CHAPTER 5 : WATER RESOURCE AVAILABILITY

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5.1 Introduction

The Study Area is located on the interior plateau of South Africa, north of the watershed between the river systems draining north and east to the Indian Ocean and the river systems draining south and west to the Atlantic Ocean. The Limpopo and Olifants River systems, primary catchments A and B respectively, drain the Study Area in a generally northerly direction while the Vaal-Orange River system, primary catchment C, lies south of the watershed.

The drainage system in South Africa has been subdivided into quaternary sub-catchments, ie four levels of subdivisions, for purposes of water resource evaluation. The quaternary sub-catchments in the Study Area are shown in Figure 5-1 from which it can be seen that the boundaries of the Study Area and the Extended Supply Area (ESA) of Magalies Water do not coincide well with the sub-catchment boundaries. A very small portion of the Vaal River catchment, in Koster District to the west of Johannesburg, drained by the headwaters of the Mooi River lies within the ESA but is not included in the Study Area.

The Study Area is located in a semi-arid to arid part of the country with predominantly summer rainfall. Runoff in the area is strongly seasonal and very variable from place to place. It is also significant that the main centre of economic activity in South Africa, based on rich gold deposits found on the Witwatersrand in the 1860's, is located in the southern portion of the Study Area around Johannesburg. For this and other reasons the water resources of the Study Area are highly developed to supply water for domestic use, mining, industry, power stations and irrigated agricultural. Furthermore, the rivers draining the Study Area are all main tributaries of rivers of common interest to neighbouring states, namely Botswana, Zimbabwe and Mozambique.

The Study Area includes portions of Gauteng, North Western, Northern, and Mpumalanga Provinces. Development of the water resources of South Africa is the responsibility of the Central Government while responsibility for water treatment, distribution and supply and the reticulation and treatment of wastewater is the responsibility of Second and Third Tier authorities such as Provincial Government departments, water boards, regional authorities and local authorities. Where these authorities do not yet exist or do not have access to the necessary capacity, the Central Government through DWAF should perform these functions as an interim measure.

Information on the occurrence, development, utilization and control of water resources is available from many sources. However, comprehensive information on certain critical components of the water resources system such as abstractions from rivers and from groundwater is not available.

5.2 Rainfall and Evaporation

The climate of the Study Area reflects the combined effect of the topography of the country dominated by the Drakensberg mountains, which form an escarpment running in a generally north-south direction 200 km to 250 km from the east coast on the Indian Ocean, the position of the country in the mid-latitudes of the southern hemisphere and the dominant meteorological systems moving over this part of the globe.

Meteorological data, which gives definition to the climate, is collected by the Weather Bureau of the Department of Environment Affairs and Tourism. Other agencies such as the DWAF and the Departments of Agriculture also collect some meteorological data.

Detailed information concerning rainfall and evaporation for representative stations located in the Study Area is given in Section 2.2.

5.3 Water Resources in the Study Area

Streamflow in the river systems draining the Study Area is recorded at 127 gauging stations installed and maintained by DWAF. The gauging station network in South Africa comprises mostly carefully designed and calibrated structures, usually fitted with autographic recorders. In some cases no recorders are fitted and daily observations of flow depth on gauge plates are made by observers. In a few instances it is not possible to construct a gauging structure so resort is made to rated river sections. Where possible, major reservoirs are also used as flow gauging stations by computing daily inflows from water balances.

Streamflow data is available in various formats, either digitally or on hard copy, from DWAF. It is important to note that flow recordings represent the prevailing conditions of upstream land use, abstractions and discharges. A considerable amount of analysis is necessary to arrive at flow sequences representing natural conditions. Data has to be tested for consistency, missing data has to be "patched in", and the effects of development have to be removed.

This is an onerous task which was undertaken on a country-wide basis, first in 1969, updated in 1983 and again in 1994. The results of the most recent revision, known as Water Resources 1990, are available in a suite of 13 reports and the data is available on CD Rom for gauging stations and for quaternary and higher level sub-catchments.

Quaternary sub-catchments illustrated in Figure 5-1 were delineated according to a national system which takes account of variation in catchment conditions, the drainage pattern formed by the river system, features such as gauging stations and dams and a desire to limit the size of quaternary sub-catchments to a maximum of about 2,500 km^2. Care is taken to account for areas of blind drainage within sub-catchments. The 60 quaternary sub-catchments in the Study Area are listed in Table 5-1 together with relevant information on each.

The average naturalised runoff records for seven gauging stations listed in Table 5-2 illustrate the strong seasonality of streamflow in the Study Area. Naturalised flow records demonstrate this trend even more strongly. Abstraction and utilization of streamflow for any purposes whatever, has an immediate and significant impact on the low flow or base flow regime. The actual runoff in a stream is therefore significantly depleted by existing upstream development.

Utilization of streamflow in the Study Area has been developed to the extent that large storage dams have been built on virtually every main river to regulate the variable runoff to meet increasing water demands. This seriously affects runoff in the river system downstream of the storage facilities.

5.4 Resource Development

Ninety storage dams have been identified in the Study Area. Twenty two of these dams, those listed in Table 5-3, have a capacity of 1.0 mcm or more. Thirteen dams are in the category from 0.25 to 1.0 mcm, thirty two are in the range 0.1 to 0.25 mcm and twenty three are smaller than 0.1 mcm. The total storage capacity of all dams in the Study Area is approximately 909 mcm. The dams with larger than 1.0 mcm storage have a combined capacity of around 842 mcm, ie they compose 93 % of the total storage capacity available. From a water supply and utilization point of view, the numerous smaller dams are of lesser importance, however they do play a significant role as sources of water for private irrigation, stock-watering, recreation, and for pollution control and soil conservation.

Most of the major dams and virtually all of the minor farm dams in the Study Area were built for irrigation purposes. Water supplies from some of these dams were later reallocated for domestic use only but irrigation still predominates as a water use sector.

5.5 Water Use in Agriculture

The significant water use sectors in agriculture are stock-watering, irrigation and afforestation. Before reporting on the present situation regarding water use in these sectors it is appropriate to review the basis of water rights in the Study Area which, to a large degree, determines water use.

5.5.1 Water Rights

Water rights in the Study Area are determined by the current legal system in South Africa. The system is based on the principle of riparian rights to surface water where the agricultural use of water plays a dominant role in the allocation of resources. Surface water is generally classed as public water, the rights to which are attached to land riparian to the river in which it occurs.

The allocation of surface water resources for primary domestic use is usually based on the intervention of a Water Court or the State through the Minister of Water Affairs and Forestry. Groundwater, an important source for domestic use, is classed as private water at present where the owner of the land in question has sole discretion over its abstraction and use.

Much of the water used for domestic purposes in the Study Area is derived from Government Water Schemes developed by the State in terms of the Water Act, Act 54 (1956). An essential element of the provisions of the Water Act is that the Minister may declare Government Water Control Areas (GWCA) in the public interest which then enables the State to build water schemes to supply users which do not necessarily occupy riparian land. The Minister has the power to allocate water from such a Government Scheme for irrigation, domestic use or for any other purpose but he has to recognise existing rights.

If for instance, it is necessary to reallocate public water presently being used for irrigation, to domestic users, it will be necessary to compensate irrigators for the decreased availability of water. This implies that water rights are attached to the land and owners of the land are entitled to use these rights and to reap the benefits.

Since the role of Magalies Water is primarily to supply water for domestic use the sources of water would have to be one of the following:

(1) groundwater abstracted on land to which the community concerned has some right of ownership or tenure, eg state-owned, communal or tribal land, municipal land or privately owned land whose owner agrees to the use of the water (usually in return for some compensation);

(2) a Government Water Scheme where the State supplies water in bulk, eg the Loskop Government Water Scheme at Loskop Dam or the similar scheme at Roodeplaat Dam;

(3) a bulk water supplier such as Rand Water who has developed a source or who has bought water from the State eg from the Vaal River System at Vaal Dam; or

(4) a source developed by Magalies Water for their own use. Since the State is responsible for water resource development in South Africa, few such examples exist. For example Umgeni Water has almost sole access to a number of sources in the Mgeni River but most of the infrastructure is owned by the State.

It should be noted that South African water law is currently the subject of a fundamental review and water rights will probably be significantly affected in future. The preliminary indication is that access to water by the public will become more open in future and that the existing benefit of having access to rights in perpetuity to the disadvantage of others will be reduced.

The situation in the Study Area is such that competition for irrigation water has far outstripped the capacity of unregulated streamflow and major storage dams have been built by the State in virtually every significant river. In order for the State to build Government Water Schemes, and to enable the Minister to allocate the available supplies in an equitable way, it was necessary to declare a number of Government Water Control Areas.

Government Water Control Areas (GWCA) are proclaimed for one of the following reasons:

(1) In order to regulate the abstraction and use of public water for irrigation more strictly than is possible through the normal provisions of the Water Act, Act 54 of 1956. Institution of Government water control places an obligation on the Minister to determine and make known the actual water rights of each property in the GWCA.

(2) To enable the State to construct a Government Water Scheme in the control area and to supply water from the scheme in accordance with arrangements determined by the Minister. Water rights must at least be respected in these arrangements.

The following fourteen GWCA's, illustrated in Figure 5-2, are located in or adjacent to the Study Area:

- Rust de Winter Government Water Control Area
- Lindleyspoort Government Water Control Area
- Koster River Government Water Control Area
- Koster River Dam Catchment Government Water Control Area
- Hex River Government Water Control Area
- Buffelspoort Government Water Control Area
- Hartbeespoort Government Water Control Area
- Pienaars River Government Water Control Area
- Loskop Dam catchment Government Water Control Area
- Crocodile (West Transvaal) Government Water Control Area
- Loskop Government Water Control Area
- Magalies Government Water Control Area
- Scheerpoort Government Water Control Area
- Sterk River Government Water Control Area

It is important to note that water rights are determined by law and can only be exercised when the water is available. Since runoff in the Study Area is very variable, the reliability of supplies for irrigation has usually been improved considerably by the construction of storage dams to regulate the runoff. Areas irrigated form storage dams are either scheduled in a Government Irrigation Scheme or scheduled by an Irrigation Board.

5.5.2 Irrigation Boards

Irrigation Boards are established under the terms of the Water Act, Act 54 of 1956, to enable local representatives to operate and maintain communal water works such as dams, canals, pipelines and drainage systems and to regulate the distribution of the water available for irrigation. Irrigation Boards have also been established simply to regulate the abstraction of uncontrolled run-of-river, to build and operate communal water schemes and to regulate the use of water from Government Water Schemes. In each case irrigators pay a levy to the Board determined according to the area irrigated and set at a level sufficient to cover the costs of the Board. Management of this system is by way of a schedule of irrigated land on each property and payment of the levy entitles the irrigator to a share of the available water up to a maximum annual quota.

The following nineteen Irrigation Boards have been established in or adjacent to the Study Area and are shown in Figure 5-3:

* Bon Accord
* Buffelshoek
* Glyklip
* Hartbeespoort
* Scheerpoort
* Koster
* Krokedilrivier
* Kromdraai
* Modderfontein
* Olifantsnek
* Rietpoort
* Rietvallei-Weltevreden
* Rondavelskraal
* Twyfelpoort
* Vergenoegd
* Warmbad
* Bloempoort
* Trans-Elands
* Gouwsberg

5.5.3 Use of Groundwater for Irrigation

Groundwater in the Study Area is a significant resource which is currently used for both primary water supply and irrigation. Boreholes are an important source of water supply in large parts of the Study Area and the extent to which this source can be exploited in future has to be assessed.

The groundwater potential is based on hydro geological and geomorphological data and is discussed in Section 5.10.5.

On private farms (outside GWCA's) the area irrigated from boreholes varies according to the availability of surface water and groundwater. Groundwater is generally pumped into storage dams which are also supplied from surface water sources. It is therefore not always possible to clearly identify the water source. Satellite imagery has been used in the past but the results must be verified with spot checks on the ground. No such work was conducted for this Study.

Groundwater quality is an important consideration for primary use as well as in crop production and stock-watering. On the Rust de Winter GWS water quality problems are experienced with groundwater only. The farmers are of the opinion that these problems are due to the presence of fluorspar deposits in the ground which result in high concentrations of fluoride which have a detrimental effect on livestock. Groundwater quality issues are described in Section 5.10.7.

Considerable use is made of groundwater for irrigation in the eastern and western parts of the Study Area. In the Springbok Flats area adjoining Moretele 2, almost all water for irrigation is obtained from underground sources and since the onset of the drought in 1981, irrigators have been making increasing use of groundwater. The only available figures for groundwater abstraction for irrigation are those for the Springbok Flats basaltic aquifer (which falls outside the Study Area), which was estimated to be 40 mcm/a. The volume of groundwater abstracted is considered to have been balanced by recharge amounting to some 4.6% of the mean annual precipitation.

Two Government Subterranean Water Control Areas (GSWCA) are found in the Study Area, namely:

- Nyl Valley GSWCA
- Kroondal-Marikana GSWCA

These two GSWCA's were proclaimed for different reasons (irrigation and mining) but as with a GWCA, the water is already fully allocated to different users, who have a set quota based on the amount of water available and the chance that there is surplus water available for further development. Other users are therefore unlikely to obtain a quota.

5.5.4 Stock-Watering

Stock-watering and game ranching rely on a combination of surface water, springs and boreholes for water supply. Very little information is available on the growth in the livestock population or present carrying capacities of grazing land in the Study Area. Results of the latest livestock census (end of March 1995), from the Department of Agriculture on cattle, goats, sheep and pigs are given in Table 5-4. No data was available from the census concerning the part of the Study

Area within Mpumalanga but the livestock density was assumed to be similar to that in other rural parts of the Study Area.

According to the Olifants River Basin Study, the safe stock carrying capacity of the Olifants River catchment on the eastern side of the Study Area is 4 to 5 ha/large stock unit, except in the vicinity of the former Kwandebele where the capacity is 6 to 8 ha/large stock unit. In these areas the veld is over grazed and serious soil erosion occurs. The carrying capacity of the rest of the Study Area varies substantially because of the topography, climate and different land use practices but it is not expected to be more than 8 to 10 ha/large stock unit. Overgrazing problems are common. In the northern portions of the Study Area around Nylstroom and around Swartsruggens, game farming is common and the capacity could be as high as 3 to 4 ha/large stock unit.

The average daily water requirement for a representative large stock unit (LSU) is about 50 litres per day. A large stock unit is equivalent to one head of cattle or game, six sheep or goats, twelve pigs or one hundred chickens. The total population of equivalent large stock units in the Study Area is about 458,000 (384.942 head of cattle and game, 43,000 equivalent large stock units for sheep and goats and about 30,000 equivalent large stock units for Moutse). The total estimated present stock-watering requirements is thus about 8.36 mcm/a.

The RDP guidelines do not make specific provision for agricultural water demands but if meat production is to keep up with human population growth, the livestock population will have to grow proportionately. On the other hand, the safe stock-carrying capacity must be respected as a limitation. It is also important to note that in the rural areas livestock must be seen as part of the survival strategy of otherwise impoverished communities and that stock-keeping plays an important role in tribal culture. Stock-watering requirements cannot be ignored in the assessment of rural water needs.

5.5.5 Water Use in Irrigation

Irrigation is one of the biggest water uses in the country and is therefore a major factor in present and future water resource management in the Study Area. Many variables such as irrigation efficiency, irrigation technology, type of crops irrigated and crop management affect irrigation demand.

Irrigation in the Study Area is supplied from two sources, namely:

- Surface water sources (dams, canals, rivers)
- Groundwater sources (boreholes)

These two major sources can be further subdivided, from a management view-point, into areas which are subject to Government water control and those which are subject to the provisions of the Water Act.

Most of the major storage dams in the Study Area were originally built mainly for irrigation purposes (see Table 5-3 for a list of dams including those used for irrigation). In a number of cases their use has changed and some of the water is now used for domestic or industrial purposes. Most, if not all, minor dams (farm dams) are privately owned and were built for irrigation, for soil conservation purposes, for stock-watering or aesthetic reasons.

In most cases major dams are located in a GWCA and form part of a GWS from which water is allocated by the Minister of Water Affairs and Forestry for irrigation and for other purposes. Irrigation Boards (IB) are formed to manage the allocation of water from Government Schemes or from their own works. Irrigated land is scheduled either under a GWS or an IB.

Water for irrigation is usually released from a dam into the river or into a canal system from which the irrigators abstract their quota. Many of the minor dams in the Study Area were built for augmenting allocations from major schemes, particularly during drought periods when allocations from major dams are restricted. Irrigators also make use of balancing dams for storing water abstracted from a canal or river. They then irrigate on demand from these dams.

Private irrigation is not scheduled as described above and is usually served directly from a river.

A detailed review of the occurrence of irrigation in each of the tertiary sub-catchments in the Study Area is given below in respect of Government Water Schemes, Irrigation Board Schemes and Private Irrigation Schemes.

(1) Upper Crocodile River Sub-catchment A21

(a) *Government Water Schemes (GWS)*

The following four GWS's occur in this sub-catchment:

i) *Hartebeespoort Dam Government Water Scheme*

Hartebeespoort Dam on the Crocodile River, downstream of the confluence with the Magalies River, was built to supply water to irrigators on the Hartebeespoort Government Water Scheme. The dam supplies water through 540 km of canals. The Eastern canal has a capacity of 8.5 m^3/s and is 48 km long. The Western canal has a capacity of 8.5 m^3/s and is 56 km long. The Northern canal which is an extension of the Eastern canal has a capacity of 2.4 m^3/s and is 30 km long.

The total length of the secondary branch canals is 118 km and the tertiary canals 288 km.

A total of 16,218 ha is scheduled for irrigation on the Hartebeespoort Government Water Scheme. State canals supply 13,554 ha, the old private canals supply 2,800 ha and 374 ha is supplied directly from the dam. The maximum annual water quota is 6,200 m^3/ha, a total of 100.6 mcm/a.

Water is also supplied from Hartebeespoort Dam for domestic and industrial use, mainly through the Brits water supply scheme.

ii) *Roodekopjes Dam*

Klipvoor Dam, Vaalkop Dam and Roodekopjes Dam are managed as a system to optimise their yields.

Roodekopjes Dam, downstream of the confluence of the Crocodile and the Sterkstroom rivers, was completed in 1986. The primary purpose of the dam is to supply water to irrigators along the Crocodile River upstream of the confluence with the Pienaars River and to supply the domestic and industrial sectors to the north and west of the dam via Vaalkop Dam. The profile of the canal from Roodekopjes Dam to Vaalkop Dam is parabolic, 18.5 km long with a slope of 1:4 000 and a capacity of 4.0 m^3/s.

Klipvoor Dam, Vaalkop Dam and Roodekopjes Dam are managed as a system to supply water to irrigators in the Crocodile River (Western Transvaal) Government Water Control Area. The total scheduled area is 10,714.6 ha. Roodekopjes Dam supplies 1,833.2 ha on the Crocodile River which can only be commanded from this dam, and 1,847. 1 ha between the Elands River and the Pienaars River giving is a total of 3,680.3 ha. The annual quota is 8,000 m^3/ha for a maximum annual allocation of 29.4 mcm.

iii) *Buffelspoort Dam*

The Buffelspoort Dam was built to supply water to irrigators in the Buffelspoort Government Water Scheme. The dam is on the Sterkstroom River which is a tributary of the Crocodile River. Of the 1,938 ha scheduled for irrigation, only approximately 970 ha are irrigated at present. The balance of about 1,000 ha is on farms now used for mining purposes. About 6.4 mcm/a is committed.

The total area irrigated from GWS's is 20,893 ha with an annual quota of 136.55 mcm.

iv) *Middelkraal Dam*

This dam is on the Marikana River, which is a tributary of the Sterkstroom River. The dam was completed in 1966 and supplies water to the Middelkraal Government Water Scheme. An area of 103 ha is scheduled under the scheme but only 25 ha are irrigated because of mining activities. Very little water has been available from this dam since about 1985 and only about 155,000 mcm/a is committed.

The total area irrigated from GWS's is 20,893 ha with an annual quota of 136.55 mcm.

(b) *Irrigation Board Schemes*

Six Irrigation Boards listed in Table 3.2.2 in this sub-catchments and supply water from communal canals with the benefit of storage.

Table 5-5: Irrigation Boards in the Upper Crocodile Catchment

Board Name	Source of Water	Scheduled Area (ha)
Magalies N	Magalies River	187.8
Magalies S	Magalies River	193.3
Zeekoehoek	Magalies River	171.0
Kromdraai	Bloubankspruit	137.9
Sterkwater	Sterkstroom	164.0
Buffelshoek	Barnards River	144.0
Total		998.0

The total water used in Irrigation Board Districts is not recorded and is estimated to be about 6.9 mcm/a.

(c) ***Private irrigation schemes***

The Hartebeespoort Irrigation Act of 1914 (Act 32 of 1914) prohibits the construction of dams in the Hartebeespoort Dam catchment area but does allow abstraction of water from public streams (within the restrictions of Section 9B of the Water Act, 1956). In spite of this restriction, many small farm dams have been built in this sub-catchment, most of which are upstream of Hartebeespoort Dam. The estimated capacity of these dams is 17 mcm. It is estimated that about 9,058 ha are under private irrigation using up to 58 mcm/a. Much of this usage is from the Magalies and Scheerpoort Rivers.

(2) Elands River Sub-catchment A

(a) *Government Water Schemes*

Only four GWS's occur in this sub-catchment, namely:

i) *Crocodile River GWS*

Vaalkop Dam is managed as part of a system with Klipvoor Dam on the Pienaars River and Roodekopjes Dam on the Crocodile River. This dam is at the confluence of the Hex and Elands River and water is released for irrigation downstream of the dam along the Crocodile and Elands rivers.

A 4.0 m^3/s canal was constructed from Roodekopjes Dam to Vaalkop Dam in 1984 to augment supplies to the Magalies Water purification works at Vaalkop from where water is supplied as far north as Thabazimbi as well as towards the south and west for domestic, industrial and mining purposes.

Klipvoor Dam, Vaalkop Dam and Roodekopjes Dam supply water to the Crocodile River (Western Transvaal) Government Water Scheme area. The total area scheduled under this scheme is 10,715 ha. Vaalkop Dam supplies 340 ha along the Elands River, which can only be supplied by this dam, with a maximum annual water quota of 8,000 m^3/ha. Up to 2.7 mcm/a is supplied for irrigation.

ii) *Hex River GWS*

Bospoort Dam was originally constructed to supply water to Rustenburg and to the Bospoort Irrigation Board. In 1989 the dam was incorporated into the former Bophuthatswana and the Government Water Control Area was deproclaimed. Since then no water is released for irrigation and all the water available is used for domestic, mining and industrial purposes.

iii) *Elands River GWS*

Lindleyspoort Dam on the Elands River was built in 1938 to supply water to irrigators in the Lindleyspoort Government Water Control Area by means of canals. The dam supplies a scheduled area of 1,587 ha with an annual water quota of 5,300 m^3/ha, ie a maximum of 8.4 mcm/a.

A total of 1,927 ha is irrigated from GWS's in this sub-catchment and receives a quota of 11.1 mcm/a.

iv) *Koster River Dam*

This dam is on the Koster River and supplies the Koster River GWS. An area of 541 ha is scheduled with an annual quota of 5,300 m^3/ha/a. The maximum annual allocation is thus 2.87 mcm.

(b) *Irrigation Board Schemes*

Four Irrigation Boards listed in Table 3.2.3 occur in this sub-catchment and supply water from their own communal dams or from spring-fed sources.

Table 5-6: Irrigation Boards in the Elands River Catchment

Board Name	Source of Water	Scheduled Area (ha)
Olifantsnek	Olifantsnek Dam	1,459.7
Modderfontein	Springs	87.3
Glyklip	Waterkloofspruit	81.3
Total		**1,628.3**

No records exist of the water available for irrigation in these irrigation districts but extreme shortages have been experienced over the last 10 years. In years of good runoff it is estimated that about 16 million mcm/a will be used.

(c) *Private irrigation schemes*

Best available information indicates that about 2,710 ha are irrigated in private schemes, often with the use of small dams. Treated effluent from Rustenburg is discharged to the Hex River where it is reused for irrigation at Paardekraal. It is estimated that about 15 million mcm/a would be used when water is available while only about 4.5 million mcm/a is available on a regular basis.

(3) Pienaars River Sub-catchment A23

(a) *Government Water Schemes (GWS)*

Only two GWS's occur in this catchment, namely:

i) *Crocodile River GWS*

Klipvoor Dam on the Pienaars River downstream of Roodeplaat Dam was completed in 1970. The purpose of the dam is to supply water to irrigators along the Pienaars and Crocodile Rivers in the Crocodile River (Western Transvaal) Government Water Control Area. The total Area scheduled is 10,715 ha. Klipvoor Dam supplies 6,695 ha with a maximum quota of 8,000 mcm/ha. Up to 53.6 million mcm/a is supplied for irrigation.

ii) *Pienaars River GWS*

Roodeplaat Dam on the Pienaars River was constructed in 1959. It supplies water to the Pienaars River Government Water Scheme and to Magalies Water purification works at Wallmannsthal and Temba. The irrigation canal has a capacity of 1.0 mcm/s and served a scheduled area of 880 ha with a water quota of 6,500 mcm/ha/annum. The maximum volume supplied for irrigation is therefore 5.7 million mcm per annum. The area scheduled has since decreased to 750 ha but the quantity of water available is unchanged.

A total of 7,445 ha is irrigated from GWS's using a total of 59.5 million mcm/a when a full quota is available.

(b) *Irrigation Board Schemes*

The two Irrigation Boards listed in Table 3.2.4 Occur in this catchment and both supply water from their own storage dams.

Table 5-7: Irrigation Boards in the Pienaars River Catchment

Board Name	Source of Water	Scheduled area (ha)
Bon Accord	Bon Accord Dam	966
Warmbaths	Bischoffs Dam	231
Total		**1,197**

No reliable records of water use in these irrigation districts are available but the sources of water are reasonably reliable and supply about 11 mcm/a.

(c) The information available indicates that private schemes account for most of the water used in the Pienaars River sub-catchment with about 5,197 ha under irrigation, mostly form the Apies and the Pienaars Rives and some of their tributaries. No information is available on water used by private irrigation schemes but this is estimated to be about 52 mcm/a in years of good runoff.

(4) Lower Crocodile Sub-catchment A24

A large portion of the Crocodile River GWS is located in this catchment but irrigated from upstream storage in Roodekopjes, Klipvoor and Vaalkop Dams described above. A total of 10,714 ha is irrigated from this three dam system on the GWS schedule. In addition an area of 3,840 ha is scheduled for irrigation from the alluvial aquifer along the river. This groundwater source is fed from streamflow so all water abstracted from the system is deemed to be from storage and accounts for about 31 mcm/a.

The total area irrigated with water abstracted in this sub-catchment is 6,699 ha which uses about 63 mcm/a.

Private irrigation in this catchment includes 200 ha from the Sand River, 16 ha from the Bierspruit and 2,643 ha from the Crocodile River at Makoppa giving a total area of 2,859 ha. It is estimated that 32 mcm/a is used for this irrigation.

(5) Tributaries of the Olifants River in Sub-catchments B20, B31 and portion of B32

(a) *Government Water Schemes (GWS)*

No GWS falls within this area.

(b) *Irrigation Boards*

The three Irrigation Boards listed in Table 3.2.5 occur in this catchment. Only Bloempoort is included as a water demand because its abstraction point is within the Study Area.

Table 5-8: Irrigation Boards in the Olifants River Sub-catchments (B20, B31 and a portion of B32)

Board Name	Source of Water	Scheduled Area (ha)
Bloempoort	Moses river and canal	340
Trans-elands	Elands River	832
Gouwsberg	Loskop Dam	1,267
Total		**2,439**

The quota is 7,700 mcm/ha/a which gives a maximum of 2.6 mcm/a being used for irrigation.

(c) *Private irrigation schemes*

The best available information indicates that about 740ha are irrigated in private schemes. It is estimated that about 7.2 mcm/a would be used by private irrigators.

(6) Summary

Use of water for irrigation has been evaluated by sub-catchment and in respect of Government Water Schemes, Irrigation Board Schemes and Private Irrigation Schemes. A summary of the estimated water usage is given in Table 5-9.

5.6 Water Availability

Due to the semi-arid nature of the Study Area storage is necessary to ensure that reliable water supplies are available to meet needs for domestic use and industry, irrigation and other uses. The small amount of forestry in the area is obviously rain fed and stock-watering is dependent on springs, boreholes and run-of-river flow. Groundwater is a major source of water for domestic use in the Study Area at present.

The major storage dams listed in Table 5-3 have a total capacity of about 1,161 mcm and a MAR of 790 mcm; if the Crocodile basin is considered, the storage capacity of 516 mcm exceeds the MAR of 494 mcm. It is important to note that three of the main dams, namely Roodekopjes, Vaalkop and Klipvoor, are operated as a system and that the their combined yield is dependent on the way in which Rietvlei, Hartebeespoort and Roodeplaat Dams are operated. Furthermore, the reliability or security of supplies has a strong influence on the available yield.

The total quota for existing irrigation of 584.6 mcm/a given in Table 5-9, alone exceeds the total estimated yield in the Study Area without taking cognisance of other uses. In practice most of the domestic and industrial needs in the Study Area are supplied with water imported from external sources and much of the irrigation development is subject to severe periodic shortages as it is supplied at a lower level of reliability.

It is important to note that options are available for reallocation of supplies between user sectors from existing major dams.

5.7 Afforestation

The Study Area is located in a semi-arid to arid part of the country with predominantly summer rainfall. Average annual rainfall varies from 414 to 674 mm. The climatic conditions are not ideal for forestry and the expansion of afforestation is most unlikely.

It is estimated that about 30 to 120 mm/ha/a reduction in run-off occurs in forested areas. Most plantations in the Study Area are privately owned and no commercial forestry exists. The largest areas of forest are in the Olifants River sub-catchment. The present extent of forest development and water used is given in Table 5-10.

5.8 Urbanisation

Urban development has a big influence on the run-off and return flows to the system and has a highly significant effect on the yield of several dams in the Study Area. These highly modified run-off patterns will change the calculated MAR figures for the dams and proper model studies to simulate these conditions are necessary to be able to accurately determine the existing water resources's potential.

Most of the upper Crocodile River sub-catchment which includes Pretoria and Johannesburg is urbanized. These areas form part of the catchment for Hartebeespoort Dam which is a big source of irrigation water and regulates the yield of several other important dams further downstream.

Urbanisation is considered in more detail for the purpose of the water balance model in Section 5.4.2 of Supporting Report E.

5.9 Interbasin Transfers

Since the establishment of Pretoria and Johannesburg in the 1860's , water demand for domestic, industrial and mining use in the Study Area has grown steadily. In spite of a policy of utilizing local water sources before developing supplies from further away, it soon became necessary to import water, mainly for use in the Pretoria area but also for mining use near Rustenburg.

Approximately 500 mcm/a is imported from the Vaal River Supply System by Rand Water and supplied to Pretoria, Ga-Rankuwa and Mabopane and to Rustenburg and the platinum mines along the Bushveld Igneous Complex via the Barnardsvlei Scheme.

5.10 Water Requirements for the Environment

Ecosystems, mainly in and along rivers in the Study Area, require water for their maintenance. Although these water requirements are not defined and protected in South African legislation it is generally accepted that water resource planning and development must take account of public interest in environmental systems. Principles of Integrated Environmental Management are now commonly followed in water resource planning where so called Relevant Environmental Impact Prognoses (ROIP) are prepared.

One of the main outcomes of environmental investigations in water resource planning is the need for assessing and providing for Instream Flow Requirements (IFR). These assessments involve a complex process requiring a multi-disciplinary team of specialists and can only focus on a particular river or section of a river. No generalised information is available on IFR's which are essentially site specific and dependent on factors such as the present conservation status of the rivers and management objectives for future conditions.

IFR's are usually expressed as a flow regime, ie minimum flow rates and flood events, for extremely dry seasons and for maintenance conditions in more average years. Water must be present in the river system to satisfy IFR's and is mostly non-consumptive with losses only to seepage and evapo-transpiration.

Rivers in the semi-arid Study Area are mostly ephemeral in natural conditions, ie periods of no flow are common under natural conditions. It is well know that the original river regime has significantly changed as a result of the extensive volume of storage in the system, abstractions for various uses and return flows of treated wastewater, the origin of much of which was imported from neighbouring catchments.

It is not possible to make general estimates of water requirements for environmental systems but it can safely be said that the availability of water from any new development proposals would probably be limited by these considerations. Between 12% and 20% of the mean annual runoff (MAR) has been found to be necessary for IFR's in some other rivers in South Africa. The use of river channels as conveyances for water supplies from sources such as dams to demand centres such as irrigation schemes or water treatment plants could, to some extent, satisfy IFR's. Regulated releases into rivers could also have a negative effect on ecosystems if, for instance, there is insufficient variability of flow.

5.11 International Commitments

Rivers in the Study Area are all tributaries of systems which cross or form international boundaries. Neighbouring states therefore share a common interest in the water resources with the RSA. These interests are recognised in international law but are not specified or quantified in treaties or agreements. Principles involved in formulating treaties between co-basin states have been codified in the so-called Helsinki Rules.

In the absence of specific requirements for cross-border flows in international treaties, it is not possible to define the water requirements for this purposes. However, it is usual practice for States to advise their co-basin neighbours of water resource development proposals and sometimes to undertake joint investigations such as the Joint Upper Limpopo Basin Study (JULBS) initiated some years ago by the RSA and Botswana.

5.12 Geohydrology

5.12.1 Borehole Statistics

For the purpose of this Study, a consolidated database was constructed for groundwater in the Study Area. This brought together information from several sources as follows:

(1) HydroCom Database of the former Bophuthatswana Department of Water Affairs;

(2) National Groundwater Database created for DWAF by the Institute for Groundwater Studies at Free State University which is operated and managed by the DWAF Directorate of Geo-hydrology;

(3) National Water Quality Database which is also operated and managed by the DWAF Directorate of Geo-hydrology; and

(4) Hydrocensus undertaken by VSA Earth Scvience Consultants for EVN in the former Kwandebele which is also stored in the HydroCon database.

Salient statistics in regard to the consolidated groundwater information are presented in Table 5-11. This information is contained in the hydro-geological database compiled for the purposes of this Study. The spatial distribution of this data is shown together with other pertinent information on the groundwater Maps included in the Data Book.

The statistics presented in Table 5-11 indicate a serious shortcoming in the database in that there are a large percentage of boreholes for which information regarding status and equipment does not exist. This deficiency cannot be easily or cheaply rectified and would require at least a reconnaissance type hydro-census to effect an improvement. Relevant conclusions which can be drawn from the statistics are summarized as follows:

(1) Almost 50% of the boreholes for which depth information is available are less than 60 m deep;

(2) Only 17% of the boreholes for which yield data is available can deliver more than 2 l/s;

(3) The borehole success rate, based on the percentage of boreholes yielding more than 0.1 l/s, is moderate at 62%;

(4) As a corollary to item (c), the failure rate is comparatively high at 38%;

(5) The depth to groundwater rest level is less than 30 m in 85% of the boreholes for which information is available;

(6) Quality restrictions on potability due to excessive nitrate or fluoride concentrations is nearly equally distributed between the number of boreholes for which data is available; and

(7) A very low percentage of boreholes (5%) suffer potability restrictions due to excessive concentrations of both nitrate and fluoride.

5.12.2 Groundwater Characterization

Following the work of Vegter (1995) and Water Systems Management (1995), the characterization of groundwater occurrence in the Study Area recognizes both primary and secondary aquifers representing four hydro-geological regimes. These are identified as follows:

(1) Intergranular regimes

These are represented by Quaternary deposits comprising unconsolidated to semi-consolidated alluvial deposits (sand and gravel). The hydro-geologically more significant of these are found mainly along the more mature lower courses of the major rivers.

(2) Weathered-and-fractured regimes

These are represented by pores in disintegrated or decomposed to partly decomposed rock above fractures which are principally restricted to a zone directly below groundwater level. Both the compact igneous and sedimentary rocks (excluding dolomite and limestone) within the Study Area can be associated with these regimes.

(3) Fractured regimes

The fractured regimes are characterized by the presence of fractures restricted principally to a zone directly below groundwater level. Their occurrence in the Study Area can again be associated with compact igneous and sedimentary rocks.

(4) Karst regimes

These regimes are generally represented by dolomite and limestone formations in which a secondary porosity has been developed by mechanisms such as chemical dissolution resulting in the formation of openings varying in size from fissures to extensively developed caves.

5.12.3 Groundwater Exploration

The scientific exploration of groundwater resources in the Study Area has relied extensively on various geophysical techniques. Early exploration activities utilized primarily the direct current (DC) electrical resistivity and the magnetic techniques. These methods were and still remain suitable for identifying variations in the electrical resistivity of lithologies in depth and the presence of magnetically susceptible structures respectively. Whereas the magnetic technique still represents the most widespread geophysical exploration method in use, the DC technique has largely given way to the electromagnetic technique. This is attributed to the better detection capabilities of narrow fracture systems and the greater speed of execution which the latter technique generally enjoys over that of DC surveys. It is suggested that the deep (>500 m) electromagnetic sounding capability offered by the Geometrics Stratagem instrument might prove extremely valuable in locating deeper-seated aquifers in the Study Area.

The geophysical methods of exploration have further been augmented by remotely sensed data in the form of aerial photographs, satellite images (eg. Landsat and SPOT) and airborne geophysical surveys such as radiometric and magnetic data (held by the Council for Geoscience). Of these, aerial photograph interpretation (API) probably enjoys the greatest application. This is due mainly to the ready availability and comparatively low cost of these images in conjunction with the better resolution (scale factor) which they offer. The more direct method of investigation such as the drilling of exploration boreholes is rarely exercised. Certainly, this option is never exercised in regard to small scale community water supply projects due primarily to the cost. Such activity, however, is warranted and has been exercised where the development of groundwater resources on a larger scale such as for municipal or town water supply has been undertaken.

5.12.4 Groundwater Occurrence

The groundwater drainage pattern in the Study Area generally represents a muted version of the surface water drainage pattern. Depth to groundwater level across the Study Area is shown on a map included in the Data Book.

Recharge in the southern Springbok Flats area is estimated by Nel (1992) at 2.7% of the total annual rainfall. At Warmbaths, the mean annual recharge is estimated at 7% of the MAP by Taylor (1980). Fayazi (1994) recognizes a recharge figure of 4.6% for the northern Springbok Flats, this figure decreasing to some 2% in the west in sympathy with lower mean annual precipitations. In light of the above, it is reasonable to presume that the annual recharge from rainfall averages some 3% of the MAP across the Study Area.

The storativity (storage coefficient) of groundwater bearing formations in the Study Area varies through three orders of magnitude. The intergranular regimes are generally considered to possess the greatest storativity values (>1 %). The weathered-and-fractured groundwater regimes can reasonably be expected to possess storativity values in the order of 1% to 0.1%, whilst those of fractured regimes are generally <0.1%.

An indication of the potential volumes of groundwater held in storage is provided by the following examples. At Warmbaths, the estimated available storage potential of the basalt aquifer underlying the municipal property Het Bad 465KR (area 7 km^2) amounts to 2.5 mcm (Taylor, 1980). The basaltic aquifer of the northern Springbok Flats is estimated to hold some 2,900 mcm of groundwater in storage over an area of 1,508 km^2 (Fayazi, 1994). An analysis of borehole yield information contained in the hydro-geological database indicates a wide variation in this parameter. The variation is related to the widely differing hydraulic properties of rock types locally and the nature of the associated groundwater regimes. In the primary alluvial aquifer adjoining the Crocodile River, boreholes capable of yielding in excess of 20 l/s are not uncommon (Hobbs, 1983). Foster (1983) reports that successful boreholes yielding in excess of 2 l/s at Nylstroom are associated with zones of deep weathering on a wide igneous intrusion. At Warmbaths, boreholes tapping the basaltic aquifer are capable of yielding in excess of 10 l/s (Taylor, 1980). The dolomite formations occurring the Study Area are not known to be extensively karstified and therefore are not considered to represent major potential sources of groundwater.

5.12.5 Groundwater Harvest Potential

The sustainable yield of groundwater resources, ie. the groundwater resource potential, within the Study Area is gauged on the basis of the Harvest Potential Map (included in Section 2.1 of the Main Report) to be in the order of 488 mcm/a as shown in Table 5-12.

The groundwater harvest potential map derives from work undertaken by Seymour (1995), the basis of which is contained in a report titled "Explanation Report for the Groundwater Harvest Potential Map of South Africa 1995". The calculation of the Groundwater Harvest Potential entails a number steps which are summarised as follows:

(1) Interpolation of calculated point values of mean annual recharge to areas which identify aquifer systems and then calculating the mean annual volume of recharge per unit area. This value is made equivalent to and assigned the term recharge abstraction (RA).

(2) Estimation of the available storage (AS) of each aquifer system based on model theory applied to strike frequency analysis and average storativity values for the given rock type.

(3) Calculation of storage time (ST) of each aquifer system calculated as the quotient of available storage (AS) and recharge abstraction (RA), ie. ST = AS/RA.

(4) Calculation of the drought deviation (DD) represented by the ratio of the 20th and the 50th (median) percentile values of annual precipitation, eg. if the 20th percentile precipitation per year = 400 mm and the 50th percentile precipitation per year = 610 mm then DD = 400/610 = 0.66.

(5) Calculation of the minimum recharge (MR) as the product of the recharge abstraction (RA) and the drought deviation (DD), eg. if RA = mean annual recharge = 30 mm/yr and DD = 0.66 then MR = 30 x 0.66 = 20 mm/yr.

(6) Calculation of the sustainable yield, harvest potential or safe abstraction (SA) as the product of the minimum recharge (MR) and the storage time (ST), ie. SA = MR x ST.

In order to classify groundwater quality, DWAF have the following classification:

Class 0 :	Ideal water quality; suitable for lifetime use;
Class 1 :	Good water quality; rare instances of negative effects;
Class 2 :	Water safe for short term use only; common instances of negative effects with long term use;
Class 3 :	Unacceptable water quality for domestic use; unsuitable domestic use

without treatment: consider use for livestock watering; and

Class 4 : Unacceptable water quality for domestic use and stock-watering purposes; unsuitable for domestic use without treatment.

Based on the groundwater database, the likely quality across the Study Area is shown in Figure 5-4 according to this classification.

If the 88 mcm of groundwater which is subject to adverse quality considerations (Class 2, 3 and 4 water) is subtracted, then the total sustainable yield or harvest potential reduces to some 400 mcm. It is not unreasonable to regard 30% (120 mcm) of this volume as exploitable.

5.12.6 Groundwater Utilization

The current magnitude of groundwater resource utilisation within the Study Area is estimated to be in the order of 20 mcm/a. This figure includes all classes of water quality. Areas which can be singled out as supporting the bulk of this utilisation are, in the Eastern Zone, Moretele 2 area (1.24 mcm); in the Central Zone Warmbaths/Nylstroom (1.10 mcm), and Klipvoor (1.82 mcm) areas; and in the Western Zone the Thabazimbi area (12.40 mcm).

It is evident that the estimated 20 mcm currently utilised represents only 17 % of the 120 mcm considered to be sustainably exploitable. This comparison indicates that considerably more groundwater is available than is currently being utilised.

Groundwater resources in the Study Area are utilized for potable water supply to rural communities, for stock-watering purposes, irrigated agriculture and, in a few instances, for urban water supply. It is extremely difficult to quantify the volume of groundwater abstracted for potable water supply to rural communities (although an estimate is included in the water demand projection), and for stock-watering purposes. With regard to irrigated agriculture, partly reliable figures are only available for those areas where such activities and the groundwater exploitation for this purpose are concentrated geographically.

5.12.7 Restrictions on Groundwater Utilisation

These comprise aspects related to the regional and local distribution of groundwater resources in terms of their accessibility, exploitability and quality. It is clearly understood that the development of groundwater resources is strongly influenced by the spatial distribution of "low", "medium" and "high" harvest potential areas.

(1) Groundwater Quality

A large proportion of the population within the Study Area is currently wholly reliant on groundwater for domestic water supply, especially communities in more rural areas away from the large population centres. Due to the relatively shallow nature of many of these boreholes, they are vulnerable to bacteriological and chemical pollution, especially from poor sanitation. Basic pit latrines are the predominant form of domestic sanitation, especially in rural areas, and offer no protection against such pollution.

The most important detrimental factors influencing the potability of groundwater are excessive concentrations of the elements nitrate (N) and fluoride (F). The SABS 241-1984 standard sets recommended acceptable limits of 6 mg/l N for nitrite and nitrate and 1.0 mg/l for fluoride with maximum permissible limits of 10 mg/l N and 1.5 mg/l F respectively.

Maps produced by the WRC of DWAF in 1995 for groundwater quality show areas of nitrate risk, (concentration exceeding 10 mg/l as N nitrite/nitrate in more than 20 % of analysed samples), and fluoride risk, (concentration exceeding 1.5 mg/l as F in more than 20 % of analysed samples), for the entire country. Most of the Study Area is shown to be subject to these high nitrate levels and localized pockets are subject to fluoride risk (the Pilanesberg area, northern parts of Brits and Odi 1 Districts and eastern parts of Bronkhorstspruit District and Kwandebele).

A report to the WRC produced by CSIR, "A Preliminary Investigation of the Nitrate Content of Groundwater and Limitation of the Nitrate Input", (WRC Report No 368/1/93), utilized data from the DWAF database and found that higher levels of nitrate (greater than 20 mg/l but in most cases greater than 50 mg/l) mostly occurred in five areas of the country. Boreholes along the Crocodile River formed one such area and the Springbok Flats area (immediately north of Moretele 2) was another. High nitrate levels in these two locations are mostly due to anthropogenic activities ie due to contamination from poor sanitation, sewage disposal (untreated), solid waste disposal to landfill, livestock and other pollution sources and are characterized by locally high nitrogen levels in the proximity of the source of pollution. The report recommended a dual approach to reduce nitrogen inputs using regulatory control measures and a programme of publicity. In addition it was recommended that long-term trends be monitored, vulnerable areas delineated and that further studies concentrate on mechanisms of natural nitrate accumulation and on the nitrate problem. Studies by Fayazi (1994) indicate that excessively high nitrate concentrations (±53 mg/l N) are to be found in groundwater from the basalts of the Letaba Formation in the northern Springbok Flats.

A paper presented at the conference Groundwater '95 held in Midrand in September 1995, "Distribution and Cause of High Fluoride Groundwater, Western Bushveld, South Africa" by LP McCaffrey, JP Willis and RT Watkins of the University of Cape Town, addresses the levels of fluorides over most of the Study Area. Dental fluorosis is endemic in the area with between 80,000 and 110,000 people thought to be adversely affected. The Pilansberg Alkaline Igneous Complex and the Nebo and Lebowa Granites have consistently high fluoride concentrations in excess of 3 mg/l and is attributed primarily to the dissolution of fluorite and chemical weathering of fluoride-bearing material. The sporadic occurrence of high fluoride levels in the Karoo sediments toward the east is ascribed to deep boreholes which penetrate through these rocks into the underlying granites. Recent work by Fayazi (1985 and 1995), addressed, amongst other things, high-fluoride and high-nitrate groundwater in the northern Springbok Flats area.

Both authors recognize that the quality of groundwater in respect of nitrate and fluoride is substantially dependant on the rock type.

The database compiled for this Study contains 4,875 hydro-geochemical analyses which address the full spectrum of macro elements (major cations and anions plus nitrate, fluoride, electrical conductivity and pH) In terms of physical properties, based on electrical conductivity (or TDS) values, the ambient quality of groundwater in the Study Area might be classed as good. This is based on 46% (2,220 out of 4,875) of the chemical analyses exhibiting electrical conductivity values of less than 70 mS/m, which value meets the recommended acceptable limit set for this parameter by the SABS 241-1984 Specification for Water for Domestic Supplies. Further, a total of 4,643 samples (95%) have electrical conductivity values which meet the maximum permissible limit of 300 mS/m set by this standard. These observations match that of Vegter (1995), who indicates that the TDS value of groundwater in the region falls in the range < 1,000 mg/l. The distribution of areas with electrical conductivity, fluoride, chloride and nitrate values is shown on a map in the Data Book. The likely groundwater quality according to the DWAF classification for the Study Area is shown in Figure 5-4. Vegter (1995) further identifies Type A ($Ca+Mg/Cl+SO_4$) and Type B ($Ca+Mg/HCO_3$) groundwaters as the dominant hydrochemical types in the Study Area.

It is extremely important to recognise the fact that groundwater quality might vary considerably from locality to locality even within a relatively small area. The zones of poorer quality water indicated on the Harvest Potential Map must, therefore, not be seen to represent areas within which all groundwater is of an unacceptable quality. Similarly, areas which are shown to support an acceptable quality of groundwater almost certainly include site specific occurrences of unacceptable quality groundwater. This is illustrated in the Groundwater Quality Map in the Data Book.

(2) Groundwater Accessibility

This property relates to the probability of sinking a borehole with a yield of greater than 0.1 l/s (Vegter, 1995). This information is shown on the map showing Potential Village Water Supply from Groundwater which is included in the Data Book from which it appears that:

(a) groundwater accessibility is more favourable (range > 60%) in the east rather than the west of the Study Area; and

(b) the greater portion of the Study Area has a borehole accessibility in the range 40% to 60%.

(3) Groundwater Exploitability

This property relates to the probability of sinking a borehole with a yield of greater than 2.0 l/s (Vegter, 1995). This information is also shown on the map showing Potential Village Water Supply from Groundwater which is included in the Data Book from which it appears that:

(a) a small area south of Warmbaths in the north-eastern corner of the Study Area represents the only portion where the groundwater exploitability is better than 50%; and

(b) the greater portion of the Study Area has a groundwater exploitability of between 20% and 30%.

(4) Borehole yield

The yield for proposed boreholes is estimated primarily from Figure 5-5, Borehole Yield. The Potential Village Water Supply from Groundwater map also provides an indication of the exploration area and the number of boreholes required for each village community, should groundwater development be a feasible option.

(5) Borehole location

If groundwater is a viable option for medium term planning then it is anticipated that boreholes will have to be located outside of villages because of the expected groundwater contamination which will most likely occur if located within the village. For planning purposes it will be assumed that the boreholes must be located 1km outside of the village boundary. In the case of multiple boreholes a distance of 500 m apart will also be assumed.

Table 5-1: Quaternary and Tertiary Catchment Information (1/3)

Catch-ment	Gross Area (km^2)	Net Area (km^2)	Forest Area (km^2)	Irrig. Area (km^2)	MAE (mm)	MAP (mm)	MAR (mm)	Net MAR (mcm)	Gross MAR (mcm)	Dams
A21A	482	482		9.4	1,700	684	34	16.2	16.2	$
A21B	527	527		5.2	1,700	672	19	10.0	10.0	$
A21C	761	761		1.8	1,700	682	49	37.3	37.3	$
A21D	372	372		8.2	1,700	714	56	21.0	21.0	$
A21E	290	290		13.1	1,700	707	55	15.8	15.8	
A21F	1001	852		37.1	1,700	677	25	21.3	25.1	
A21G	160	160		3.1	1,700	694	82	13.2	13.2	
A21H	514	514		8.8	1,700	668	36	18.7	18.7	$
A21J	1151	1151		32.2	1,700	637	19	21.5	21.5	$
A21K#	865	865		5.0	1,700	651	37	31.9	31.9	$
A21L	213	213		21.6	1,750	589	12	2.7	2.7	$
A21	6336	6187		145.6	1,702	667	33	209.5		
A22A	707	673		2.3	1,800	604	21	14.0	14.7	$
A22B	284	284		2.8	1,800	599	20	5.7	5.7	$
A22C	515	515		.6	1,750	611	16	8.3	8.3	
A22D	542	542		6.0	1,800	582	15	7.9	7.9	
A22E	813	813		7.7	1,800	597	16	13.2	13.2	
A22F	1690	1690			1,800	604	16	27.6	27.6	
A22G	499	499		1.9	1,700	656	23	11.7	11.7	$
A22H	579	579		.8	1,700	658	24	13.7	13.7	$
A22J	592	592		3.4	1,750	600	17	10.1	10.1	$
A22	6221	6187		25.5	1,774	610	18	112.3		

Catch-ment	Gross Area (km^2)	Net Area (km^2)	Forest Area (km^2)	Irrig. Area (km^2)	MAE (mm)	MAP (mm)	MAR (mm)	Net MAR (mcm)	Gross MAR (mcm)	Dams
A23A	682	682		15.0	1,750	698	42	28.8	28.8	$
A23B	814	814	1	2.7	1,800	645	19	15.8	15.8	
A23C	491	491		2.9	1,800	574	8.8	4.3	4.3	
A23D	145	145			1,750	706	115	16.7	16.7	
A23E	490	490	3	23.6	1,750	674	29	14.3	14.3	$
A23F	565	565		1.7	1,800	596	10.1	5.6	5.6	$
A23G#	952	952		3.3	1,750	591	17	16.3	16.3	$
A23H	1,058	1,058		3.2	1,750	600	11	11.9	11.9	
A23J	931	931		2.9	1,750	585	9.8	9.1	9.1	
A23K	1,131	1,131		2.0	1,750	606	13	14.8	14.8	$
A23L	329	329		7.7	1,750	604	13	4.2	4.2	$
A23	7,588	7,588	4	65.0	1,762	617	19	141.7		
A24A	493	493		21.8	1,750	599	14	7.1	7.1	$
A24B	709	709		28.2	1,750	617	17	11.7	11.7	$
A24C	802	802		50.4	1,800	589	9.6	7.7	7.7	$
A24D	1,328	1,262			1,850	600	12	14.8	15.5	
A24E	688	688			1,800	592	11	7.9	7.9	
A24F	591	461			1,800	602	13	5.8	7.4	$
A24G	736	736			1,700	645	28	20.6	20.6	$
A24H	1,339	1,058		12.6	1,750	639	34	36.0	45.6	$
A24	6,686	6,209		113.0	18.13	592	18	111.5		

Catch-ment	Gross Area (km^2)	Net Area (km^2)	Forest Area (km^2)	Irrig. Area (km^2)	MAE (mm)	MAP (mm)	MAR (mm)	Net MAR (mcm)	Gross MAR (mcm)	Dams
A61A	381	381		5.5	1,700	629	49	18.7	18.7	$
A61B#	362	362		2.7	1,700	618	35	12.7	12.7	
A61C#	587	362		3.5	1,741	608	21	9.2	12.6	$
A61	1,330	1,105		11.7	1,710	620	37	40.6		
B20A	574	574		3.1	1,650	661	38	21.7	21.7	
B20B	322	322		3.1	1,700	667	37	11.8	11.8	
B20C	364	364		2.7	1,700	675	38	13.9	13.9	$
B20D	480	480		7.7	1,750	677	36	17.3	17.3	
B20E	620	620		9.0	1,650	657	34	21.0	21.0	$
B20F	504	504		8.0	1,700	667	33	16.8	16.8	
B20G	522	522		4.6	1,700	669	44	23.0	23.0	$
B20H	563	563	1	5.3	1,750	671	42	23.4	23.4	$
B20J	407	407		12.7	1,800	696	44	18.0	18.0	
B20	4,356	4,356	1	56.2	1,708	670	38	166.9		
B31A	387	387	7	4.8	1,750	677	35	13.6	13.6	$
B31B	385	385		5.7	1,800	640	26	9.9	9.9	
B31C	373	373		1.0	1,800	607	21	7.8	7.8	
B31D	558	558			1,800	599	20	11.0	11.0	$
B31E	1,382	1,104			1,800	588	7.8	8.6	10.7	$
B31F	638	589			1,850	568	6.7	3.9	4.2	
B31G	433	433			1,850	604	20	8.6	8.6	
B31H	612	612			1,900	575	15	9.3	9.3	
B31J	1,380	459		13.5	1,900	552	5.9	2.7	8.1	$
B31	6,148	4,900	7	25.0	1,838	589	12	75.4		

Table 5-2 Naturalised Average Monthly Specific Runoff (mcm/km^2)

Station No	River	Locality	Catchment (km^2)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A2H012	Crocodile	Kalkheuwel	2,551	2,066	3,673	4,300	5,731	6,597	4,575	2,805	2,321	2,132	1,074	1,556	1,631
A2H021	Pienaars	Buffelspoort	7,483	870	1,553	2,051	4,236	2,800	1,785	1,640	1,203	633	628	487	445
A2H032	Selons	Moedwil	522	268	307	1,034	2,567	2,816	1,839	1,130	249	57	57	57	77
A2R006	Hex	Bospoort	1,080	500	861	2,222	3,963	6,787	5,944	2,333	1,472	703	667	426	407
A2R015	Crocodile	Roodekopjes	6,129	1,692	2,597	2,907	7,083	4,488	3,953	3,459	2,547	1,844	1,689	1,886	1,878
B2R001	Bronkhorstspruit	Bronkhorstspruit	1,263	2,462	3,357	5,186	9,739	6,841	4,014	2,399	1,568	1,045	1,281	990	1,219
B3R001	Elands	Rust de Winter	1,147	1,186	2,851	3,714	4,586	4,595	2,781	2,153	1,351	1,003	898	758	741

Naturalised Average Monthly Specific Runoff in the Study Area

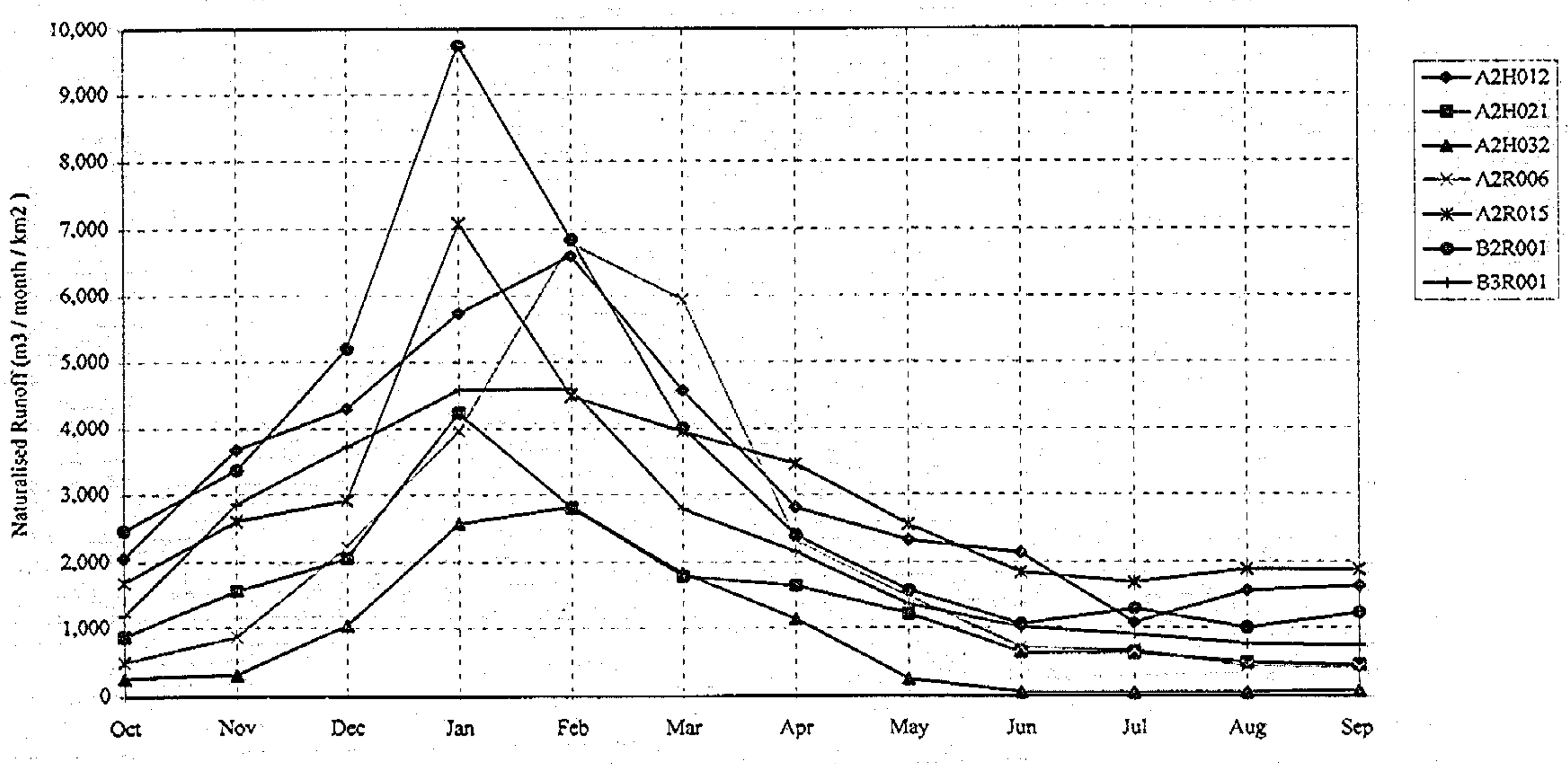


Table 5-3: Major Dams in the Study Area

Quat	Name	River	Lat.		Long.		Capacity (mcm)	Purpose
A21A	Rietvlei	Hennops	25°	52'	28°	16'	12.2	Domestic/Recreation
A21H	Hartbeespoort	Crocodile	25°	43'	27°	51'	195.0	Domestic/Irrigation
A21J	Roodekopjes	Crocodile	25°	24'	27°	35'	103.0	Domestic/Irrigation
A21K	Buffelspoort	Sterkstroom	25°	46'	27°	29'	10.3	Irrigation
A22A	Lindleyspoort	Elands	25°	29'	26°	41'	14.4	Irrigation
A22B	Koster	Koster	25°	42'	26°	54'	12.2	Domestic/Irrigation
A22G	Olifantsnek	Hex	25°	47'	27°	15'	14.2	Irrigation
A22J	Vaalkop	Elands	25°	18'	27°	28'	55.3	Domestic/Irrigation
A22J	Bospoort	Hex	25°	33'	27°	21'	18.2	Domestic
A23A	Roodeplaat	Pienaars	25°	37'	28°	22'	43.5	Domestic/Irrigation
A23E	Bon Accord	Apies	25°	37'	28°	11	4.4	Irrigation
A23G	Warmbaths - new	Buffel	24°	51'	28°	14'	7.5	Domestic
A23K	Nooitgedacht	Tolwane (Sand)	25°	31'	28°	02'	1.4	Recreation
A23L	Klipvoor	Pienaars	25°	07'	27°	48'	43.8	Irrigation
A24F	Bierspruit	Bier	24°	54'	27°	09'	3.5	Irrigation
A61A	Donkerpoort	Little Nyl	24°	40'	28°	19'	3.4	Domestic
B20C	Bronkhorstspruit	Bronkhorst	25°	53'	28°	43'	59.0	Domestic
B20H	Premier	Wilge	25°	48'	28°	52'	5.0	Domestic
B31D	Rust de Winter	Elands	25°	14'	28°	32'	27.2	Irrigation
B31D	Kromdraai	Elands	25°	16'	28°	34'	1.8	Flood
B31D	Kromdraai	Elands	25°	16'	28°	35'	1.1	Industrial
B31F	Mkombo	Elands	25°	06'	28°	55'	205.8	Domestic
Total Capacity							842.2	

Table 5-4 : Livestock Census Results (March 1995)

Province	Magisterial District	Cattle	Sheep	Goats	Pigs
Mpumalanga	Moutse	*** ***	*** ***	*** ***	*** ***
	Total				
Gauteng	Bronkhorstspruit Cullinan Wonderboom	57,731 20,229 15,464	36,510 11,398 10,705	1,960 660 1,686	3,170 4,035 33,495
	Total	93,424	58,613	4,306	40,700
Northern Province	Warmbath (approx. 20%) Waterberg (approx. 10%)	7,413 9,103	1,854 2,020	1,294 580	5,614 1,201
	Total	16,516	3,874	1,874	6,815
North West	Bafokeng Brits Koster Mankwe Moretele Odi Rustenburg Swartsruggens	10,929 28,340 68,320 48,475 40,329 23,075 35,630 19,904	436 11,745 28,053 2,583 3,460 866 36,223 5,927	7,931 1,965 1,168 29,188 10,653 7,304 976 1,345	164 14,614 2,464 614 469 621 8,893 7,054
	Total	275,002	89,293	60,530	34,893
Total		384,942	151,780	66,710	82,408
Equivalent Number of Representative Large Stock Units		384,942	25,297	11,118	6,867
Add LSU for Moutse		30,000	-	-	-
Grand Total LSU		458,224	-	-	-

Table 5-9 : Summary of Water Usage in Irrigation

Sub-Catchment		Area Irrigated (ha)				Water Used (mcm/a)				Water Resouces (mcm/a)	
		GWS	IB	P	Total	GWS	IB	P	Total	Reser-voir	Run of river
Upper Crocodile	A21	20,893	998	9,058	30,949	136.6	6.9	58.0	201.5	136.6	64.9
Elands River	A22	2,468	1,628	2,710	6,806	14.0	16.0	15.0	45.0	28.3	16.7
Pienaars River	A23	7,445	1,197	5,197	13,839	59.3	11.0	52.0	122.3	2.4	39.9
Lower Crocodile	A24	3,840	-	2,859	6,699	31.0	-	32.0	63.0	0.0	63.0
Sub-Total		34,646	3,823	19,824	58,293	238.0	33.9	157.0	431.8	247.3	184.5
Olifants Trib.	B20, B31	-	340	740	1,080	-	2.6	7.2	9.8	0.7	9.1
Sub-Total		0	340	740	1,080	0	2.6	7.2	9.8	0.7	9.1
Total		34,646	4,163	20,564	59,373	238.0	36.5	164.2	411.6	248.0	193.6

Notes: The irrigable area within the Study Area supplied indirectly is excluded from the above table.

GWS Government Water Schemes
IB Irrigation Board Schemes
P Private Irrigation Schemes

Table 5-10: Forest Development and Estimated Water Use

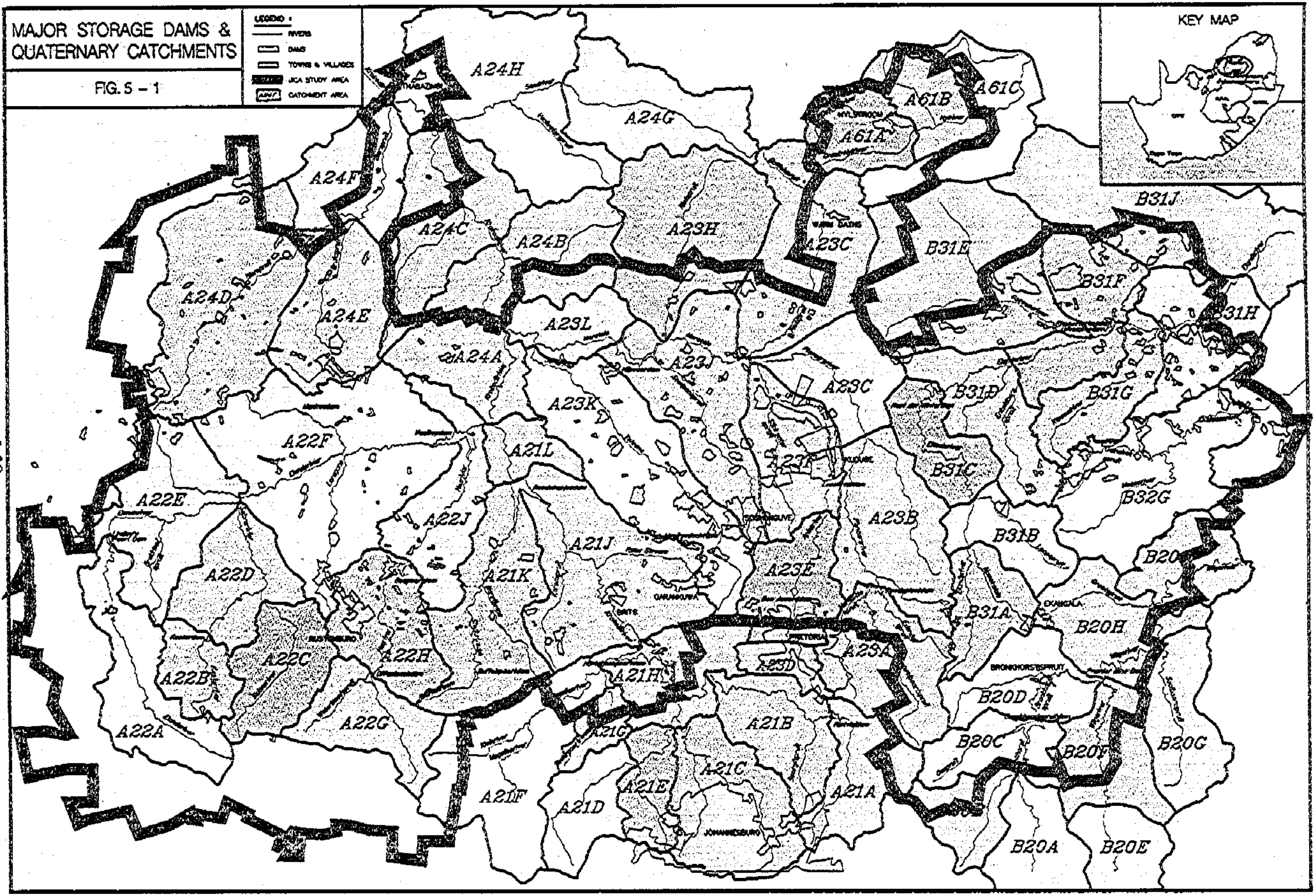
Sub-catchment	Area (ha)	Water Used (mcm/a)
Upper Crocodile	-	-
Elands River	-	-
Pienaars River	4,000	1.14
Lower Crocodile	-	-
Olifants	8,105	2.34
Upper and Lower Nyl	-	-
Total	12,105	3.48

Table 5-11 : Salient Borehole Statistics

Parameter / Status		Number	% of S	% of n
Borehole status	a In use	3,321	61	25
(n = a+b+c = 13396)	b Not in use	2,098	39	16
(S = a+b = 5419)	c No information	7,977		59
Borehole equipment	a Handpump	1,156	44	9
(n = a+b+c+d+e = 13396)	b Windpump	267	10	2
(S = a+b+c+d = 2620)	c Motorized	1,141	44	9
	d No equipment	56	2	<1
	e No information	10,776		79
Borehole depth	a 0 to <30 m	1,721	17	13
(n = a+b+c+d = 13396)	b ³30 to <60 m	4,071	40	31
(S = a+b+c = 10260)	c ³60 m	4,468	43	33
	d No information	3,136		23
Borehole yield	a. <0.1 l/s	3,378	38	25
(n = a+b+c+d = 13396)	b ³0.1 to <2.0 l/s	3,996	45	30
(S = a+b+c = 8936)	c ³2.0 l/s	1,562	17	12
	d No information or dry	4,460		33
Depth to water level	a <10 m	2,652	31	20
(n = a+b+c+d+e = 13396)	b ³10 to <20 m	3,092	36	23
(S = a+b+c+d = 8503)	c ³20 to <30 m	1,531	18	11
	d ³30 m	1,228	15	9
	e No information or dry	4,893		37
Quality restrictions on potability	a Nitrate (N >10 mg/l)	382	46	8
(n = 4875)	b Fluoride (F >1.5 mg/l)	407	49	8
(S = a+b+c = 836)	c Nitrate and Fluoride	47	5	1

Table 5-12 : Harvest Yield of Groundwater

Zone	Area of Each Level of Harvest Yield Potential (km^2)						Harvest Potential (mcm)
	8,000 ($m^3/km^2/a$)	12,500 ($m^3/km^2/a$)	20,000 ($m^3/km^2/a$)	37,500 ($m^3/km^2/a$)	50,000 ($m^3/km^2/a$)	Total Area (km^2)	
Eastern	1,300	1,000	3,327	1,801	0	7,430	157
Central	307	1,932	4,730	739	27	7,737	150
Western	1,812	8,795	1,527	697	0	12,832	181
Total	3,420	11,728	9,585	3,238	27	28,000	488



MAJOR STORAGE DAMS & QUATERNARY CATCHMENTS

FIG. 5 – 1

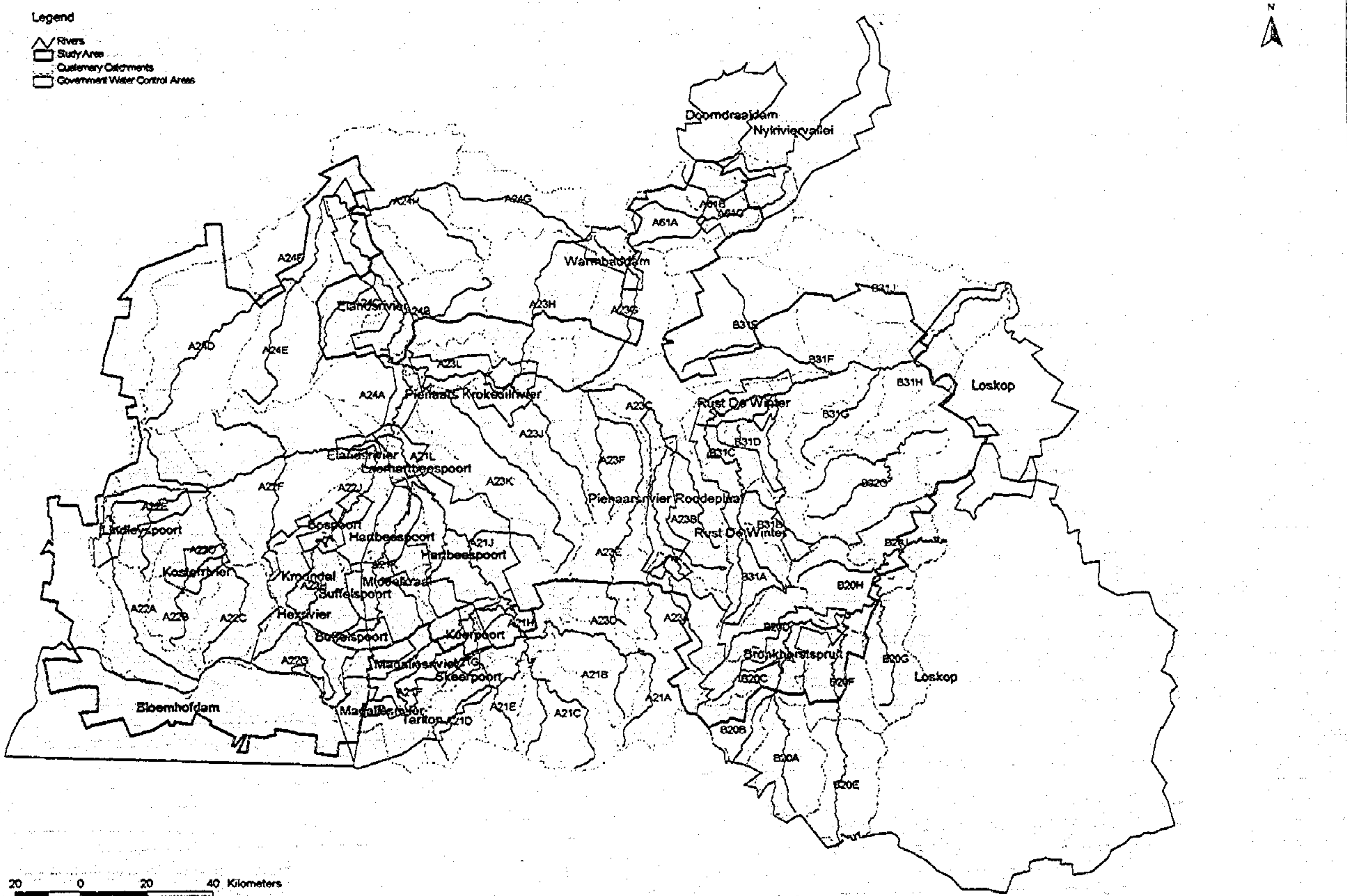


Figure 5-2: **Government Water Control Areas**

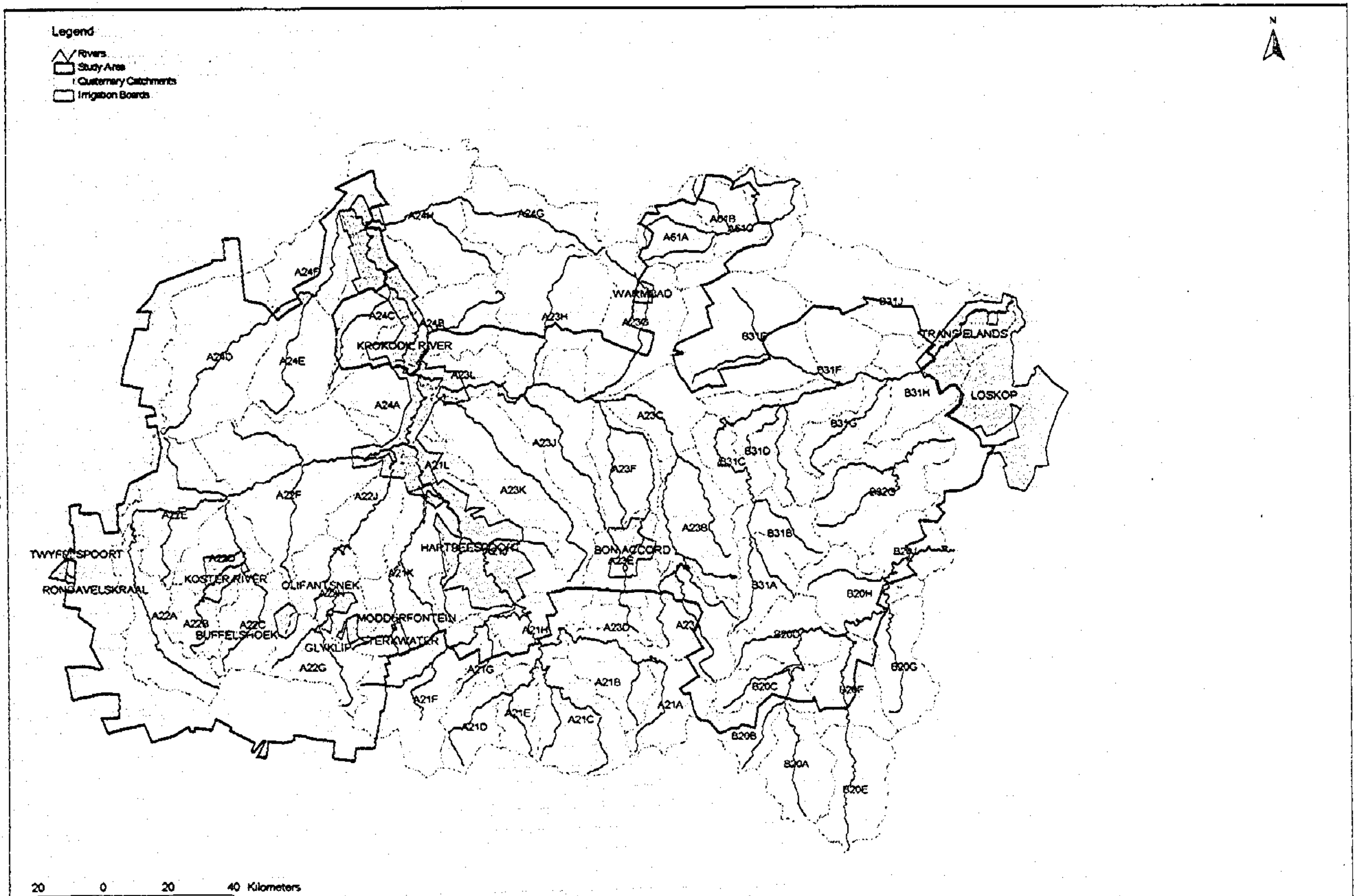


Figure 5-3: **Irrigation Boards**

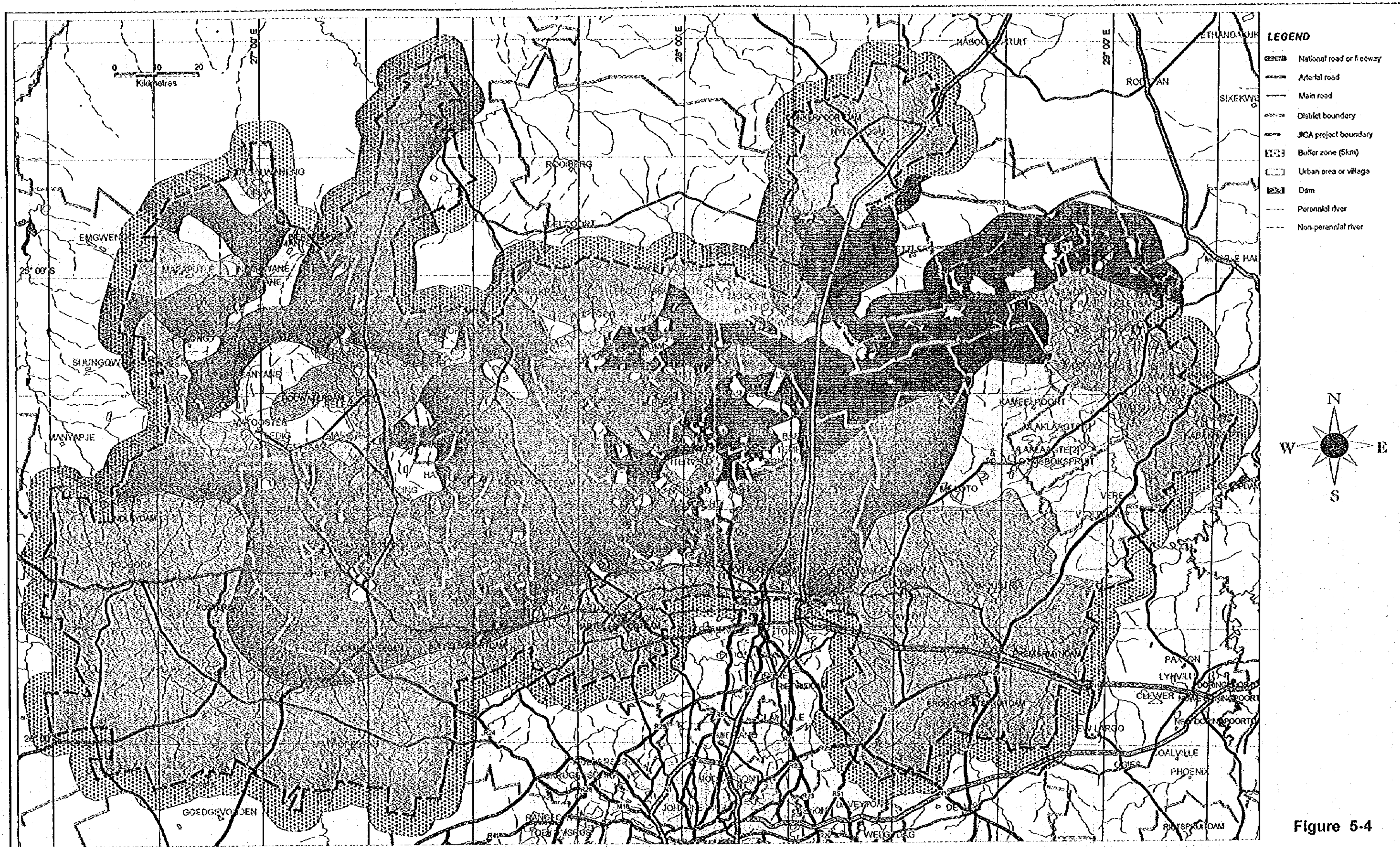


Figure 5-4

Water quality class area:
(defined by poorest water quality class for the parameters EC, Cl, N and F for at least 80% of the boreholes in the respective class area)

- Class 0: ideal water quality, suitable for lifetime use
- Class 1: good water quality, rare instances of negative effects
- Class 2: water safe for short term use only, common instances of negative effects with long term use
- Class 3: unacceptable water qulity for domestic use, unsuitable for domestic use without treatment, consider use for livestock watering
- Class 4: unacceptable water quality for domestic use and stockwatering purposes, unsuitable for domestic use without treatment, suitablity for livestock watering without treatment is limited
- Class 1, 2 and 3

Japan International Cooperation Agency (JICA)

EXPANSION OF THE CAPACITY OF MAGALIES WATER

Groundwater Quality

Scale: 1 : 850 000

Transverse Mercator (Gauss-Krüger) projection, Clarke 1880 spheroid, Central Meridian 27° East

Figure 5-4

Water quality class area:
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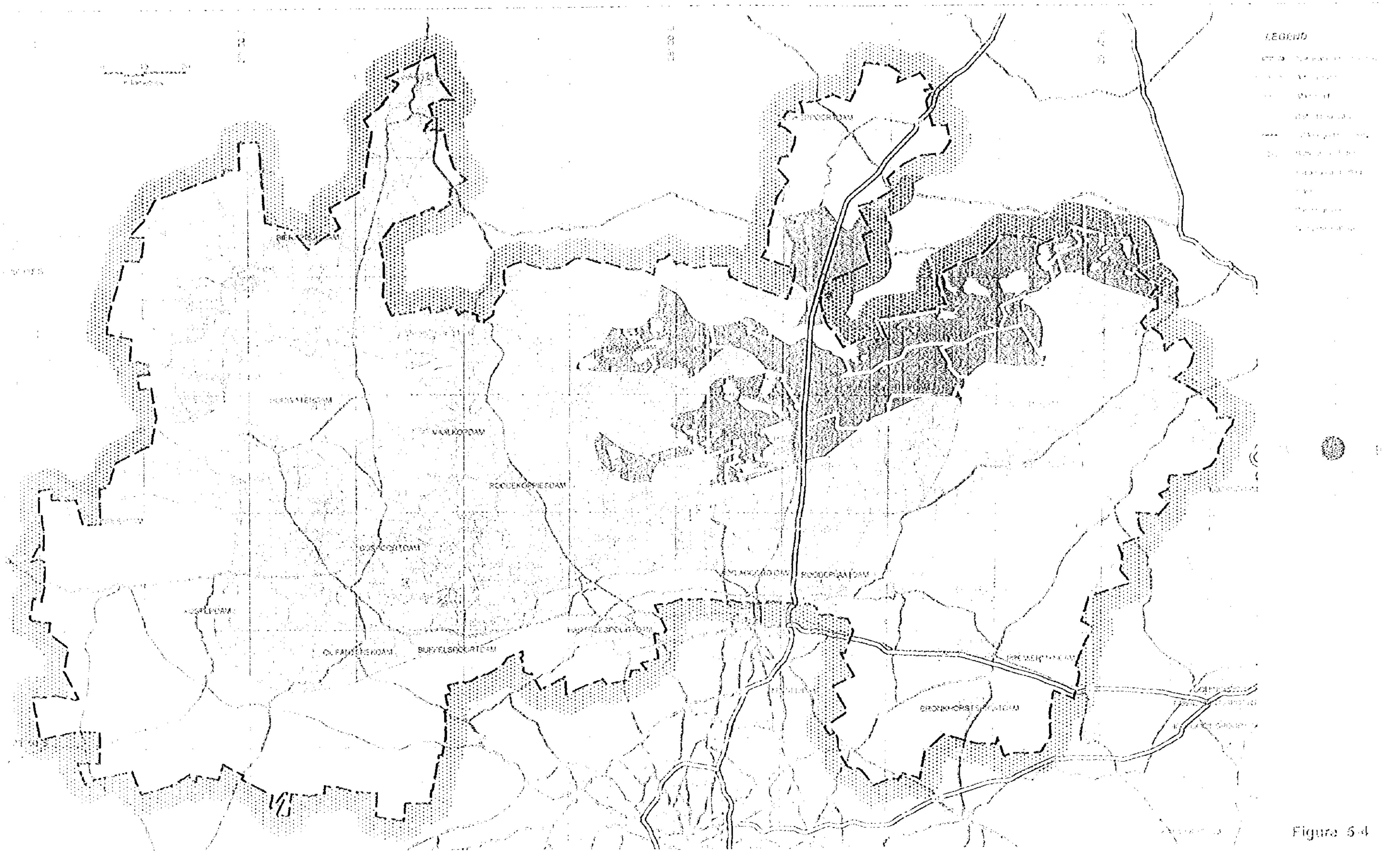

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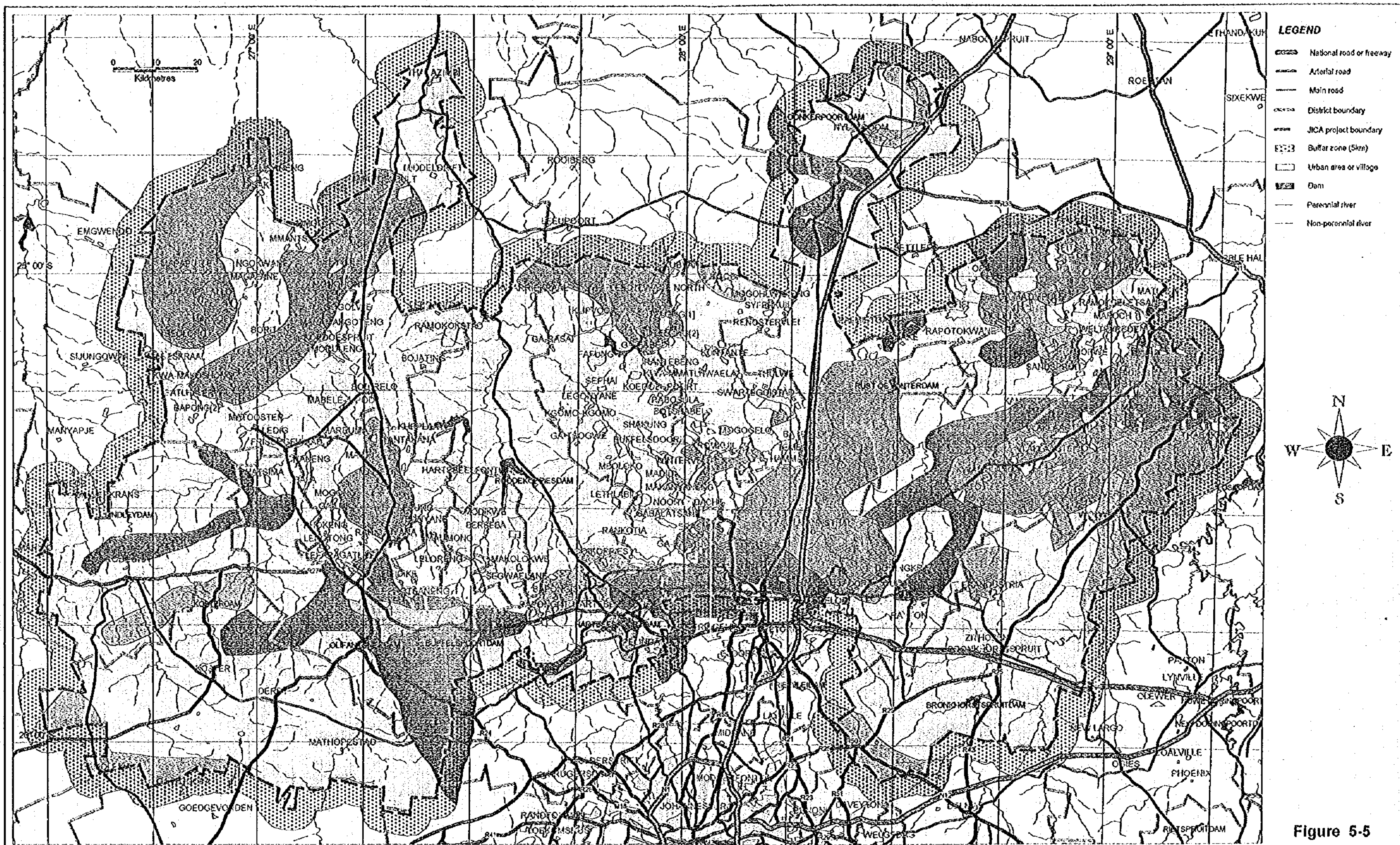

Figure 5-5

Borehole yield area [l/s]

- >= 0.1 and < 0.5
- >= 0.5 and < 3
- >= 3 and < 5
- >= 5

Japan International Cooperation Agency (JICA)

EXPANSION OF THE CAPACITY OF MAGALIES WATER

Borehole yield

Scale: 1 : 850 000

Transverse Mercator (Gauss-Krüger) projection, Clarke 1880 spheroid, Central Meridian 27° East

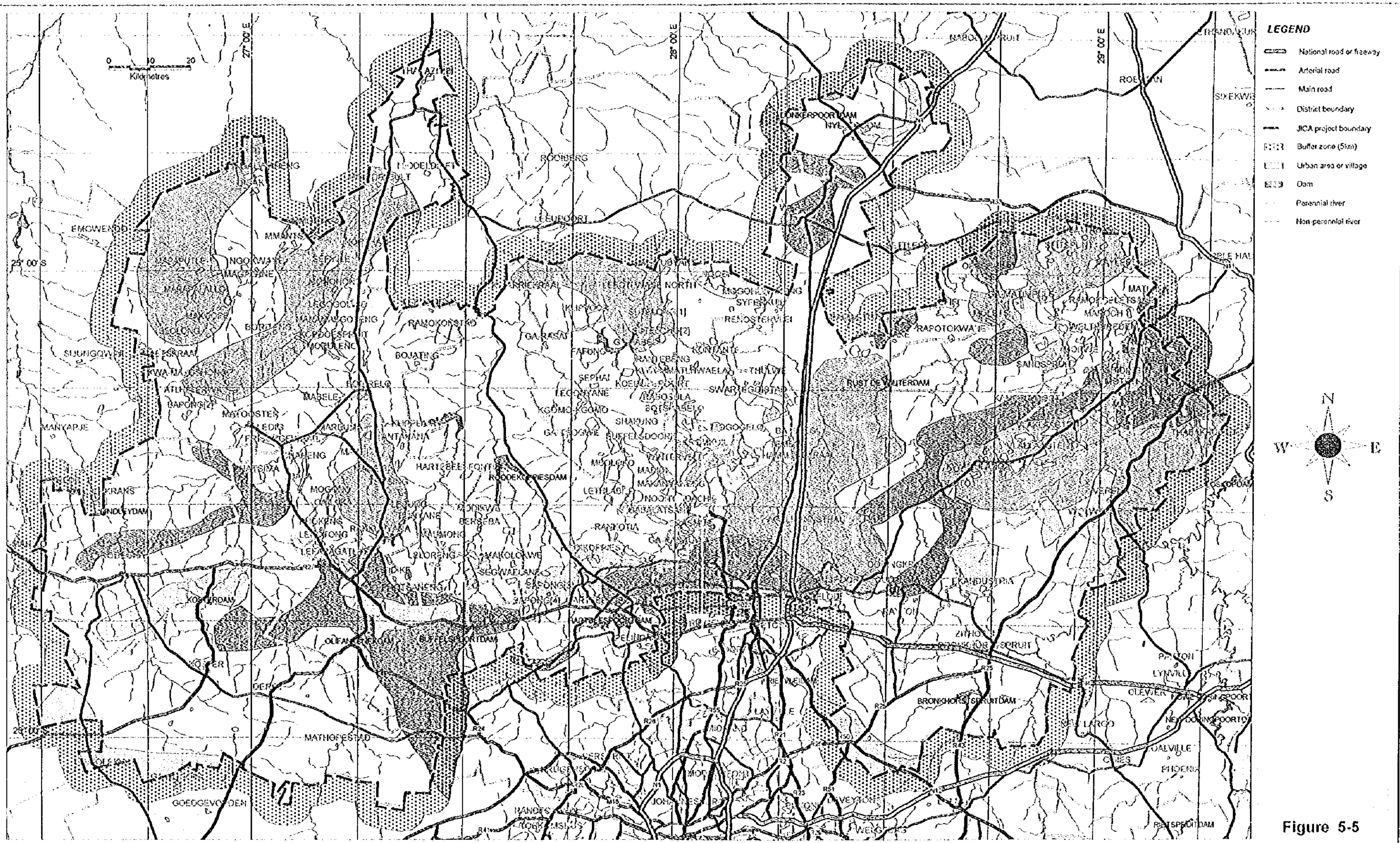

Figure 5-5

Borehole yield area [l/s]

- >= 0.1 and < 0.5
- >= 0.5 and < 3
- >= 3 and < 5
- >= 5

Japan International Cooperation Agency (JICA)

EXPANSION OF THE CAPACITY OF MAGALIES WATER

Borehole yield

Scale: 1 : 850 000

Transverse Mercator (Gauss-Krüger) projection, Clarke 1880 spheroid, Central Meridian 27° East

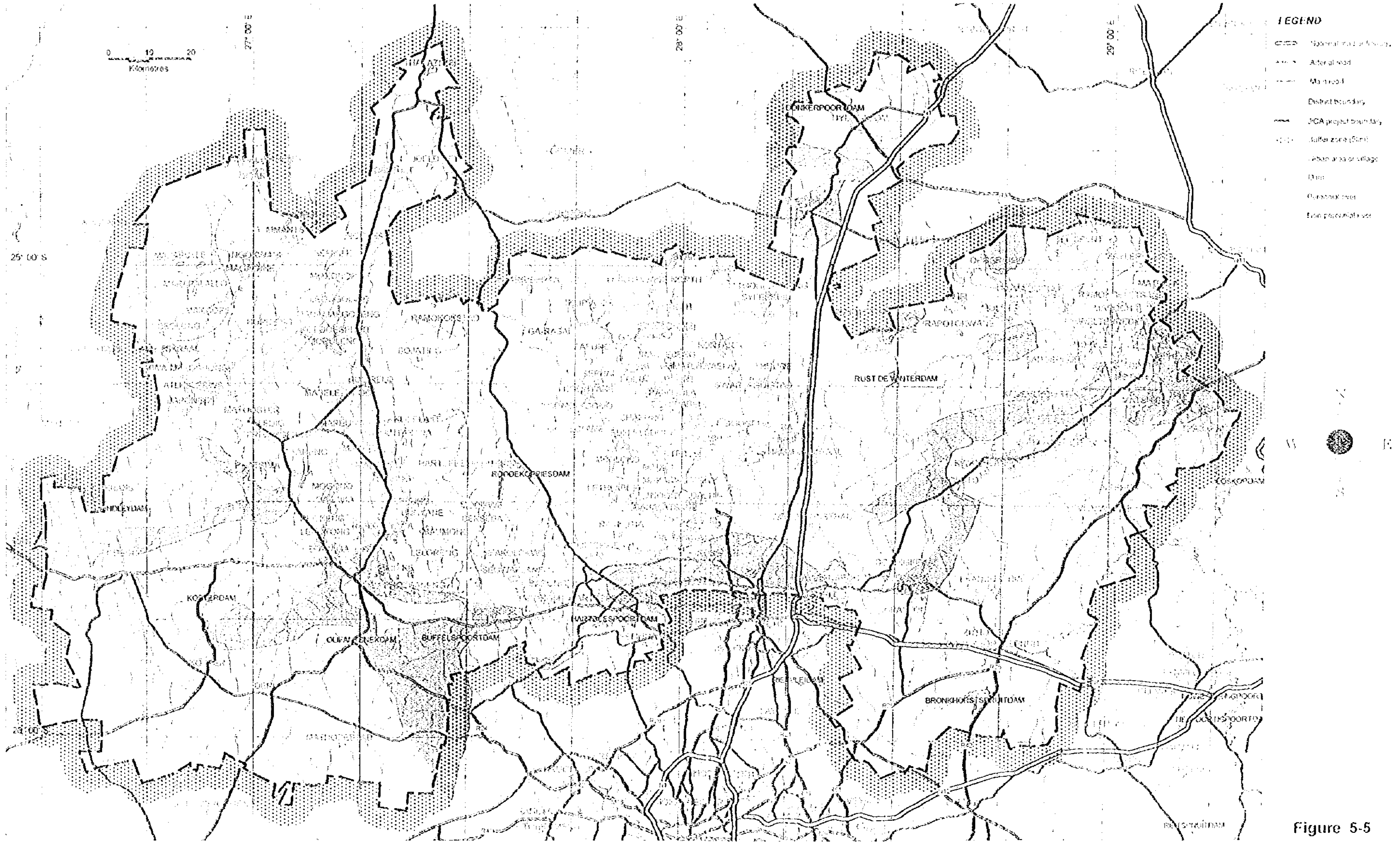

Figure 5-5

Borehole yield area [l/s]

- >= 0.1 and < 0.5
- >= 0.5 and < 3
- >= 3 and < 5
- >= 5

Japan International Cooperation Agency (JICA)

EXPANSION OF THE CAPACITY OF MAGALIES WATER

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