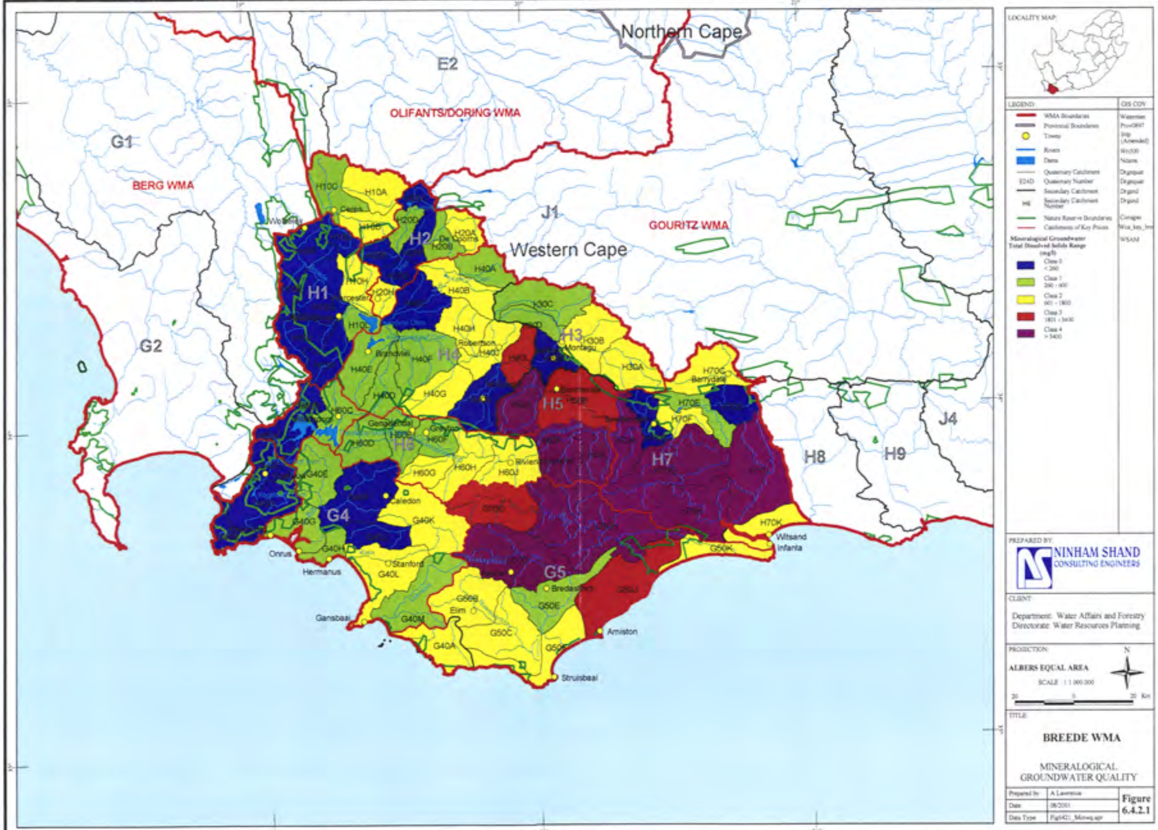
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
MINERALOGICAL
SURFACE WATER QUALITY
Prepared by: A Lawrence

Figure 6.4.1.1


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
GOURITZ WMA
Western Cape
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
H10C
H10A
Ceres
H20D
H20A
De Doorns
H20B
H40A
H10H
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H40B
H30C
H40H
Robertson
Montagu
H30B
H30A
Brandvlei
H40F
H40E
H40G
H40D
H60C
Genadendal
H60F
Greyton
H60D
H60G
H60H
H60J
Riviersonderend
H70C
Barrydale
H70E
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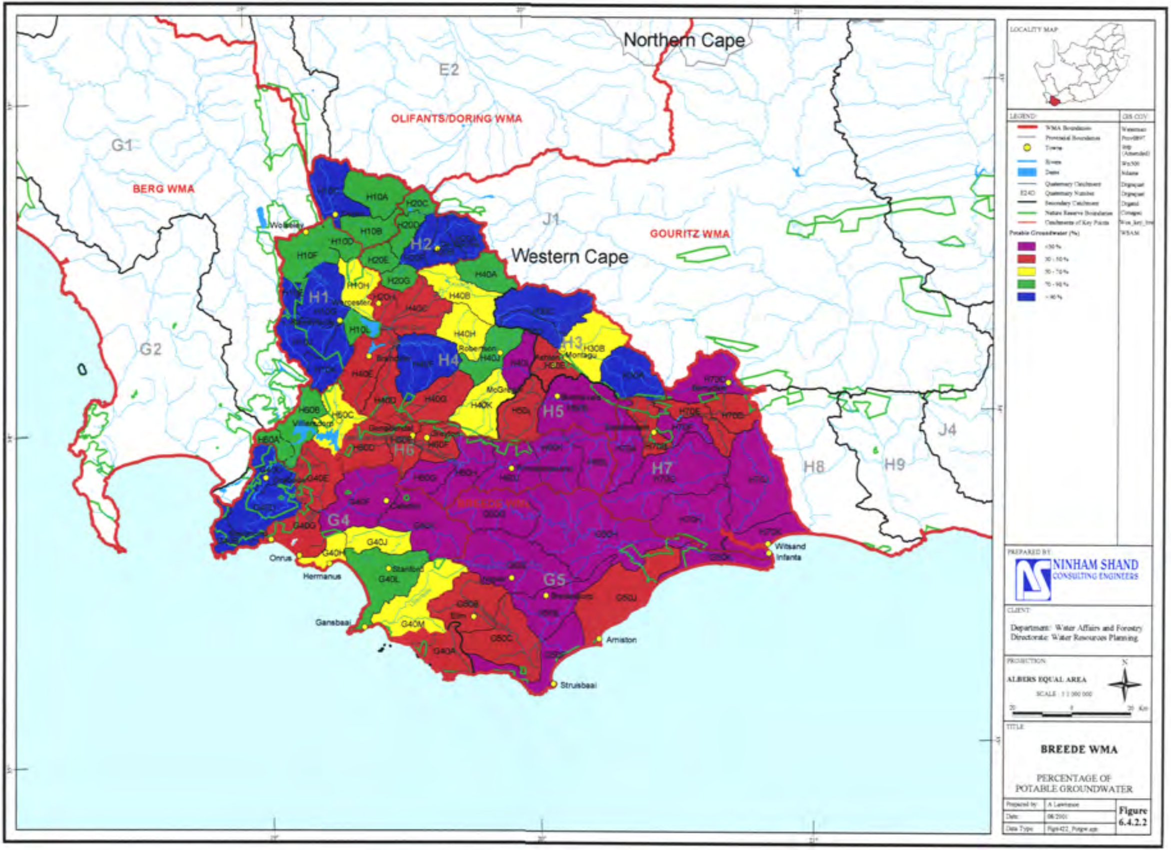
H70K
Witsand
Infanta
G50K
Caledon
G40E
G40G
G40K
G40H
Onrus
Hermanus
Stanford
G40L
G40M
Gansbaai
G50B
Elim
G50C
G40A
G50E
Bredasdorp
G50J
Arniston
Struisbaai
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D
Quaternary Number
Secondary Catchment
H6
Secondary Catchment Number
Nature Reserve Boundaries
Catchments of Key Points
Mineralogical Groundwater Total Dissolved Solids Range (mg/l)
Class 0 < 200
Class 1 200 - 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
SCALE 1 : 1 000 000
N
TITLE:
BREEDE WMA
MINERALOGICAL GROUNDWATER QUALITY
Prepared by: A Lawrence
Date: 08/2001
Figure 6.4.2.1



Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
Western Cape
H1
H2
H3
H4
H5
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H9
J4
G4
G5
BREEDE WMA
Wolseley
Worcester
Robertson
Montagu
Villiersdorp
Onrus
Hermanus
Stanford
Gansbaai
Elim
Arniston
Struisbaai
Witsand
Infanta
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H10L
H20C
H20D
H20E
H20G
H40A
H40B
H40C
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H40E
H40D
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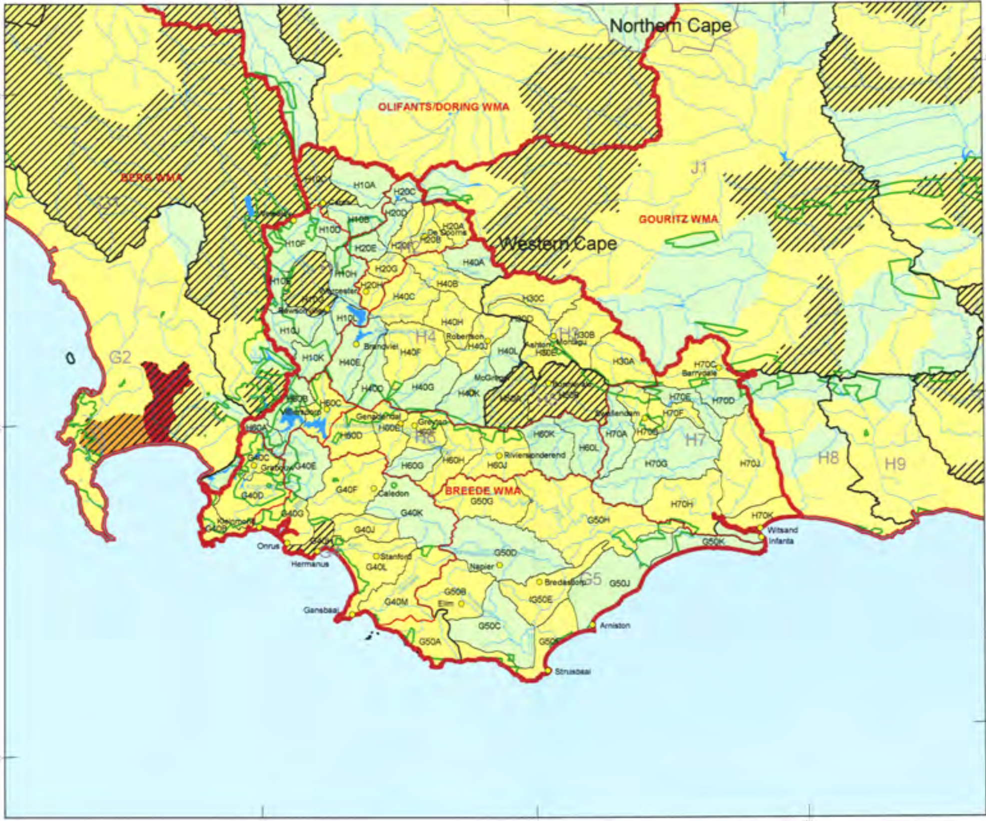
H30B
H60B
H60A
H60C
H60D
H50C
G40E
G40G
G40H
G40J
G40L
G40M
G40A
G50B
G50C
G50J
H70E
H70G
H70K
H73C
LOCALITY MAP
LEGEND
GIS COV
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Catchments of Key Points
Potable Groundwater (%)
PREPARED BY
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
BREEDE WMA
PERCENTAGE OF
POTABLE GROUNDWATER
Prepared by:
A Lawrence
Date:
08/2001
Figure
6.4.2.2



LOCALITY MAP

LEGEND

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.

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Directorate: Water Resources Planning

PROJECTION

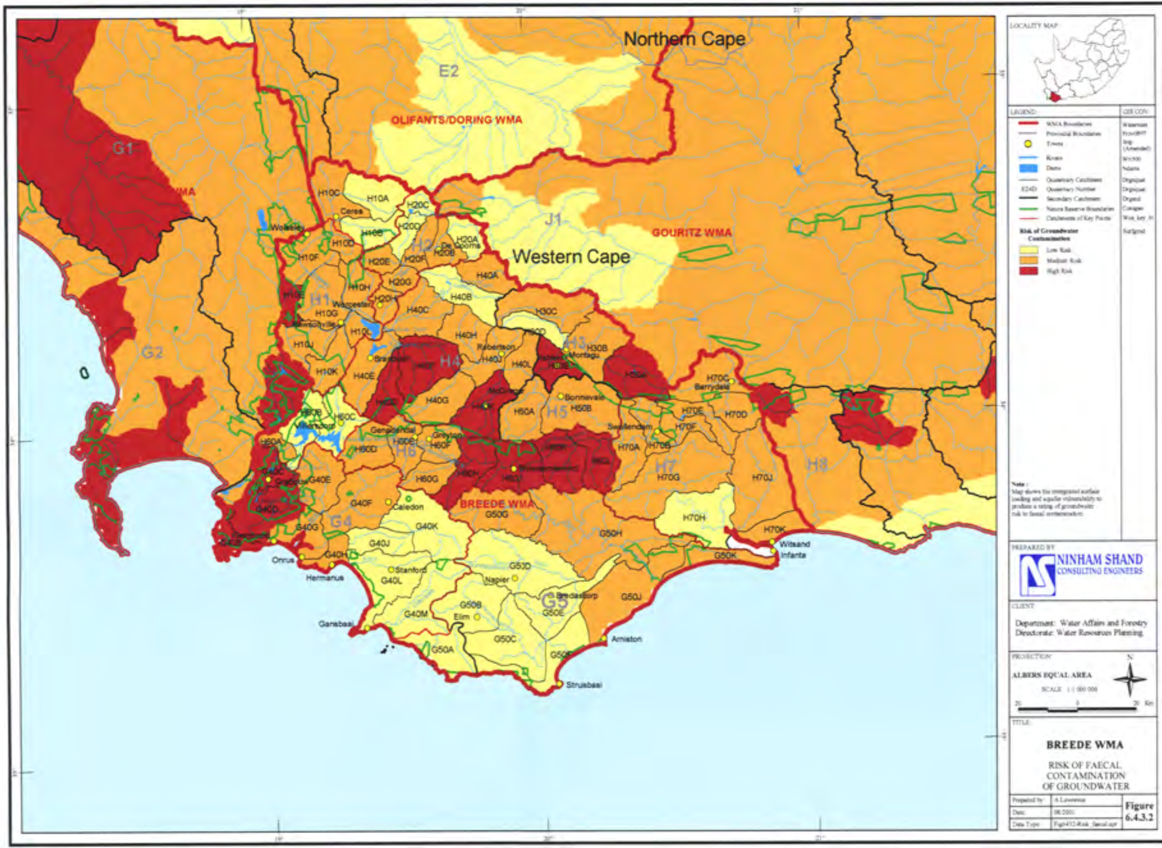
ALBERS EQUAL AREA

TITLE

BREEDE WMA

POTENTIAL FAECAL CONTAMINATION OF SURFACE WATER

Figure 6.4.3.1


Northern Cape
Western Cape
OLIFANTS/DORING WMA
GOURITZ WMA
BREEDE WMA
E2
J1
G1
G2
G4
G5
H1
H2
H3
H4
H5
H6
H7
H8
Ceres
Wolseley
Worcester
Rawsonville
Robertson
Montagu
Bonnievale
Barrydale
Swellendam
Genadendal
Greyton
Villiersdorp
Caledon
Grabouw
Onrus
Hermanus
Stanford
Napier
Bredasdorp
Elim
Gansbaai
Arniston
Struisbaai
Witsand
Infanta
LOCALITY MAP
LEGEND
Risk of Groundwater Contamination
Low Risk
Medium Risk
High Risk
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PROJECTION
ALBERS EQUAL AREA
TITLE
BREEDE WMA
RISK OF FAECAL CONTAMINATION OF GROUNDWATER
Figure 6.4.3.2


Northern Cape
Western Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
G2
J1
GOURITZ WMA
J4
H8
H9
BREEDE WMA
H1
H2
H3
H4
H5
H6
H7
G4
G5
Ceres
Wolseley
De Doorns
Worcester
Rawsonville
Brandvlei
Robertson
Montagu
Ashton
McGregor
Bonnievale
Barrydale
Swellendam
Villiersdorp
Genadendal
Greyton
Riviersonderend
Caledon
Grabouw
Kleinmond
Hermanus
Stanford
Napier
Bredasdorp
Elim
Gansbaai
Arniston
Struisbaai
Witsand
Infanta
Pesticide residues have been detected in the Hex River indicating that pesticides may be a concern in areas where intensive irrigation takes place.
Nitrate levels increase during the winter high flow months indicating wash-off of fertilizer from agricultural areas.
Turbidity in the middle Breede River is unnaturally elevated during the low flow summer months as a result of irrigation water releases from Brandvlei Dam. This negatively affects the aquatic ecosystem.
Concerns have been expressed about organic and nutrient pollution from aquaculture activities in largely natural mountain streams.
Many of the mountain streams are coloured dark brown due to the presence of humic substances. These streams are also naturally acidic with low pH's.
There are signs of nutrient enrichment and eutrophication in the middle and lower reaches of the Breede River.
LOCALITY MAP
LEGEND
GIS COV.
WMA Boundaries
Provincial Boundaries
Towns
Rivers
Dams
Quaternary Catchment
E24D Quaternary Number
Secondary Catchment
Nature Reserve Boundaries
Catchments of Key Points
PREPARED BY
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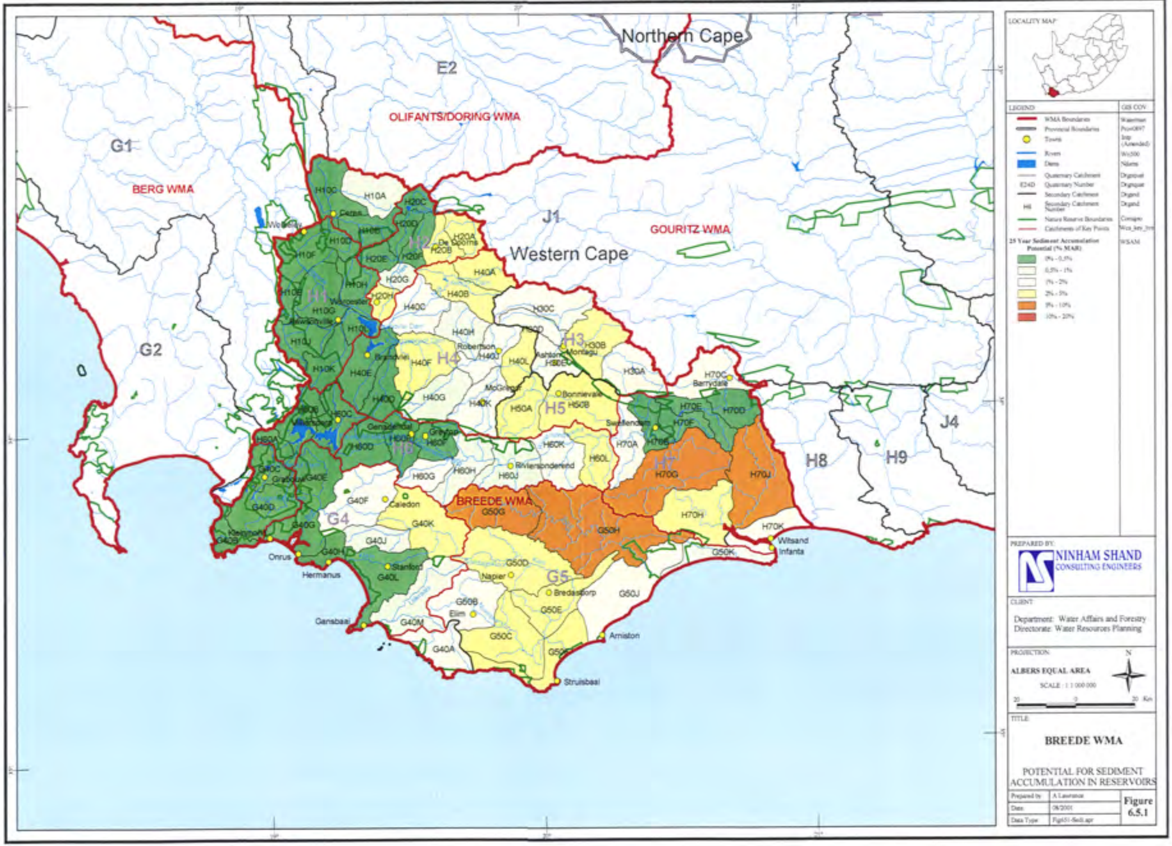
PROJECTION
ALBERS EQUAL AREA
N
20 0 20 Km
TITLE
BREEDE WMA
WATER QUALITY ISSUES
Prepared by A Lawrence
Figure 6.4.4.1


Northern Cape
E2
OLIFANTS/DORING WMA
G1
BERG WMA
J1
Western Cape
GOURITZ WMA
G2
H1
H2
H3
H4
H5
H6
H7
H8
H9
J4
G4
G5
BREEDE WMA
Worcester
Robertson
Montagu
Ashton
Bonnievale
McGregor
Swellendam
Barrydale
Genadendal
Greyton
Riviersonderend
Caledon
Napier
Bredasdorp
Elim
Stanford
Gansbaai
Hermanus
Onrus
Kleinmond
Grabouw
Villiersdorp
Ceres
Wolseley
Rawsonville
Brandvlei
De Doorns
Witsand
Infanta
Arniston
Struisbaai
LOCALITY MAP
LEGEND
25 Year Sediment Accumulation Potential (% MAR)
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
N
TITLE:
BREEDE WMA
POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS
Figure 6.5.1

BREEDE WMA

YIELD BALANCE OVERVIEW

Figure 7.2.1