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Joint Limpopo River Basin Study Scoping Phase Final Report

Limpopo Basin Permanent Technical Committee

REPÚBLICA DE MOÇAMBIQUE
MINISTÉRIO DAS OBRAS PUBLICAS E HABITAÇÃO
DIRECÇÃO NACIONAL DE ÁGUAS

On behalf of the

LIMPOPO BASIN PERMANENT TECHNICAL COMMITTEE - LBPTC

JOINT LIMPOPO RIVER BASIN STUDY
SCOPING PHASE

Final Report
Main Report

January 2010

Botswana

Mozambique

South Africa

Zimbabwe

FINANCED BY

SOUTHERN AFRICAN DEVELOPMENT COMMUNITY
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TOWARDS A COMMON FUTURE

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PREPARED BY BIGCON CONSORTIUM

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Consultores Associados, Lda

BKS

INTER-CONSULT

Group Consult
Botswana (Pty) Ltd

MAIN REPORT

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LIST OF ABBREVIATIONS

BBM	Building block methodology
BHN	Basic human needs reserve
CSIR	Council for Scientific and Industrial Research (South Africa)
DFID	Department of International Development of the United Kingdom
DNA	National Directorate of Water (Mozambique)
DRIFT	Downstream Response to Imposed Flow Transformation
DWA	Department of Water Affairs (Botswana)
DWAF	Department of Water Affairs and Forestry (South Africa)
EF	Environmental flow
EFR	Environmental flow requirements
EMC	Ecological Management Class
ER	Ecological Reserve
FSR	Flow stressor response
GTZ	German Technical Cooperation
ICOLD	International committee on large dams
ITCZ	Intertropical Convergence Zone
IWMI	International Water Management Institute
IWRM	Integrated water resources management
KNP	Kruger National Park
LBPTC	Limpopo Basin Permanent Technical Committee
LIMCOM	Limpopo Water Course Commission
m.a.s.l.	meters above sea level
MAP	Mean Annual Precipitation
MAR	mean annual runoff
NWA	South African National Water Act
SADC	Southern African Development Community
SARDC	Southern African Research and Documentation Centre
UIM	Urban, industry and mining
WDM	Water Demand Management
WRC	Water Research Commission (South Africa)
WRD	Water Resources Development
ZINWA	Zimbabwe National Water Authority

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ACKNOWLEDGEMENTS

The results of the scoping phase required a joint effort of the Limpopo Basin Permanent Technical Committee and its Technical Steering Committee, the water authorities of the basin states, GTZ, and the Consultant. The compilation of the large amount of data has only been possible through assistance from personnel of the various water authorities, institutes and organisations in Botswana, South Africa, Zimbabwe and Mozambique, related to water and environmental management. The Study Coordinator and the Interim Secretary have guided the work to reach the end product of the scoping phase: this report.

All contributions to the data compilation and the writing of the Final Report from the Study Coordinator and individuals from the water authorities in the four countries and GTZ are greatly acknowledged.

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0 EXECUTIVE SUMMARY

Background

On behalf of the Limpopo Basin Permanent Technical Committee and its member countries Botswana, Zimbabwe, South Africa and Mozambique, the Direcçao Nacional de Águas (DNA) of Mozambique, contracted the Consultant BIGCON, a consortium composed of CONSULTEC Mozambique, BKS South Africa, Interconsult Zimbabwe and GroupConsult Botswana, to undertake the initial Scoping Phase of the Joint Limpopo River Basin Study. The assignment was financed by the German Technical Cooperation (GTZ) and commissioned by the Federal Ministry for Economic Cooperation and Development of Germany, in Delegated Cooperation with the Department of International Development (DFID) of the United Kingdom.

The overall objective of the Joint Limpopo Basin Study is to quantify the present and future water balance in the Limpopo River basin in each of the four co-basin states, and to plan future water resource development and management options so as to meet the future water demands in an optimal, sustainable and equitable way. The specific objectives defined for the scoping phase were:

- to confirm the adequacy of all existing studies and data considered essential to a basin study and prepare a report which will be used as input in the further phases of the basin study; and
- to indicate where additional information is required and, with this in mind, devise a work program for the subsequent phase of the Joint Limpopo River Basin Study.

The Scoping Study started in October 2008 and was completed by January 2010. During this time consultations were held with all member states. Based on the work undertaken, an inventory on existing information was made, including previous studies on the Limpopo River, maps and GIS, climatic data, surface water data and reservoir levels, groundwater data and hydrogeological information, water quality and riverine sediment transport, water demand and use, socio-economic information and legal and institutional information. The inventory identified a very large amount of data, especially on hydrometeorology and water quality. The meta-data on these data and information are presented in this scoping report and should be the starting point for the comprehensive study.

Challenges and opportunities for water resources management

The Limpopo River basin is shared by four countries: Botswana, South Africa, Zimbabwe and Mozambique and has a total catchment area of approximately 408,000 km^2. The catchment characteristics are very diverse covering different climatic and topographic zones. Water resources thus differ much between the different sub-catchments and between countries.

Topography varies from above 2,000 m.a.s.l. in the mountain regions of South Africa, to the vast low-lying flood plains in the Mozambican part of the catchment. The climate in the Limpopo River basin ranges from tropical dry savannah and hot dry steppe to cool temperatures in the mountainous regions. The average rainfall of the basin is 530 mm per annum, ranging from 200 to 1,200 mm/a, while the average evaporation is 1,970 mm/a, ranging from 800 to 2,400 mm/a. Rainfall is distinctly seasonal and occurs mainly in the summer months (October to March). Droughts are frequent, but floods can also occur in intensive rainy periods. Extreme rainfall can occur caused by tropical cyclones entering the river basin from the Indian Ocean.

The Limpopo River basin is the home to around 14 million people in the four riparian states. Essentially, access to water is of critical strategic importance to development in all parts of the basin. Large urban centres such as Gaborone, Pretoria, Johannesburg and Bulawayo are major users of water resources within the basin. In the rural areas water is used for domestic purposes, livestock watering and irrigation. Many people in the rural areas are vulnerable to secure water supply for domestic use and livestock and reliability of subsistence agriculture. Water allocation between upstream and downstream areas and between urban and rural users is therefore essential challenges for water management.

The greatest user of water by sector in the four Limpopo River riparian states is irrigation, which takes approximately 50% of the total water demand. In Botswana and Zimbabwe, however, urban supply is the major user. Total estimated present demand is about 4,700 Mm^3/a. Almost two thirds of the demand is in South Africa, 30% in Zimbabwe, 6% in Mozambique and 2% in Botswana. Total natural runoff generated from rainfall is approximately 7,200 Mm^3/a showing that a significant portion of the runoff generated in the basin is currently used.

The Limpopo River basin is already quite developed in terms of storage dams, from which the majority of water abstractions are made. On the other hand, the records of river flows in the Limpopo River in Mozambique show that a considerable volume of water flows into the sea. Although the river regime shows large variability with floods that cannot be captured, and flows must be reserved for the conservation of the delicate ecological system in the estuary, there is still opportunity for further infrastructural development to increase the efficiency of the water resources utilisation.

Protected environmental areas comprise a very large part of the Limpopo River basin. The Great Limpopo Transfrontier Park, comprising of the Kruger National Park in South Africa, the Limpopo National Park in Mozambique and the Gonarezhou National Park in Zimbabwe, takes up a very large part of the river catchment and borders both the Limpopo and Olifants rivers. The large national parks contain unique biota with several threatened species and contribute significantly to the economies in the river basin through tourism. It is therefore essential that any development of infrastructure, agricultural or industrial schemes are done without causing harmful effect to the environment and especially the protected areas.

The analysis of the water quality data has indicated that the river is already negatively impacted, especially in the Olifants River that has much agricultural and industrial activity. The environmental status of the rivers in the Limpopo River basin varies from natural (in the national parks) to highly modified (e.g. in upper Olifants River). Further potential deterioration of the water quality and the instream habitats by unsustainable practices in urban areas and along the river by agricultural and mining activities must be contained.

The above challenges and opportunities show that joint transboundary river basin management is required to reach equitable and sustainable use of the water resources of the Limpopo River basin. Mutual benefits and equitable sharing of resources are key approaches to cooperation on water management in the Limpopo River basin. The legal and institutional mechanisms are in place for the riparian countries of the Limpopo River basin to achieve progress in the joint management of the water resources. All countries have signed the SADC Revised Protocol on Shared Watercourses whose principles are key for joint management, and all countries have the laws and regulations and also the institutions required for a cooperative effort.

Data inventory

The Limpopo River basin, with its complexity, has been the focus of many studies related to water resources. A list of major studies on individual river basins or thematic studies covering the Limpopo River basin is given in this report.

Geographical data are generally available in all countries, most often in GIS format. Difficulties were, however, found when generating maps and geographical information databases for the whole basin because of different formats and projection systems. Obtaining GIS data often has associated costs and much information is still only available as scanned PDF-document format.

Climatic data, such as rainfall and pan evaporation, as well as river runoff and reservoir levels are available for a large number of gauging stations in the Limpopo River basin. Data are basically measured in the same way in all countries and are thus compatible. The difference between the countries is mainly in the coverage, spatially and temporally. Due to the large number of stations located in South Africa, a sufficient number of stations with high quality and long records can be chosen. In the other three countries relatively fewer stations show long and consistent records. Many rainfall stations operated by farms, schools, etc., especially in Zimbabwe and Botswana, also still have the historical records in hard copy.

Regional groundwater information, such as geological and hydrogeological maps and the data on major groundwater outtakes are available, which provide essential input for basin-scale water resources management. More detailed data on groundwater in the Limpopo River basin is in abundance when it comes to boreholes. However at very few of these boreholes are continuous measurements of water levels made. Information is most often limited to the location, depth and maybe geological characteristics.

Water quality data are available from water sampling in the major rivers of the Limpopo River basin. Similarly to the climatic and runoff data, the vast amounts of data are available in South Africa, while information on water quality is more limited in the other countries. All four countries have separate sets of legislation for the maintenance of water quality standards.

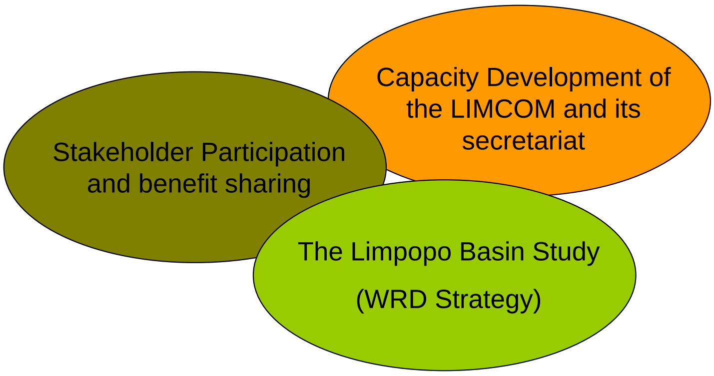
Suspended sediment data is one parameter that is normally analysed as part of the water quality monitoring and thus give some input to the sediment transport assessment. In both Mozambique and Zimbabwe limited measurements of suspended sediment have been made through the depth-integrated methods at key runoff stations. In addition to the sediment sampling, all major dams in South Africa are surveyed periodically which provides a measure to monitor reservoir siltation.

Most of the available data on water use relates to water demand and not to effective water use. Estimates of present water demand are available from all four countries. Problems of compatibility exist mainly because the level of aggregation of the information differs and the same base year is not used.

Population data for the four Limpopo River basin states are available. The population data is obtained from national censuses which are conducted every ten years in each of these states. Economic information for activities covering agriculture, industry, tourism etc. is also available. Problems of compatibility also exist because the methods of conducting censuses differ from country to country and that emphasis is given on different aspects of the economic activities.

Proposal for comprehensive study

The overall objective of the Joint Limpopo River Basin Study puts much focus on the technical aspects leading to a basic understanding of key variables as water resources, water demand, infrastructural development and environmental issues. It is thus proposed that the Limpopo Basin Study will form one part of the necessary measures for achieving Integrated Water Resources Management (IWRM) in the transboundary Limpopo River. Other major components are the capacity development of the LIMCOM and its secretariat as well as the stakeholder participation process and introduction of benefit sharing of the Limpopo River.



All these components are on-going processes forming the transboundary IWRM for the Limpopo River basin. Also the Limpopo Basin Study must be regularly updated to accommodate the continuous development in the river basin and in the region. All components are interdependent and cannot proceed on their own.

The objective of the Limpopo Basin Study points towards the development of a ***Water Resources Development Strategy for the Limpopo River Basin***. It is thus suggested that the scope of work for the comprehensive study is structured to develop such strategy. However, it is also important to build the technical capacity for updating the strategy and to create awareness of it through public participation. The proposed scope of work should therefore also include components for technical capacity development of the LIMCOM and the water authorities of the four countries as well as for public participation. These will provide linkages to the other IWRM mechanisms.

It is proposed that the scope of work for the comprehensive study is following four major components that are carried out in parallel:

Component 1: Development of a joint Limpopo River basin monograph. This monograph should include a detailed description of the surface and groundwater resources, existing infrastructure and socio-economic conditions, current water use and demand, and key environmental issues for the river basin.

Component 2: Development options and principles. This component shall lead to identified development options for infrastructure and economic activities, and proposed principles for its prioritisation.

Component 3: Technical capacity development. This component shall focus on developing joint capacity for updating the Water Resources Development Strategy. It includes coordinated development of joint basin tools for the water authorities of the four basin countries to monitor and update key variables for water resources development and management.

Component 4: Public participation. This component aims to build awareness and to receive feedback on the Water Resources Development Strategy from the major stakeholders of the Limpopo River basin.

The requirements of the different components of the proposed comprehensive study are detailed in sections 5 and 6 of the Main Report. The focal point institutions for the implementation of the comprehensive study are the Limpopo Watercourse Commission (LIMCOM) and its Secretariat, the national water authorities of the four basin states and the regional water authorities responsible for the Limpopo River basin in each country. The implementing agency for the comprehensive study is proposed to be the LIMCOM secretariat, while a Project Steering Committee, including representatives from each country's national and regional water authorities should be established to supervise and coordinate the services provided.

Conclusions

The main report for the scoping phase gives an overview of the Limpopo River basin and the proposed scope of work for the comprehensive study. It also proposes a division into 27 sub-basins to get similarly sized and geographically homogenous areas. Annexes 1 to 5 give a detailed description of the core data and information available for the Limpopo River basin for the establishment of a joint Water Resources Development Strategy. The meta-data and source information presented in these annexes are accompanied with a database including all data compiled in the scoping phase. In addition, Annex 6 identifies the sources for data in adjacent areas of water resources management, which have relatively less importance for basin-scale water resources management but which may be found of interest in the comprehensive study.

The assessment has generally shown that there are data available for joint integrated river basin management in the Limpopo River basin. A challenge is the discrepancies in the data quantity and quality obtained from South Africa compared to the other three countries. The comprehensive study must therefore focus on extracting the most essential data from the large amount of information available in South Africa and if necessary, correct and update data for Botswana, Zimbabwe and Mozambique to produce a complete database for transboundary basin management. Minor data gaps exist, which are of importance for the IWRM in the Limpopo River basin, such as complete ecological characterisation of all river basins, but all of these can be dealt with as part of the comprehensive study.

Although challenges exist in relation to data coverage and quality, the scoping phase has shown that sufficient data and information are available for the commencement of the comprehensive study that can be initiated based on the material and guidelines given in this main report and its enclosed annexes. Focussing the comprehensive study on making data homogenous and to fill in information gaps will create the basis for a joint water resources development strategy for the Limpopo River basin.

1 INTRODUCTION

The Limpopo River is one of the largest river basins in the SADC region, having as co-basin states Botswana, South Africa, Zimbabwe and Mozambique that formed the LIMCOM - Limpopo Water Course Commission.

The Republic of Mozambique, through the Ministry of Public Works and Housing, National Directorate of Water – DNA, on behalf of the Limpopo Basin Permanent Technical Committee (LBPTC), has received funds from the German Technical Cooperation (GTZ) to undertake the Joint Limpopo River Basin Study – Scoping Phase. The study has been commissioned by the Federal Ministry for Economic Cooperation and Development of Germany, in Delegated Cooperation with the Department of International Development (DFID) of the United Kingdom

The objectives of the Scoping Phase were:

- to confirm the adequacy of all existing studies and data considered essential to a basin study and prepare a report which will be used as input in the further phases of the basin study; and
- to indicate where additional information is required and, with this in mind, devise a work program for the subsequent phase of the Joint Limpopo River Basin Study.

This report is the result of the conducted work by the consortium of Consultant's led by CONSULTEC (Mozambique) and including BKS (South Africa), Interconsult Zimbabwe and GroupConsult (Botswana).

Chapter 2 of the report gives an overview of the Limpopo River basin, while Chapter 3 discusses challenges and opportunities for water resources management. Chapter 4 goes through the data availability for a comprehensive study, followed by a detailed scope of work in Chapter 5.

Further details can be found in the six Annexes. Annex 1 presents the most relevant maps that could be collected. Annex 2 includes the meta-data on hydrology and climate, specifically on runoff, rainfall and evaporation, besides some additional information on modelling of surface water resources. Annex 3 gives details about water demand in the four countries as well as about the main hydraulic infrastructures. Annex 4 deals extensively with the water quality data in the four countries. Annex 5 presents the socio-economic data and the legal and institutional settings in the countries and in the region. Finally, Annex 6 includes information about some outstanding data that may be of relevance in the comprehensive study.

2 THE LIMPOPO RIVER BASIN

2.1 Geography and catchment division

The Limpopo River basin is shared by four countries: Botswana, South Africa, Zimbabwe and Mozambique (**Figure 2.1**). The total catchment area is approximately 408,000 km^2 which is distributed amongst the four countries as follows:

Botswana	81,400 km^2
South Africa	184,150 km^2
Zimbabwe	62,900 km^2
Mozambique	79,800 km^2
Total	**408,250 km^2**

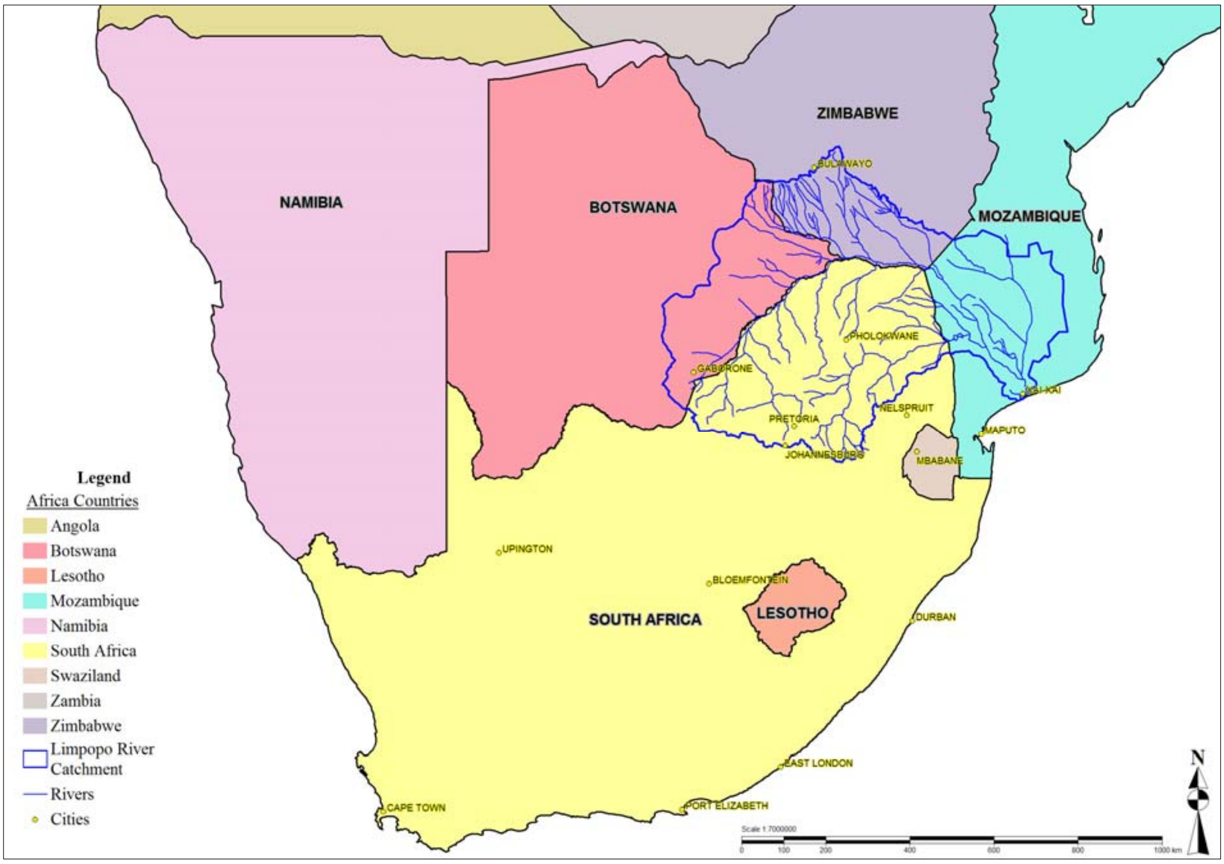


Figure 2.1 Regional map showing the Limpopo River basin

The Limpopo River (1,770 km long) flows from the Limpopo Province in South Africa in a great arc, first north, forming part of the South Africa-Botswana border, then east, forming the South Africa–Zimbabwe border and finally southeast through Mozambique to the Indian Ocean. Where the Limpopo River flows into the Indian Ocean near Xai Xai in Mozambique, it has a width of approximately 300 meters, partly obstructed by sandbanks. The western two thirds of the basin constitute part of the continental plateau and the eastern third coastal plain.

The main tributaries of the Limpopo River are:

Left Bank	**Right Bank**
Marico	Crocodile (West)
Notwane	Lephalala
Bonwapitse	Matlabas
Mahalapswe	Mokolo
Lotsane	Lephalala
Motloutse	Mogalakwena
Shashe	Sand
Mutshilashokwe	Nzhelele
Mzingwani	Levuvhu
Shabili	Olifants (Elefantes)
Bubi	Lumane
Mwenezi (Uanetze)	
Changane	

These 24 tributaries have very different catchment areas from the small Shabili River in Zimbabwe to the large Olifants River, which is shared by South Africa and Mozambique. A proposed division into 27 sub-basins is made in Section 3.4 to get similarly sized and geographically homogenous sub-basins.

The layout of the Limpopo River basin and its tributaries are presented in **Figure 2.2**. Figure 2.2 includes the major cities, international boundaries and nature reserves found in the basin.

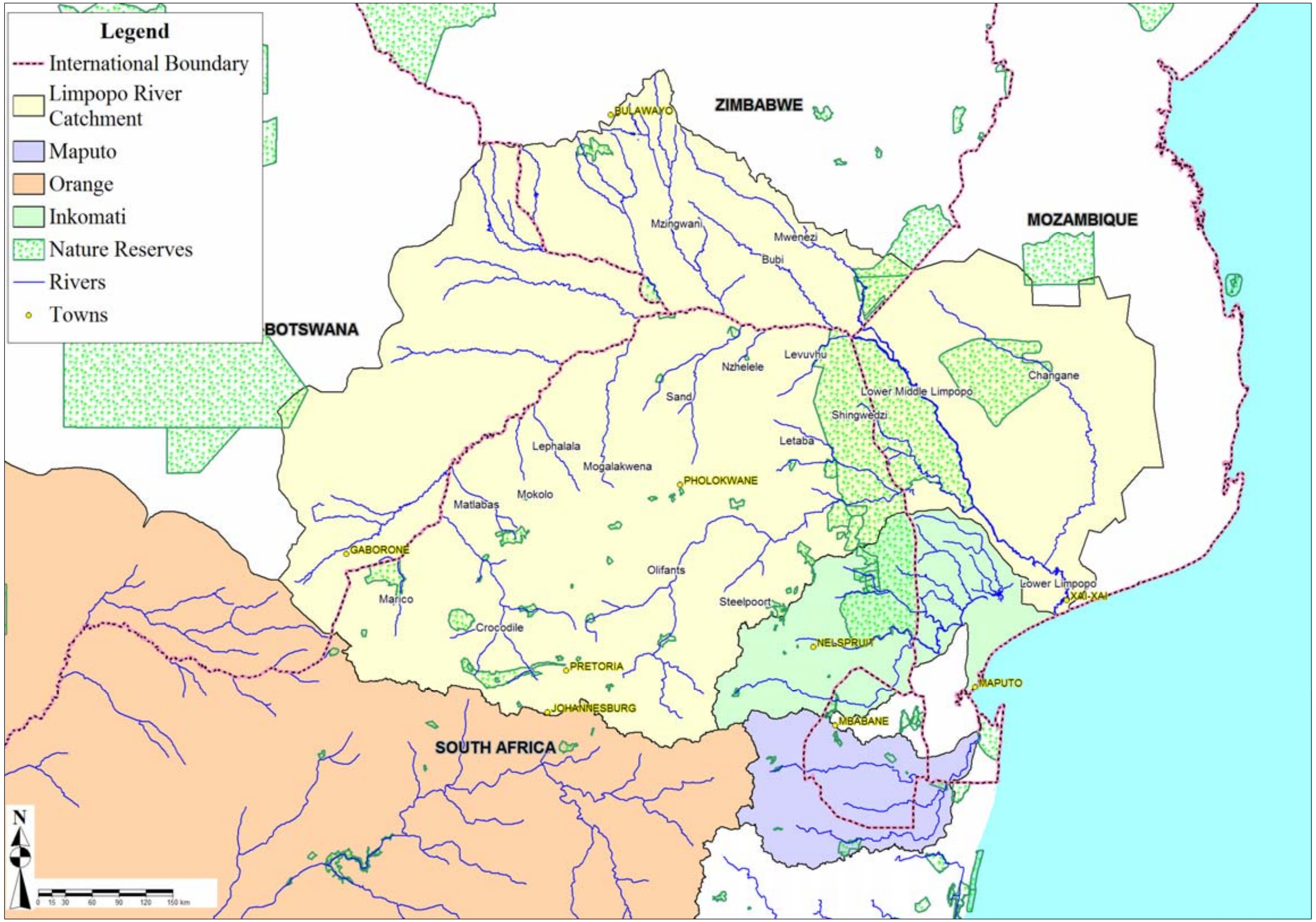


Figure 2.2 Limpopo River basin layout

2.2 Topography and climate

The topography of the Limpopo River basin is presented in **Figure 2.3.** Topography varies from above 2,000 m.a.s.l. in the mountain regions of South Africa to the vast flood plains in the Mozambican part of the catchments. The last 175 km of river stretch has elevations below 7 m.a.s.l.

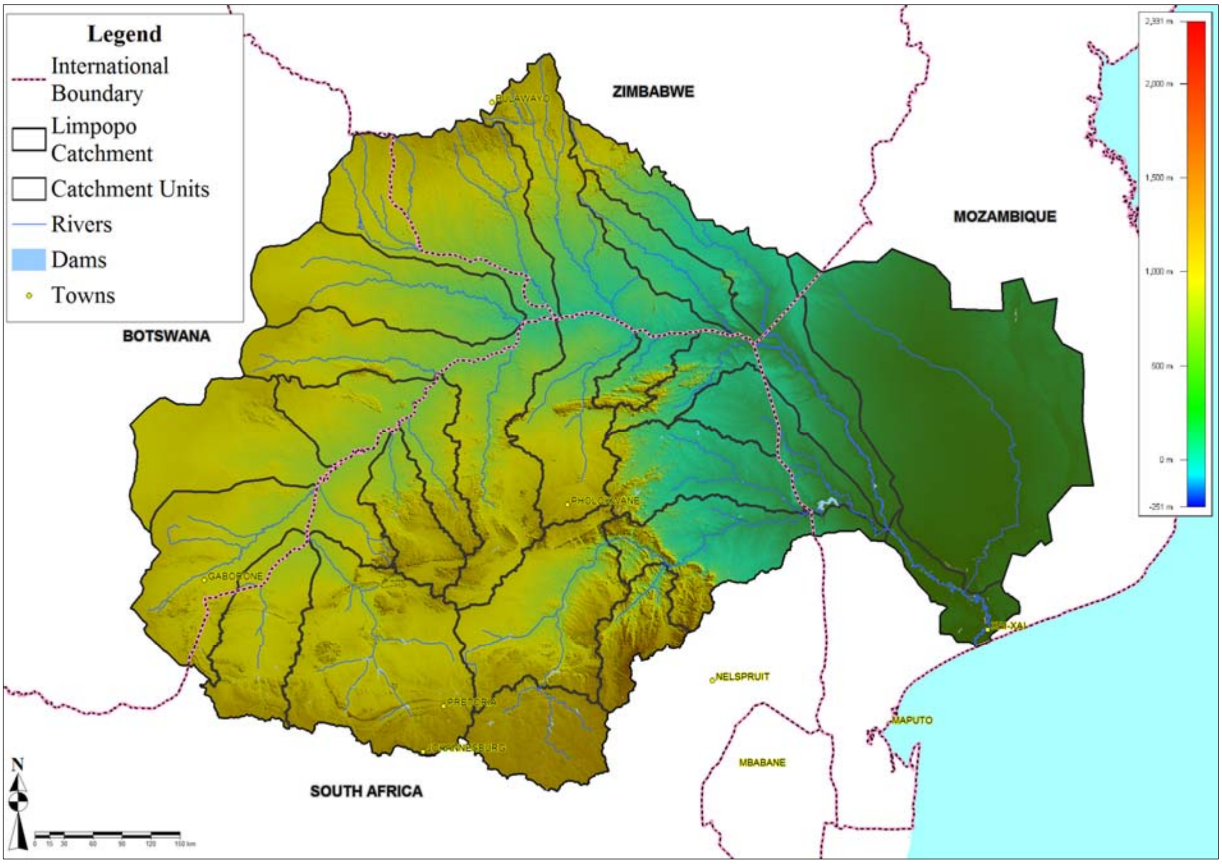


Figure 2.3 Topography of the Limpopo River basin

The river basin is mainly characterised by flat or undulating plains with grass- and bushland. The exceptions to the generally flat landscape are the mountainous regions in South Africa, such as the Waterberg, Strydpoort Mountains and the Drakensberg range that comprises the divide to the Inkomati River in the south-eastern part of the catchment.

The climate in the Limpopo River basin ranges from tropical dry savannah and hot dry steppe to cool temperatures in the mountainous areas. The main governing factor for rainfall patterns in the basin is the movement of the Intertropical Convergence Zone (ITCZ). The average rainfall of the basin is 530 mm per annum, ranging from 200 to 1,200 mm/a, while the average evaporation is 1,970 mm/a, ranging from 800 to 2,400 mm/a. The areas that receive the highest rainfall are the mountainous areas in South Africa, while the lowest rainfall is found along the Limpopo River between Zimbabwe and South Africa. A preliminary calculation of catchment rainfall has been conducted based on the compiled rainfall data in the scoping phase (see **Figure 2.4**).

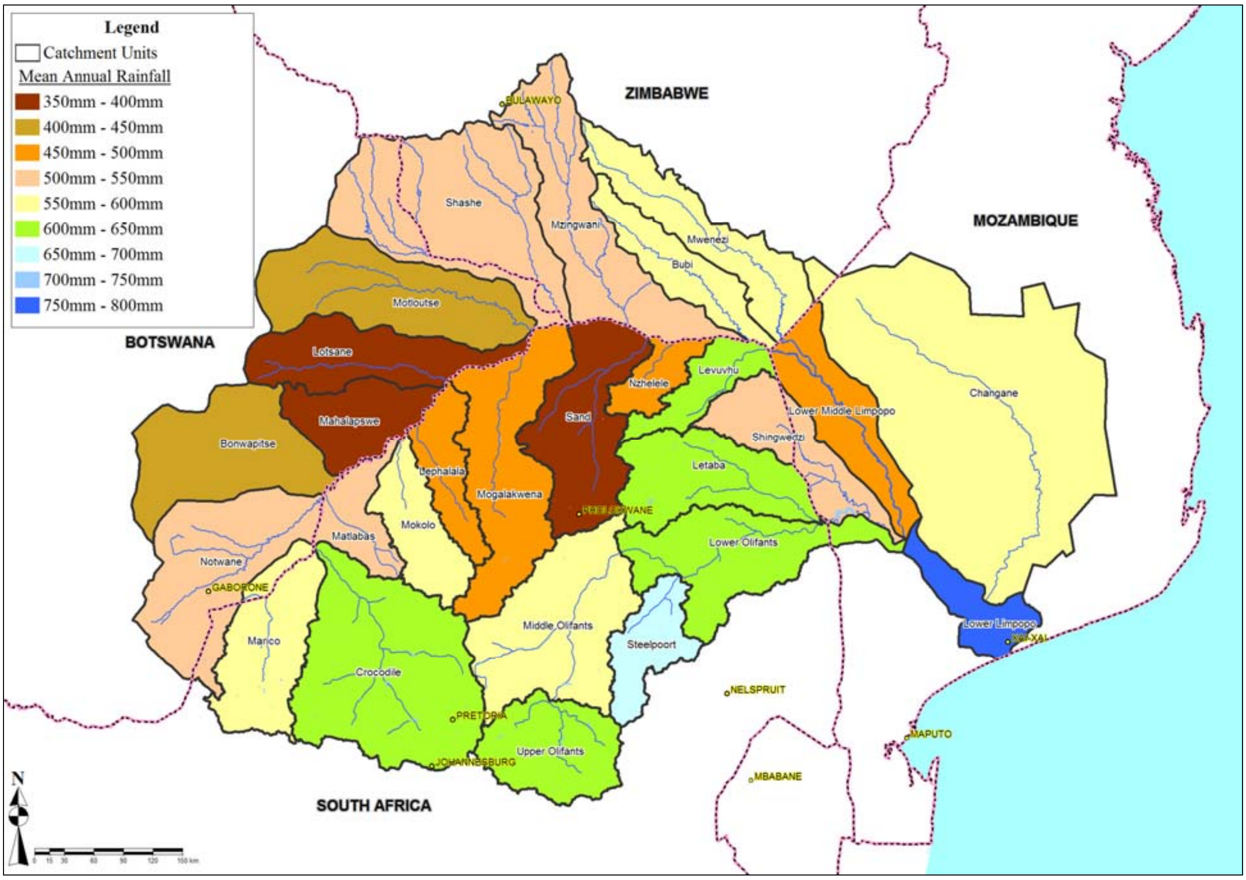


Figure 2.4 Average rainfall in the sub-basins of the Limpopo River

Rainfall generally is lowest in the catchment in the western parts of the Limpopo River basin (below 400 mm). The two tributaries (Mahalapswe and Lotsane) in Botswana as well as the Sand River in South Africa show the lowest average rainfall. The highest average catchment rainfall is found in the upper reaches of the Olifants River in South Africa as well as in the lower Limpopo stretches in Mozambique.

Precipitation occurs mainly in the summer months (October to March) with the peak of the rainy season in January. Most of the rainfall results from thunderstorms, therefore rainfall events of short duration and a flooding nature can be expected. Droughts are frequent but floods can also occur in intensive rainy periods. Extreme rainfall can occur caused by tropical cyclones entering the river basin from the Indian Ocean. An example was the Eline Cyclone that caused severe flooding in the Limpopo River in 2000.

Similarly to the rainfall, air temperatures in the Limpopo River basin show a marked seasonal cycle, with highest temperatures during the summer months and lowest temperatures during the cool and dry winter months. In summer, the daily temperatures may soar above 40°C, while in winter temperatures may fall to zero. The mean maximum temperature in the Limpopo basin generally varies from 30 to 34°C during summer to 22 to 26°C in winter.

2.3 Socio-economic conditions

The Limpopo River basin is an arid to semi-arid region where water is of critical strategic importance to all development. Water has a potential limiting effect on all future development in the region. The Limpopo River basin is home to around 14 million people in four riparian states.

Urban centres such as Gaborone, Francistown (both in Botswana), Pretoria, Johannesburg, Polokwane (South Africa), Bulawayo and Beitbridge (Zimbabwe) and Xai-Xai and Chokwè (Mozambique) are major users of water resources of the basin, supplying industries and municipalities. Together with these urban centres are rural areas where water is used for domestic purposes, livestock watering and irrigation.

Irrigation is concentrated largely in South Africa, but Zimbabwe and Mozambique also have large irrigated area. Irrigation relies on stored water. The majority of the rural population, mostly subsistence farmers, relies on rain-fed agriculture for their livelihoods.

Table 2.1 shows total population for the Limpopo River basin states for the year 2007. Botswana has the highest percentage (69%) of its population living in the Limpopo River basin followed by South Africa with 22%, Zimbabwe with 10% and lastly Mozambique with 7%.

Table 2.1 Population characteristics of countries of the Limpopo River basin

Country	Total 2007 population (million) estimated	Total population in Limpopo Basin 2007 (million) estimated	% in Limpopo River basin
Botswana	1, 756,651	1,205,580	69
South Africa	47, 900,000	10, 720,838	22
Zimbabwe	11,392,629	1, 140,833	10
Mozambique	20,366,795	1,389,703	7
Total	**81,416,075**	**14,456,954**	**18**

2.4 Water use and developed infrastructure

2.4.1 Water demand

In Botswana, urban/industrial water supply is the largest and fastest growing sector of water use in the Limpopo River basin. The annual use was estimated to be in the order of 60 Mm^3/a (Environmentek, CSIR, 2004), with a projection to attain 118 Mm^3/a by the year 2020.

Most of the irrigation in this country was along the Limpopo river banks. It attained 1,500 ha in 1985, but was reduced to about half of that in the 1990s due to continued drought. Most of the irrigation is done with water from boreholes and "sand-river" wells, with limited amounts taken from river flows. Total licensed volume of water for irrigation is in the order of 20 Mm^3/a. There are plans to increase irrigation area, using mostly treated effluent. The planned Lotsane Dam, located some 3 km west of the town of Maunatlala, will also contribute for the irrigation water supply.

Projections for rural water supply indicate a total demand of about 20 Mm^3/a for the year 2025. Presently rural water supply is essentially through the abstraction of groundwater.

Livestock is very important in socio-economic terms, with a total of about 2.2 million animals in the Limpopo area, of which 70% is cattle. The corresponding water demand is quite significant, in the order of 25-30 Mm^3/a . This demand is widely dispersed and part of it is rurally based, so it will have to be analysed in detail how it can be satisfied in the future in competition with other water uses.

Total water demand for South Africa is presently in the order of 3,000 Mm^3/a, of which 1,485 Mm^3/a are for irrigation, which is the largest consumer, 665 Mm^3/a for urban supply, 140 Mm^3/a for rural supply, 445 Mm^3/a for mining and power production, 45 Mm^3/a for afforestation and 250 Mm^3/a for water transfers to neighbouring river basins.

The Crocodile River, with 40% of the total water demand, and the Olifants River, with 30% of the total water demand, are the sub-catchments with the largest water use.

The perspectives for the future is that water demand for urban and rural water supply in South Africa will increase, in correspondence with the increase of population and the level of service provision, while there is no significant expected increase in the other water uses.

Water demand in Zimbabwe is concentrated in the upper part of the catchment in the Upper Mzingwane River and the Mwenezi River sub-catchments. Bulawayo, the second largest city in Zimbabwe, partially sits in the Upper Mzingwane River catchment.

The water demand data shows that agriculture and UIM (urban, industry and mining) are the largest water uses in the catchment, with figures of water demand of approximately 640 and 690 Mm^3/a. Primary use (rural water supply) only accounts for less than 1% of the total water requirements. It is expected that these water demands will grow to about 1,000; 810 and 6 Mm^3/year respectively in 2025.

There is a possibility that Bulawayo will not require water from the Mzingwane River catchment as a more sustainable option is being considered with the exploitation of the Gwayi River catchment up to the Zambezi River.

In Mozambique, almost all of the water demand in the Limpopo River basin is for irrigation, as urban and industrial demand are quite small and rural water supply is dispersed and use water from local aquifers.

Present irrigation is concentrated in two areas, Chokwè and Xai-Xai. In Chokwè, the infrastructured area is about 22,000 ha, but only about 8,000 ha is being used, with an additional 7,000 ha being rehabilitated within the next 3 years and the remaining 7,000 ha afterwards. In Xai-Xai, there are about 4,000 ha that have been recently rehabilitated. There are plans to increase this area under irrigation to 9,000 ha. The existing area uses a combination of seepage water from the hill slopes and water pumped from the Limpopo River, depending on the month of the year.

There is one large irrigation project that started being developed in Mozambique, PROCANA, for sugar cane production. PROCANA intends to develop 30,000 ha on the banks of the Elephants River.

Present water use, including other smaller irrigation users, amounts to about 270 Mm^3/a. The developments in irrigation could increase the water demand for irrigation to about 1,200 Mm^3/a in the future. One important aspect to be considered is water demand management, as the present unit water consumption, particularly in the Chokwè irrigation scheme, is too high.

Livestock is quite important in Gaza Province, in the Limpopo River basin, with an inventory in 2007 giving a total of 400,000 cattle, which would require around 7 Mm^3/a.

Although there are two major cities in the Limpopo River basin in Mozambique, Chokwè and Xai-Xai, their water demand is relatively small, now in the order of 4 Mm^3/a. Other towns, like Chibuto and others, have very small water demands.

Industrial water use in the basin is also small and mostly is part of the urban water supply systems. There is a major mining project being planned for the Chibuto area, to extract heavy mineral sands, which will abstract water from the Limpopo River. However, the investors announced recently that the project was put on hold.

Table 2.2 shows that the greatest user of water by sector in the four Limpopo River riparian states is irrigation, which takes 50% of the total water demand, followed by urban supply, although urban (including industry and mining) is the major user in Botswana and in Zimbabwe. Total present use is about 4,730 Mm^3/a, of which almost 2/3 in South Africa and 30% in Zimbabwe while Mozambique use 6% and Botswana 2%.

Table 2.2 Present water use by sector for Limpopo River riparian states (Mm^3/a)

Country	Urban	Rural	Irrigation	Mining	Power	Others	Total
Botswana	60	12	20	9	*	0	**101**
South Africa	665	140	1,485	230	215	295	**3,030**
Zimbabwe	690	6	640	*	*	0	**1,366**
Mozambique	4	9	270	0	0	0	**283**
Total	**1,419**	**167**	**2,415**	**239**	**215**	**295**	**4,750**

**included as part of urban*

Figure 2.5 shows the general distribution of water demand in relation to the mean annual runoff for the catchments of the Limpopo River basin. It shows that some of the catchments, such as Crocodile, Sand, Mzingwane and Mwenezi, have water demands exceeding the total available natural water resources.

2.4.2 Storage dams and water transfers

The Limpopo River basin is quite developed in terms of storage dams, without which it would not have been possible to make the present intensive use of its water resources. The storage capacities of large dams in the Limpopo River basin, reflected as a percentage of the mean annual runoff (MAR) per sub-catchment, is reflected in **Figure 2.6**.

There are a number of large dams in the north-eastern parts of Botswana, all in the Limpopo River basin, namely Gaborone, Shashe, Letsibogo and Bokaa dams, with total storage capacity of about 355 Mm^3. Other reservoirs planned to be built in the near future are Dikgatlhong, Lotsane and Thune dams, which will give a total yield of about 70 Mm^3/a, with a total storage capacity of about 400 Mm^3, mainly in Dikgatlhong Dam. There are also plans for a programme of small and medium dams that may produce a yield of about 20 Mm^3/a.

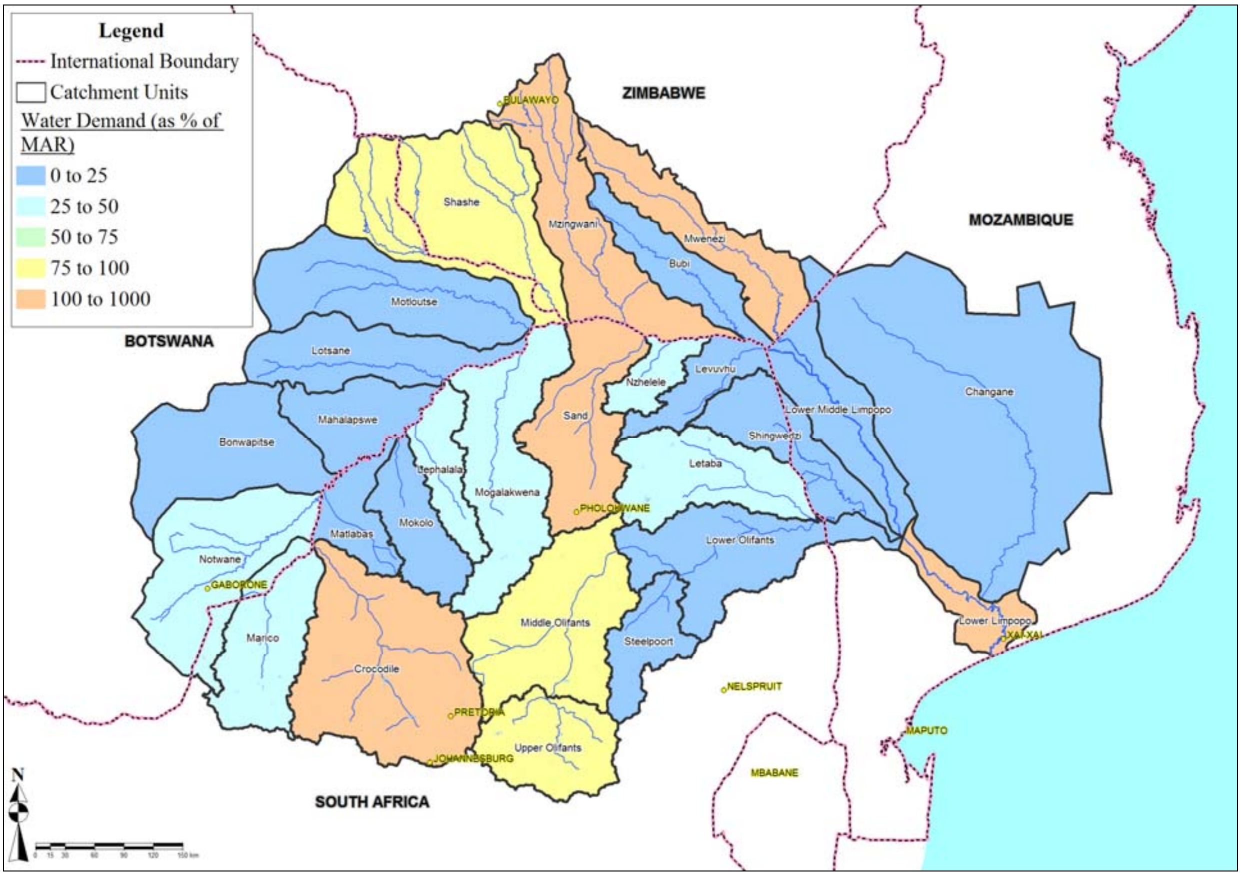


Figure 2.5 ***Distribution of water demand (as % of MAR) for the different sub-catchments of the Limpopo River basin***

There are 21 large or medium dams within the Mzingwane River catchment in Zimbabwe. Most of these dams are located in the Upper Mzingwane and Mwenezi river catchments and were constructed and are owned by the Government for irrigation, rural water supply and urban use. Bulawayo City Council owns 3 dams in the area. Smaller dams of heights of less than 10 m and capacity less than 5 Mm^3 exist, but these are usually privately owned or were constructed by NGOs as support for rural communities. Their impact on the overall hydrology of the catchment is negligible.

In South Africa, the number of major dams is quite large, with a total of 160 being classified as large dams in accordance with the criteria of ICOLD. From these, 15 have storage capacities above 100 Mm^3 and 34 are between 10 Mm^3 and 100 Mm^3. Loskop Dam on the Olifants River is the one with the largest storage, namely 375 Mm^3.

In Mozambique there is one large dam in the Limpopo River basin in Mozambique, Massingir Dam located on the Elephants River. It is the dam with the largest storage capacity in the Limpopo River basin, about 2,800 Mm^3. The dam suffered a serious accident in 2008 and studies are now going on to allow for its rehabilitation. Macarretane Dam is located on the Limpopo River, with a small storage capacity of only about 4 Mm^3.

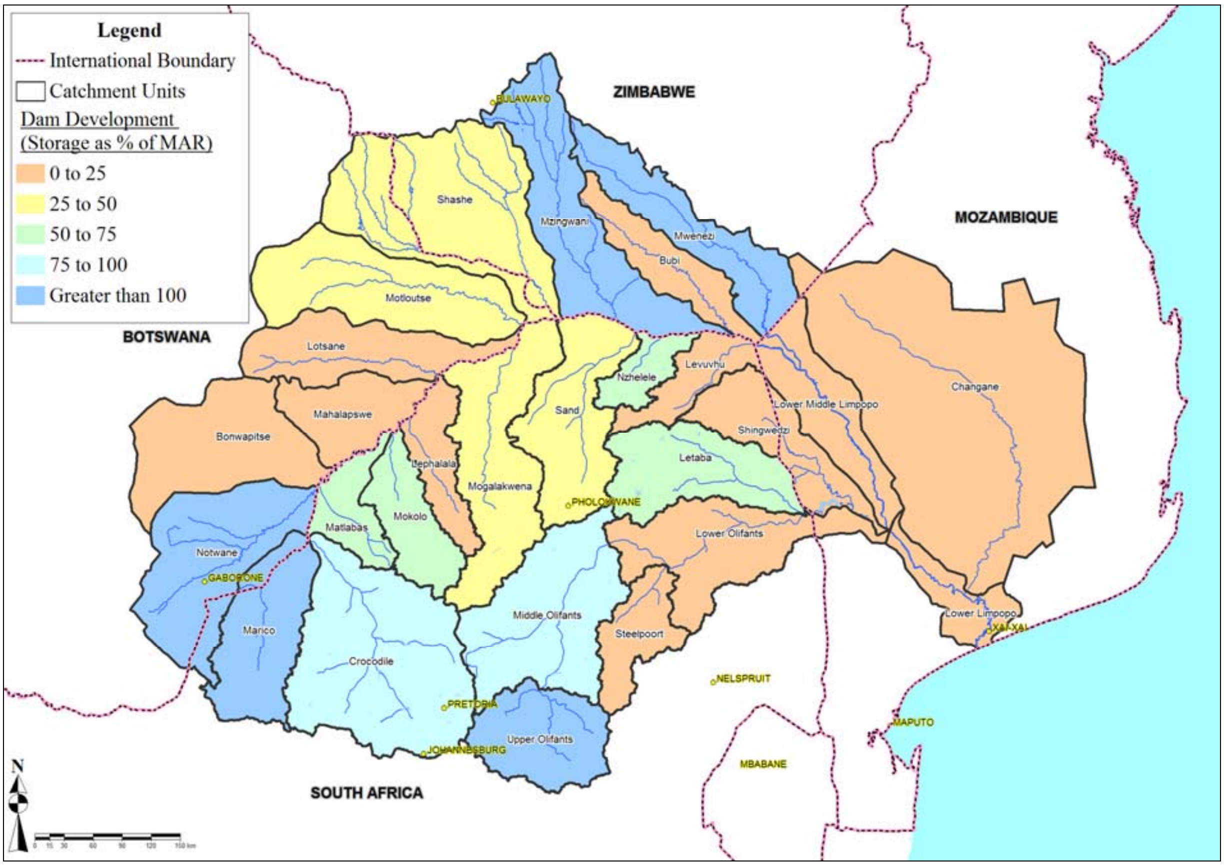


Figure 2.6 Storage capacities of large dams in the Limpopo River basin as a percentage of MAR per sub-catchment

In all countries there are many small dams, with storage capacities below 5 Mm^3 and in most cases, below 1 Mm^3. The impact of each of these dams on the basin hydrology is negligible, but the cumulative effect of a large number of these small dams in a sub-catchment must be duly taken into consideration in any hydrological modelling exercise.

There are several interbasin transfers into the Limpopo River basin. The major transfers are from the Vaal River system to the Gauteng area (Crocodile River catchment) and from the Usutu and Incomati rivers to the Olifants River for thermal power production. There are also extensive plans for transferring water to the City of Bulawayo from the Gwaai/Shangani River system. Within the Limpopo River basin interbasin transfers also occurs, e.g. from the Marico River in South Africa to Gaborone in Botswana as well as the transfer from the Shashe River via the North-South Carrier to Gaborone.

2.4.3 Water demand management

Water Demand Management (WDM) is a component of an Integrated Water Resource Management (IWRM) approach to managing resources traditionally allocated by the public sector. By effectively managing water demand, pressures on supply may be alleviated. Although WDM is classified as a demand side approach insofar as it aims to alter the behaviour of users in order to reduce demand, it is not separable from the implications it has for supply. Thus, WDM may be considered as an interface of supply and demand side considerations in the provision of water.

Water Demand Management is the lowest cost approach to meeting water demands without expanding supply, by improving the efficiency of water use. WDM uses physical (technical), social and economic interventions in order to reduce water usage demands and decrease water losses in order to achieve water balances. In the case of the Limpopo River basin, the most significant water uses where WDM can have an impact are in relation to irrigation, main urban centres, industry and mining. Water tariffs are one of the most used tools to induce an increase in the efficiency in the use of water.

Water Demand Management is a general concern for the four countries of the Limpopo Basin, with plans or concrete measures being considered in the policy or similar documents of the countries.

2.5 Water resources and water balance

2.5.1 River flow characteristics

Rainfall, and consequently river runoff, has a clear seasonal pattern with long dry periods. The average monthly flow in Chokwe in Mozambique (**Figure 2.7**) shows the large variation in flows. The months of August to October normally have very little flows.

The large seasonal and inter-annual variation of river flows has forced a large development of dams to secure water availability during the dry periods. Despite this the Limpopo River has changed from being a perennial river to drying out over large stretches of its middle and lower reaches because of the large water use in the basin.

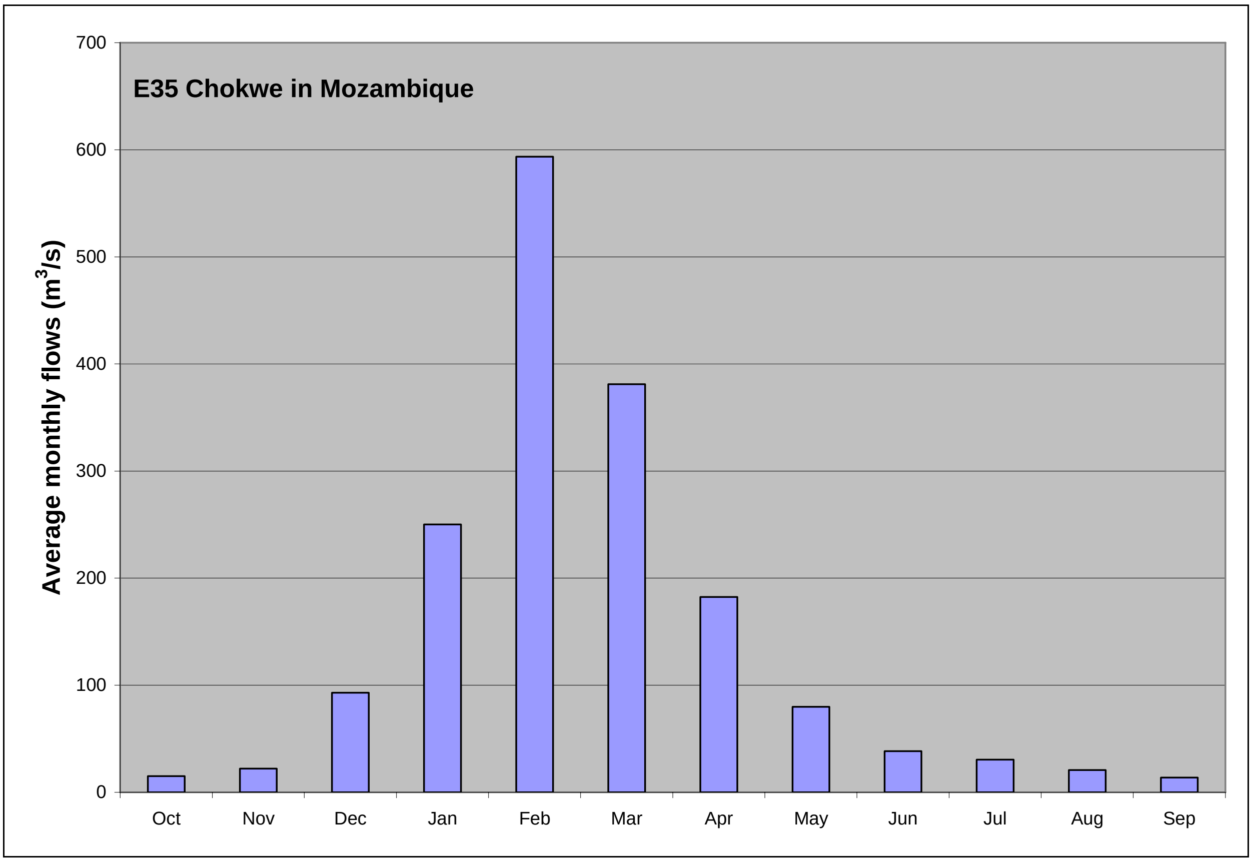


Figure 2.7 Distribution of average monthly river flows in the Limpopo River close to its mouth

The increased water use can also be seen by the long records of observed river runoff. The flows in Limpopo River at the Chokwé gauging station has steadily decreased since its start of operation (see **Figure 2.8**).

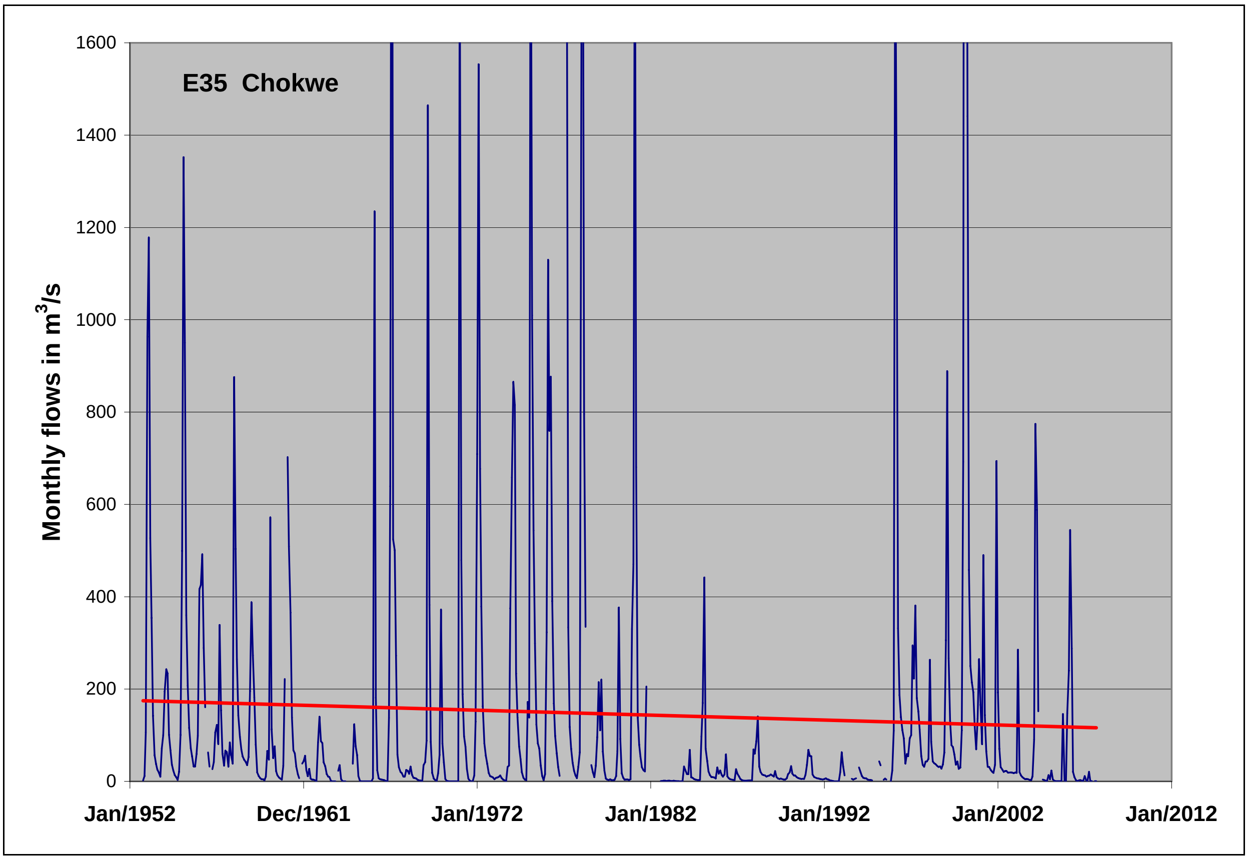


Figure 2.8 ***Observed runoff at Chokwe showing the downward trend in river flows due to increased water abstractions***

Because of the large effect of man-made influence on the Limpopo River it is difficult to assess in detail the available water resources. Observed river runoff is in almost all cases affected by upstream abstractions and cannot be used directly. The normal procedures are therefore to apply hydrological models, which are used to estimate natural runoff. This has been made for all the South African river basins as part of the national water resources management. Also in Zimbabwe assessment of natural MAR has been made in 1984 and in 2004. Based on the results from these assessments and by analysis of observed river runoff in Botswana and Mozambique, emphasising in the old records when water use was limited (before 1960), a preliminary map of average catchment river runoff (natural) has been created (see **Figure 2.9**).

Figure 2.9 shows that the water resources in the Limpopo River basin vary much. The driest areas are found in Botswana, where the natural runoff in large areas is less than 5 mm/a. Highest natural runoff is found in the catchments in South Africa dominated by mountainous regions, such as the Olifants, Letaba and Levuvhu rivers that have 40 or more mm/a. Also in the very upper parts of the catchments of Zimbabwe, Botswana, and western part of South Africa the river runoff may be high. However, since the rainfall and natural water resources decrease rapidly as the tributaries flows down towards the Limpopo River the average areal runoff becomes low to medium for sub-catchments.

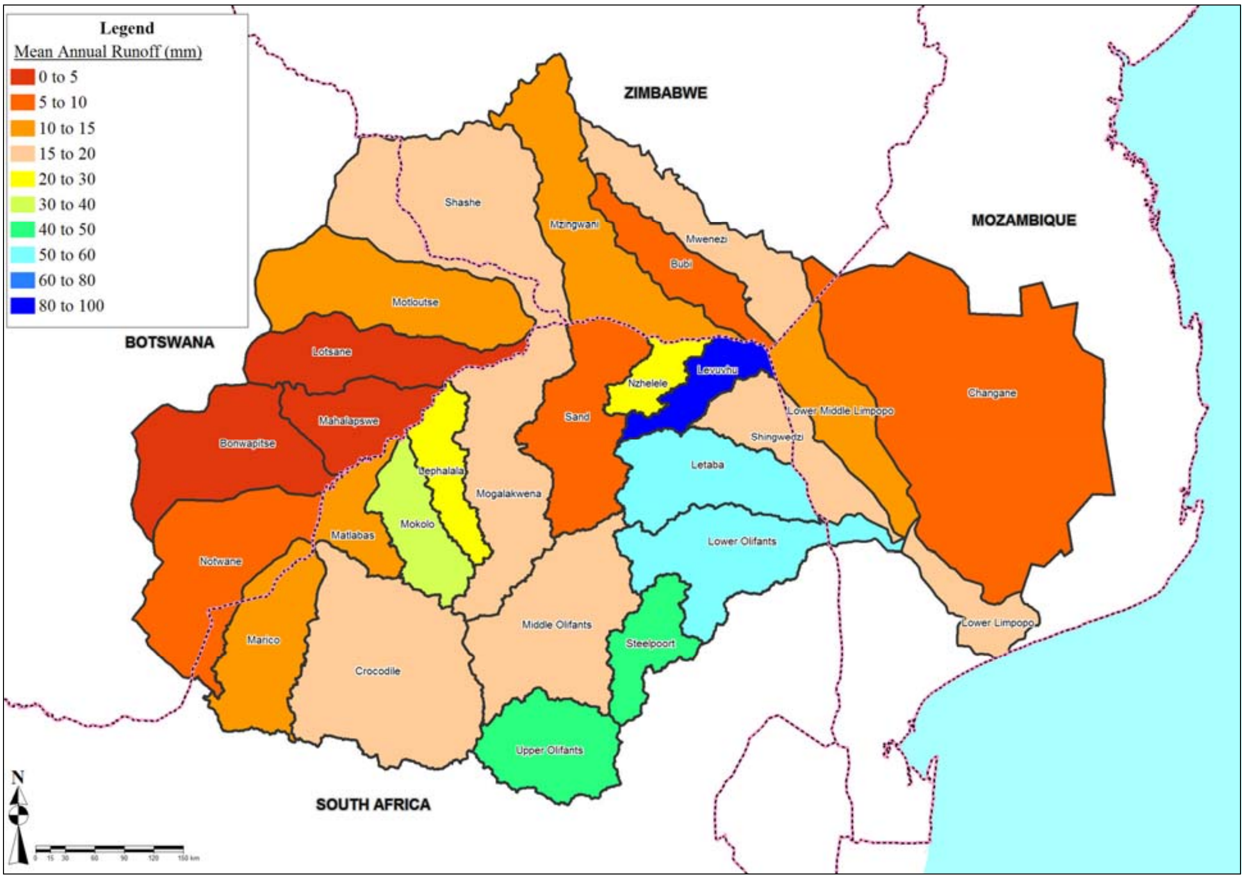


Figure 2.9 ***Preliminary estimation of mean natural water resources in the Limpopo River basin (The map depicts average catchment runoff in mm per year)***

2.5.2 Water balance

To give a preliminary estimate of the water balance, estimated water availability has been related to the present water use in each of the sub-catchments. **Figure 2.10** shows the ratio between water availability and water demands for the Limpopo River basin. It shows that for most of the sub-catchments in the Limpopo River basin, the water availability is less than the water demands and that the catchments are stressed. The surplus in the Crocodile (West) is a result of return flows from urban areas, supplied with water transferred from the Vaal River.

The data required to conduct a preliminary water balance was generally available in South Africa. The data required for preliminary water balances was not as detailed and in some cases incomplete in the other three riparian countries. This required some assumptions and extrapolations of data to estimate yields and water availability. Some water use data had to be manipulated where possible to organise total water use per sector according to the sub-catchment divisions.

The water balance estimates of Botswana, Zimbabwe and Mozambique are thus more indicative for graphical presentation, and should not be taken as accurate water balances. Shortfalls in data required for water balances are discussed for each country.

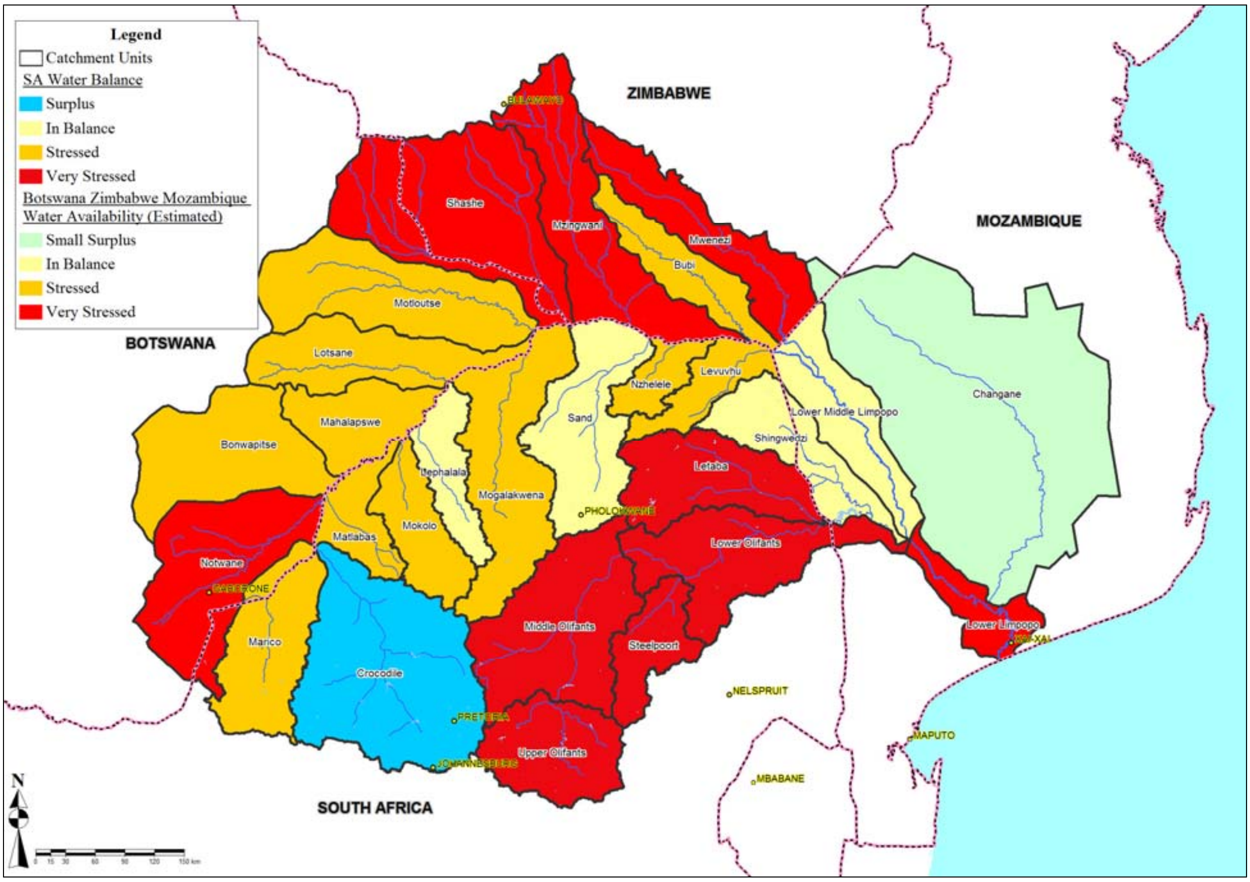


Figure 2.10 ***General water balances in the Limpopo River basis illustrated as the ratio between natural runoff and water use per sub-catchment***

There were a number of factors contributing to difficulties in acquiring the necessary data in Botswana. Water demands presented in the National Master Water Plan were not summarised by runoff catchment and generally presented as a total for the country, or not at all. The focus seems to be more on local supply, and some of the data is not very beneficial to water resources management on the basin scale. The split between supply from surface water and groundwater sources was also not quantified for some of the water demands. This is particularly important in Botswana where groundwater plays a major role in water supply. The yields of the existing major dams in Botswana were not determined in the National Mater Water Plan, and these had to be estimated via a relationship between storage, runoff and yield derived from South African and Zimbabwe data. The effect of environmental water requirements in reducing the yields and water availability has not been quantified for the dams in Botswana. There are uncertainties in the data from Botswana, and some effort will be needed to summarise and re-organise water demands and water availability according to runoff sub-catchment.

Although water balances at a common level of detail are available from the National Water Resources Strategy for all the South African sub-catchments, the base level is year 2000. Newer data from studies such as the WR2005 could be included to update the water balances.

Data on water availability and water demands was more readily available per sub-catchment for Zimbabwe. There is however conflicts in runoff (MAR) between data sources. The MAR's of the various sub-zones within the Mzingwane catchment derived in the Assessment of surface water resources in Zimbabwe (2004), are significantly different from those in the "Blue Book", which was produced in

1984 and has been generally used by the water authorities to guide water resources development. The reliability of water demands data from the Mzingwane River catchment draft river system outline plan is not certain, as the data contains some obvious mistakes, and these will need to be rectified. The split between water demands of the city of Bulawayo that are supplied partially from the Mzingwane River catchment and partially from the neighbouring Gwayi River catchment are not clear. Yields from major dams have been calculated and where used to estimate the surface water availability, and also helped derive a relationship between storage, runoff and yield for the region. The uncertainty on MAR's due to the conflicts between data sources does, however, reduce the confidence in the yields. Water has been assigned to the environment in the Mzingwane catchments, but these will need to be reviewed due to some obvious errors, and to possibly determine environmental water requirements for the countries at a more common level.

Apart from Massingir Dam, little development of surface water resources exists in the Mozambique portion of the Limpopo River basin. Most of the rural villages are supplied from groundwater and there are no surface water demands in the Changane sub-catchment. Although the yield of Massingir Dam is large, this is dependant mainly on runoff generated upstream in South Africa, and the water balance for the Lower Limpopo River sub-catchment when considering only incremental flows generated in the sub-catchment, is a water deficit. Water availability data in Mozambique is generally limited and the yields of surface water resources are not certain. The current water demands are relatively low. Some expansions, particularly in agriculture in the near future will increase water demand in the Lower Limpopo. The effect of environmental water requirements of water availability has not been quantified.

2.6 Water quality and environmental status

2.6.1 Water quality

The overall quality of the Limpopo River can be described as impacted, but not severe. The various land use activities in this very large catchment have influenced the water quality and the influence of the un-impacted rivers needs to be determined

The data in the upper and middle reaches in Botswana and South Africa show that the water quality is dominated by sodium and chloride. Nitrate and phosphate concentrations are generally below 1 mg/ℓ even if some very high values can be found locally. Below the confluence with Olifants there is a slight deterioration in quality probably caused by the large manmade influence in the Olifants River. The Olifants River is also one of most sediment-prone rivers in southern Africa caused by the intensive agricultural and industrial activities in the basin.

In Botswana, the quality of water is variable depending on the river ranging from relatively good water quality to poor water quality. Total dissolved solids concentrations range from 84 mg/ℓ to 4633 mg/ℓ. The water quality is generally dominated by sodium and chlorides. Nitrates are also variable, ranging from 0.27 mg/ℓ to 11.78 mg/ℓ.

In the upper reaches of the Limpopo catchment in South Africa the water quality is generally good, ranging from 58 mg/ℓ to 307 mg/ℓ for total dissolved solids (TDS). The water quality is dominated by sodium and chloride. Nitrate and phosphate levels are low (typically less than 0.5 mg/ℓ for nitrates and 0.05mg/ℓ for phosphates).

Water quality data of the middle reaches of the Limpopo River are measured at the monitoring point at Beitbridge. This site is monitored by both South Africa and Zimbabwe. The quality of water at this point in the Limpopo River can be described as impacted. While the TDS concentration is 350 mg/ℓ, the impact is not severe. At this point in the river, the quality reflects the influence of catchment activities upstream, and the net contribution from un-impacted rivers is important. The water quality is again dominated by sodium and chloride. Nitrate and phosphate concentrations are below 1 mg/ℓ.

The lower reaches of the Limpopo River is divided in both South Africa and Mozambique. The quality of water in the river indicates a slight improvement up to the confluence with the Olifants River where after there is a slight deterioration in quality. There is an order of magnitude difference in the nitrate results between the station in the river as it leaves South Africa and the Massingir station downstream.

TDS concentrations in the upper portion of the river in Mozambique are at 220 mg/ℓ but below the confluence with the Olifants River (TDS of 294 mg/ℓ) the TDS increases to 326 mg/ℓ. Thereafter there is further deterioration in water quality to 448 mg/ℓ. There is insufficient data to determine the dominant type of water quality, but it is expected that sodium and chlorides dominate with some influence of sulphates, a residual effect of the mining activities in the upper reaches of the catchment.

A recent case of water quality problem has been the sudden crocodile deaths in the Olifants River in the Kruger National Park in South Africa during 2008 bordering to the Massingir Dam in Mozambique. Although much research has been done, the issue has not completely been resolved and many possibilities are still being considered as potential consequences. Monitoring has been done, but no data or reports are available yet.

It has been determined that toxicants accumulate in the sediments of the Massingir dam. It is currently believed that these toxicants cause the deaths of the crocodiles. The way in which these toxicants are transferred to the crocodiles are yet unknown. There are several potential sources of these toxicants, including mines, industries, sewerage disposal and agriculture that are practiced in the catchment. It is believed that the combination of these land uses causes the toxicants in the sediments and subsequent crocodile deaths. These toxicants accumulated in the sediments over a long time, but changes in environmental conditions presumably triggered the sudden deaths caused by the toxicants.

South African National Parks currently monitors the crocodile deaths in the Olifants River. Approximately 350 crocodiles died in 2008, while only about 30 crocodile deaths were recorded in 2009. The only measure that was taken to prevent these deaths was to burn the bodies of the dead crocodiles in order to prevent other crocodiles from consuming the bodies. The reduction of crocodile deaths can either be explained by environmental changes, or it is due to this protective measure.

2.6.2 Environmental flow requirements

The legal framework and implementation environmental releases differ between the four countries.

The Reserve in the South African National Water Act (NWA) constitutes both the Basic Human Needs Reserve (BHN) and the Ecological Reserve (ER). The Ecological Reserve and EFR are regarded as synonyms. The Reserve has priority of supply before any other water user. The NWA requires that all future water-resource developments be supported by a Reserve study of the appropriate confidence level (Desktop, Rapid, Intermediate or Comprehensive).

A number of methods have been developed internationally and within South Africa, to define the environmental flows required to maintain a river in a selected target management class.

The three comprehensive methods used to determine EFRs in South Africa are:

- The Building Block Methodology (BBM) which was developed in the 1990s. The basic premise of this method is that riverine species are reliant on basic elements (building blocks) of the flow regime to maintain the river in a desired state. By combining these building blocks, an acceptable flow regime for ecosystem maintenance can be constructed. This basic premise also forms the basis of the next two methods discussed below and routinely used in South Africa.
- The Flow Stressor Response (FSR) method was developed in 2000 in South Africa to predict impacts on the low-flow part of the regime.
- The Downstream Response to Imposed Flow Transformation (DRIFT) was first used in 2003. It is a scenario based approach that describes the changes expected with various future scenarios.

These holistic methods discussed above, have severe financial and time implications.

As an alternative to these methods described above, the South African Desktop Model was developed as a rapid, low-confidence environmental flow (EF) assessment using results from the many EF assessments done at a higher confidence level. The Desktop model is routinely used in South Africa. This method allows the user to quickly get a first estimate of the EFR for any quaternary catchment in South Africa. The inputs to the model are the natural flow data and the Ecological Management Class (EMC). A desktop study of the EMCs for all the quaternary catchments in South Africa exists and can be used as input for this model.

Some higher confidence level Reserve Determinations were done in the Limpopo River basin in South Africa and are given in **Table 2.3**.

Table 2.3 Intermediate and Comprehensive Reserve studies in South Africa

Secondary drainage catchment	River	Level of reserve
A2 and A3	Crocodile (West) and Marico	Intermediate Reserve (to be completed 2010)
B	Olifants & Letaba	Comprehensive Reserves

The 1998 Water Act of Zimbabwe and Zimbabwe's Environmental Management Act provides for the necessary protection of rivers and estuaries. These acts ensure that water is made available for primary purposes and for the needs of aquatic life and associated ecosystems. Extensive work regarding effluent and waste standards and management has already been done following the amendments to the Water Act in 1998 and the subsequent passing of the Effluent and Waste Standards Statutory Instrument 274/2000. Effluent standards are classified by colour coding into blue (environmentally safe), green (low environmental hazard), yellow (medium environmental hazard) and red (high environmental hazard). The default EFR in Zimbabwe is approximately 5% of the natural flow.

A mini-DRIFT method based on a scenario approach was also developed and tested in Zimbabwe (2003) requiring a few weeks as opposed to the months and even years of the more comprehensive methodologies. The state of Mzingwane Dam, upstream and downstream was assessed through a study that was financially and technically supported by IUCN - The World Conservation Union, Regional Office for Southern Africa. This study, called Mzingwane Environmental Flows Assessment gives some indication of the required flow for fish and invertebrates. The results were however not expressed in a format that can easily be included in this report. The study team also gathered information on MARs and found conflicting MAR values. More work is required to establish what hydrology in the environmental study was used and the percentage of the EFR suggested.

The Botswana Water Master Plan (1991) constitutes a set of plans arising from the extensive analysis options for development and management of water resources of Botswana until 2020. The plans not only outline the basic physical and engineering developments, but also take into account economic, social, environmental, institutional and legal factors. No studies on the EFRs of the tributaries in Botswana are available.

Principles for environmental conservation and environmental flows are imbedded in Mozambique's Water Law of 1991 which is given priority over other uses except domestic use. This has been strengthened in the new Water Policy, approved in 2007. However, regulations and specific studies are missing. Studies done in some river basins have used the South African Desktop Model. For the Limpopo River basin in Mozambique a study was conducted in 2007 (Salomon & PDNA). It selected two sites to analyze environmental flow requirements (EFR), one about 10 km downstream of Massingir Dam and the other some 30 km downstream of the confluence of the Limpopo and Elephants rivers. The assigned categories for both sites were C/D. The Total EFR as percentage of MAR for both sites was in the order of 14% if category C was adopted and between 9 and 10% if category D was adopted. Until now, no estimates have been made of the estuarine freshwater requirements.

The major challenge to the Limpopo River basin Managers will be to accommodate and successfully implement the different methodologies, data availability, legal requirements and implementation strategies of the four basin countries. The EFR has been developed to ensure sustainable development and therefore play a major role in the determination of the system yield and available water resources for future water resources development. To give an indication of the EFR for the main tributaries, preliminary estimates have been given based on the South African desktop model in **Table 2.4**.

2.6.3 Environmental status

For the determination of environmental flows in South Africa the rivers must be classified into an Ecological Management Class. The Ecological Management Class of a catchment is dependent on the upstream development as well as the ecological sensitivity of the species in the river as well and the conservation status of the area.

Four target classes A to D are used with Class A being close to natural conditions and Class D regarded as highly modified. A catchment can also be classified as category E or F but these require measures to achieve improvements to lead it at least to category D.

Table 2.4 Estimates of the Environmental Flow Requirements for the sub-basins of the Limpopo River

Sub-catchment	Quaternary catchment at outlet	EMC or estimated EMC	Estimated EFR (% of MAR)	Comments
Marico	A23D	C	20	Large dams and irrigation activities
Crocodile	A24J	C	20	Urbanised and large irrigation areas with dams
Mokolo	A24J	C	20	Many farm dams and irrigation
Matlabas	A24J	C	20	Many farm dams and irrigation
Lephalala	A50H	D	13	Undeveloped but low Ecological Water Requirement
Mogalakwena	A36J	C	20	Mining dams and irrigation
Sand	A71K	B	28	Largely natural
Nzhelele	A80G	D	13	Irrigation and dam
Levuvhu	A91K	B	28	Kruger National Park (KNP)
Shingwedzi	B90H	A	40	Originates in KNP
Letaba	B83E	B	28	Very developed but flowing through KNP
Upper Olifants	B71F// B41K	D	13	Highly modified with mines, dams and irrigation
Lower Olifants	B73J	C	20	Developed but releases for KNP
Shashe		B	28	Development only in Upper Shashe
Mzingwani		B/C	24	Development (Bulawayo) in upper reaches of Mzingwane
Bubi		B	28	Largely natural
Mwenezi		B	28	Largely natural
Notwane		B/C	24	Notwane Dam for water supply to Gaborone
Bonwapitse		B	28	Largely natural
Mahalapswe		B	28	Largely natural
Lotsane		B	28	Largely natural
Motloutse		B	28	Largely natural
Lower Middle Limpopo		C	16	Massinger Dam
Lower Limpopo		C	15	Irrigation from Macarretane Dam
Changane		A/B	35	Natural

Estimates of the EMC and the associated Environmental Flow Requirements at the outlets of the catchments are given in **Table 2.4**. The EMCs for South Africa were taken from a desktop study, but no estimates for the other three countries are available. The estimates were based on the level of development in the river. The confidence level of this estimate is very low and it will have to be confirmed or corrected with a field study during the comprehensive river basin study.

Figure 2.11 presents this estimated EMC of the sub-basins as indicated in **Table 2.4**.

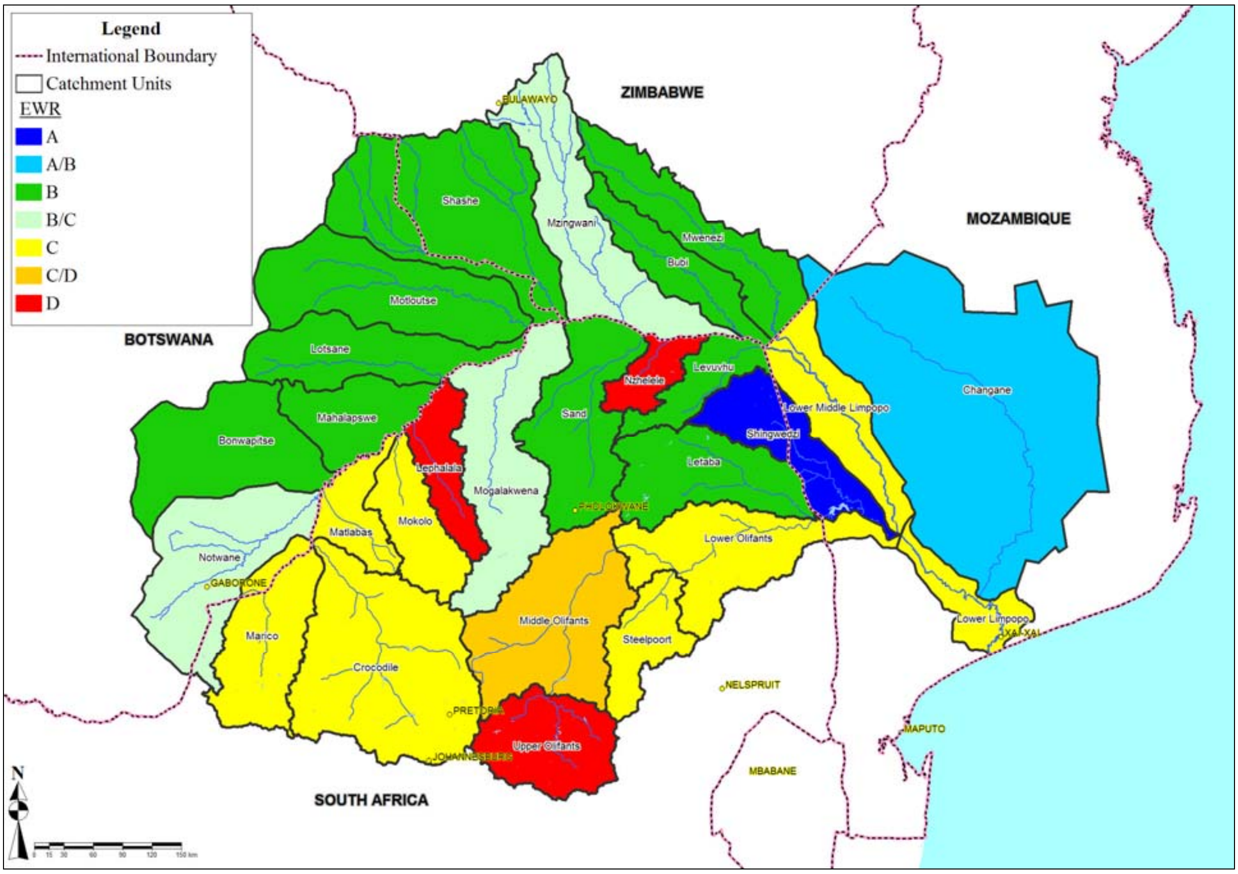


Figure 2.11 Preliminary estimate of ecological status of the Limpopo River basin

2.6.4 Protected areas

The Limpopo River basin has one of the highest percentages of protected areas in southern Africa. The Great Limpopo Transfrontier Park, presented in **Figure 2.12**, comprising of the Kruger National Park in South Africa, the Limpopo National Park in Mozambique and the Gonarezhou National Park in Zimbabwe, takes up a very large part of the river catchment and borders both the Limpopo and Olifants rivers for long stretches. In addition large areas in South Africa, such as the Pilanesberg, Waterberg and Madikwe comprise national parks and private game farms. In Zimbabwe also the Matopos National Park lies within the Limpopo River basin. In Mozambique the Banhine National Park is a conservation area located between the Limpopo River and the tributary Changane, with a perspective of it becoming also part of the Great Limpopo Transfrontier Park.

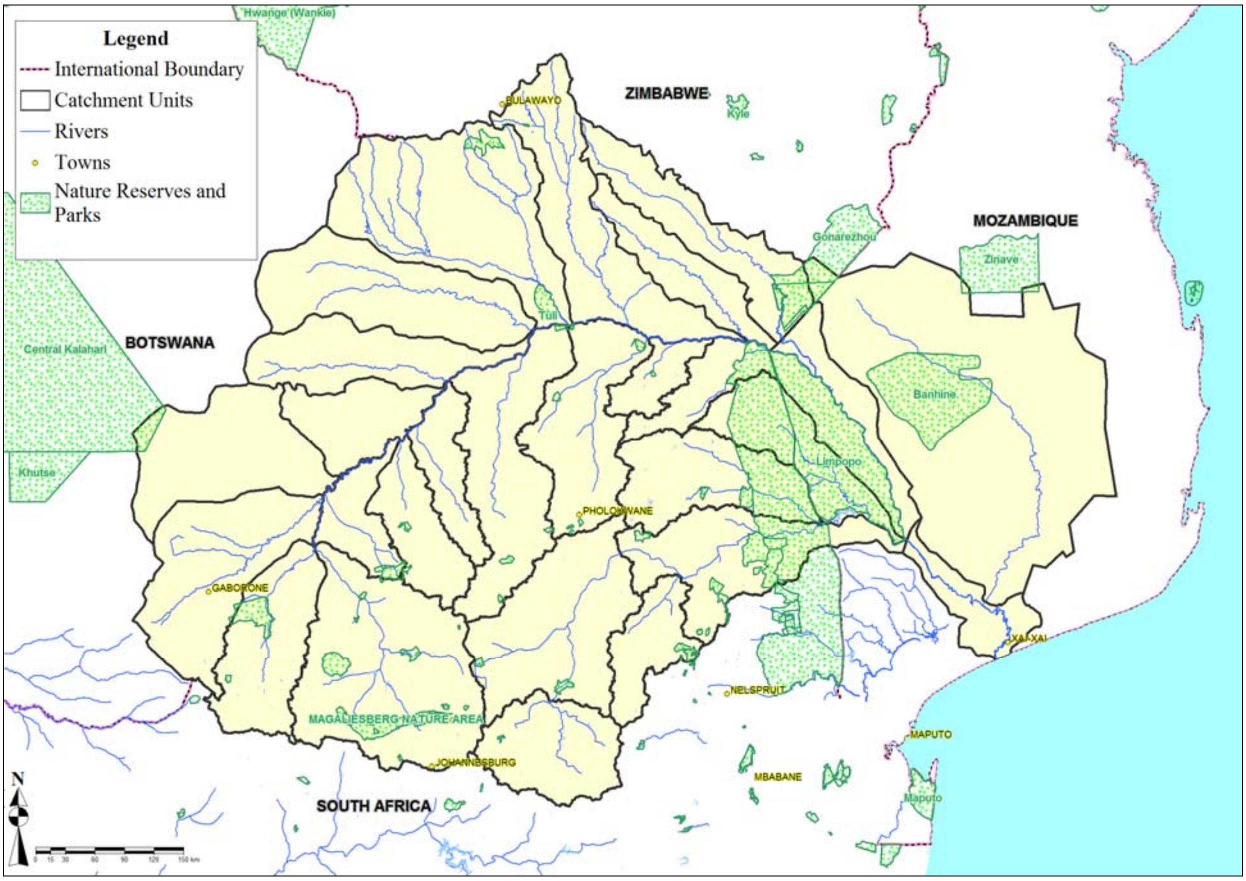


Figure 2.12 The Great Limpopo Transfrontier Park

2.7 Legal and institutional setting

National water policies together with international water law determine the framework within which the Integrated Water Resources Management Strategy of a joint basin is to be developed. National policies guide the process for exploitation and development. International agreements, water conventions and rules guide the planning, utilisation and management of common water resources.

Table 2.5 and **Table 2.6** are a summary of identified instruments (respectively legal and institutional frameworks) essential for the joint management of the Limpopo River basin. This 'comparator' table shows the links in the regional/international and the relevant national policies and laws.

It appears that the legal and institutional mechanisms are in place for the riparian countries of the Limpopo River basin to achieve substantive progress in the joint integrated management of the water resources of the basin. All have signed the SADC Revised Protocol on Shared Watercourses whose principles are key for the joint management and all have the laws and regulations and also the institutions required for this cooperative effort.

Table 2.5 Legal Framework, Limpopo River basin States

Description	Regional	Botswana	South Africa	Zimbabwe	Mozambique
Water Policy	Regional Water Policy, SADC, 2006		National Water Policy, 1997	Various Pronouncements, no single paper	National Water Policy, 2007
Water Law	Revised Protocol On Shared Watercourses, SADC, 2000 *UN Convention, *Other reference docs (Helsinki Rules, Dublin Principles, WSSD, NEPAD)	Water Law [CAP 34:01] 1968	National Water Act, No. 36, 1998.	The Water Act [CAP 20:24], 1998; The Zimbabwe National Water Authority Act [CAP 20;25] 1998	National water Law, Law No. 16/91
IWRM Strategy	Regional Water Strategy, 2007		National Water Resources Strategy.	Water Resources Management Strategy for Zimbabwe, 2000	National Water Resources Management Strategy, 2007
Environmental Protection and Management		National Policy on Natural Resources Conservation and Development, EIA Act, 6 of 2005	National Environmental Management Act No. 107, 1998	The Environment Management Act (CAP 20:27), 2002	Environmental Law, Lei nº 20/97

Table 2.6 Institutional Framework, Limpopo Basin States

Description	Regional	Botswana	South Africa	Zimbabwe	Mozambique
Council of Ministers concerned with Water	SADC Council of Ministers for Water and the LIMCOM, LBPTC			National Water Steering Committee	National Water Council
Ministry \ Department for Water	SADC Directorate of Infrastructure and Services	Department of Water Affairs (DWA)	Department of Water and Environmental Affairs (DWEA)	Department of Water Resources (DWR & ZINWA)	National Directorate of Water (DNA)
Hydro-"provincial" Water Management	River Basin Commissions e.g. LIMCOM		Water Management Areas	Catchment Managers	Regional Administration for Water (ARAs).
Stakeholder Involvement		Water Apportionment Board	Catchment Management Agencies	Catchment / Sub-Catchment Councils	Basin Committees

3 PROBLEMS TO ADDRESS

3.1 Opportunities and challenges

From an integrated water resources management point of view, the Limpopo River basin offers both challenges and prospects.

One of the largest challenges of the Limpopo River basin is to distribute the water resources in an equal and sustainable way. **Figure 3.1** shows that a very large part of the Limpopo River basin has semi-arid to arid conditions. In these areas water resources are scarce and pro-longed periods of droughts can occur. Many people living in the semi-arid areas are thus vulnerable for secure water supply for domestic use and livestock and reliability of subsistence agriculture.

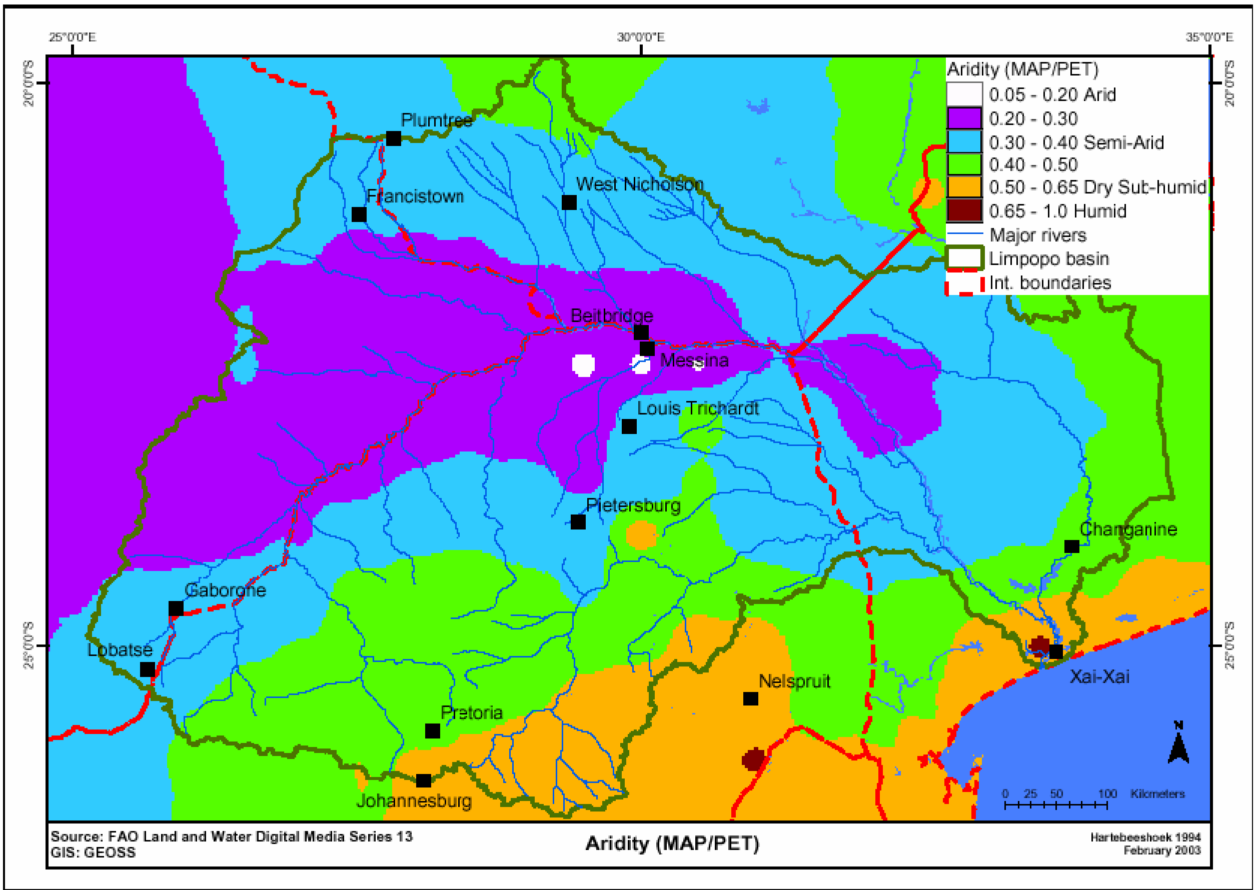


Figure 3.1 ***Map of aridity index defines as mean annual precipitation divided by the potential evapotranspiration (CSIR - 2003)***

On the other hand, the records of river flows in the Limpopo River in Mozambique show that a considerable volume flows into the sea. Although the river regime shows large variability with floods that cannot be captured and that the estuary demands a considerable inflow, this indicates the opportunity for infrastructural development to increase the efficiency of the water resources utilisation. The large-scale utilisation of the tributaries for domestic and agriculture purposes, and mining and power production in mainly South Africa is an example of how the water resources can be utilised to create economic growth and improve livelihood.

Protected environmental areas comprise a very large part of the Limpopo River basin. The large national parks contain unique biota with several threatened species and provide a significant part of economic activities in the river basin through tourism. It is therefore essential that any development of infrastructure, agricultural or industrial schemes are made without causing harmful effect to the environment and especially the protected areas. The preliminary analysis of the water quality data in the Scoping Phase has indicated that the river is already impacted. The potential further deterioration of the water quality by unsustainable upstream practices in urban areas and along the river with the agricultural and mining activities must be contained.

Groundwater in the Limpopo River basin is currently utilised to a large degree, especially in Botswana. The groundwater is, however, seldom taken into account in the river basin management that are generally focussed on surface water. A major challenge in the Limpopo River basin therefore is how to integrate groundwater and surface water use optimally to mitigate droughts. For this the groundwater/surface water interaction needs to be understood to a larger degree than is possible currently and methods of integrating groundwater sources in the system yield analysis tools must be improved.

Floods are a severe problem for the Limpopo River basin. The latest large floods in February 2000 by the Cyclone Eline caused enormous human and economic damage to the lower Limpopo River stretches. More than 700,000 persons were displaced and close to 1,000 died of drowning.

Global warming can severely increase the effects of both drought and floods. Recent studies have indicated that the intensity of extreme rainfall events has increased during the last decades. At the same time average rainfall is forecasted to decrease with up to15% for large areas of the Limpopo River basin (Schulze et al 2001). To understand the effects of climate change is one of the major challenges for the future water resources management of the Limpopo River basin.

Opportunities do, however, exist to improve the water use efficiency and to distribute the water resources to all users in the Limpopo River basin. River basin management has up to today mainly been made focussing on the national problems and prospects. A joint management of the river basin is likely to provide opportunities for joint solutions for the above challenges. Similarly water demand management has so far been implemented to a limited degree, which can open opportunities for more efficient use of the water resources.

3.2 Need for transboundary water resources management

Mutual benefits and equitable sharing of resources are key components to cooperation on water management and this is no different in the Limpopo River basin. There are four types of benefits:

- Benefits to the river;
- Benefits from the river e.g. agriculture, hydro power, secured urban water supply, etc. The challenge in this case is the optimisation and equitable sharing of these benefits;
- Reducing the costs caused by the river, e.g. flood and drought early warning systems; and
- Benefits at regional level, e.g. integration of regional infrastructure and markets.

Different joint visions or different investment priorities require various types of strategy documentation. However, in the case of the Limpopo River there is potential for mutual benefits in all of the above listed types.

The complexity of the Limpopo River basin is illustrated by the brief description in Chapter 2, while many challenges have been identified above for the future water resources management of the basin. It is thus clear that joint transboundary river basin management is required to reach equality and sustainability for water resources of the Limpopo River basin. Development of water-related infrastructure in the four countries must be conducted with clear guidelines on allocated water and agreed minimum border flows. Similarly, mechanisms for exchange of data and information must be developed for compliance and for drought and flood emergency management.

The establishment of the LIMCOM and the Secretariat has created the basis for implementing joint transboundary river basin management in the Limpopo River basin. The joint management will enhance the possibility to focus the activities and development to the most needed areas and to overcome some of the limited resources that individual countries have.

Through the establishment of a common agreed baseline in terms of river basin characteristics, such as hydrology, environmental status, water demand and environmental flow requirements, the countries could have the basis for a water-sharing agreement. Identification of possible development options as well as mitigation measures for drought, floods and ecological deterioration will enable the four countries to establish a Joint Water Resources Strategy. The joint management process will create an understanding of each other's challenges and prospects that will improve the possibilities to solve joint problems both for long-term development and emergency situations.

The water authorities of the four countries currently have varying capacity both in terms of human and financial resources. This requires focussed capacity building in which the four countries can contribute in combination with external support. Substantial investment funds will be required for the water resources management process and the necessary water infrastructure.

Similarly, the stakeholder participation process is essential to enable implementation of guidelines and allocation of water resources use. The awareness creation of the principles of water resources management is essential for successful implementation.

3.3 Choice of appropriate level of detail and scale

Experience of transboundary river basin management in southern Africa has shown that the process is not easy. Examples are the Zambezi and the Lesotho Highlands Water Project, where preparatory studies have taken many years to develop and agree on. On the other hand there are examples, such as the Incomati and Maputo rivers, where a water-sharing agreement is in place and is presently being implemented.

The overall conclusion of the previous and on-going joint transboundary river basin management is to choose the appropriate level of detail and scale for the joint studies and projects. Many issues that may be essential on the national scale may not be important on the transboundary scale. There is therefore a risk that transboundary river basin management becomes a very long process of detailed studies with the result that little joint management is actually implemented.

It is therefore essential, when putting up the guidelines for the joint Limpopo River basin water resources management, to carefully assess which data, information and studies are necessary for the transboundary scale. Examples may be detailed information on boreholes or water quality in areas far from country borders that will have limited or no transboundary impacts. Instead focus should be on border flow quantities and quality and on major activities that have or may have transboundary impacts. Focus should also be on establishing straight lines of communication between key persons and institutions in the basin states.

3.4 Sub-basin division

One of the key processes in transboundary water resources management, which are linked to the scale issue, is to agree on the sub-division of the Limpopo River basin. A sub-division is needed to enable a description of the spatial variations in the river basin and to highlight areas of water stress.

Following the concept of IWRM the river basin should be the focal point and the catchment shall therefore be divided based on the natural catchment divides rather than on administrative borders. The simplest division is therefore to divide the river basin in accordance with the main tributaries given in Section 2.1.

However, this division creates a number of major problems:

- Much data, e.g. water use and demand is based on administrative borders rather than catchment divides.
- Some tributaries may be very large and would not give sufficient sub-division to describe spatial variation in a meaningful way.
- The strict sub-division according to the catchment divides of the main tributaries results in incremental areas along the main stem of the Limpopo River, which do not belong to any tributary but stretches over a vast geographic and climatically different area.

In transboundary river basins these problems becomes apparent. Most previous studies including relevant baseline data and information were concentrated within a country and did not focus beyond the borders. In many of these studies the international borders form the boundary of runoff catchments, when hydraulically this is in-correct. Data is therefore usually available from each country with the borders forming the boundaries of runoff catchments.

Because of the national databases and administrative units in the four countries sharing the Limpopo River basin it is suggested to sub-divide the river basin for the purpose of data presentation and storage into 27 sub-basins as presented in **Figure 3.2** and **Table 3.1**. The basis of this sub-division is:

- All major tributaries fully within one country have been extended to also include the minor incremental areas close to the Limpopo River.
- Major tributaries that are shared, such as Marico, Notwane, and Shashe, have been kept transboundary since further sub-division would create too small units.
- The small tributaries mentioned in the ToR (Mutshilashokwe and Shabili) have been included in the Mzingwane since these would be too small compared to the other sub-basins.
- The Olifants River, being by far the largest tributary, was sub-divided into six sub-basins to get approximately similarly sized and geographically homogenous sub-basins.
- The Limpopo River main stem in Mozambique was sub-divided into two sub-basins because of the geographical differences.

Figure 3.2 Proposed sub-basins of the Limpopo River basin for the purpose of presentation of catchment characteristics

This sub-basin division has been used in the scoping study and results such as mean annual runoff and rainfall, total dam storage capacity, water balance and ecological status, have been presented in Chapter 2 based on these units.

For the comprehensive study it is essential that the final sub-division for data presentation and storage is agreed upon at an early stage by the four countries, since the detailed data collection and assessments must follow this division. The proposed division into 27 sub-catchments is judged appropriate from a data management point of view, while still giving sufficient description of the spatial variation in catchment characteristics.

It should, however, be noted that this sub-basin division is hydrologically not correct and cannot be used for detailed studies of the water resources and yield. The reason is that the hydrological assessment must be strict to follow the natural catchment divides and also take into account major dam storages. The catchment flows needs to be split and allocated as inflow into the different dams. This is not only important from a system yield perspective where the yields are determined at each of the major dams, but also to take into account the net effect of water attenuation, evaporation and usage downstream of the large dams. The combining of smaller dams into a single “dummy dam” is accepted and common practice. The combining of major dams with significant storage will, however, not be acceptable and may produce results that are not realistic and will most definitely be miss-leading. For the hydrological assessment, including modelling, in the comprehensive study a more detailed sub-division must therefore be made.

Table 3.1 Catchment areas of proposed sub-basins for presentation of catchment characteristics. The sub-basins are listed from upstream to downstream.

Number	Sub-basin	Catchment area (km^2)	Countries
1	Marico	13 661	Botswana, South Africa
2	Crocodile	29 448	South Africa
3	Notwane	19 493	Botswana, South Africa
4	Matlabas	6 032	South Africa
5	Bonwapitse	18 033	Botswana
6	Mahalapswe	9 038	Botswana
7	Mokolo	8 430	South Africa
8	Lephalala	6 753	South Africa
9	Lotsane	13 064	Botswana
10	Mogalakwena	19 393	South Africa
11	Motloutse	20 118	Botswana
12	Shashe	29 282	Botswana, Zimbabwe
13	Mzingwane	20 348	Zimbabwe
14	Sand	15 840	South Africa
15	Nzhelele	4 217	South Africa
16	Bubi	8 726	Zimbabwe
17	Mwenezi	13 786	Zimbabwe
18	Levuvhu	5 963	South Africa
19	Olifants Upper	11 510	South Africa
20	Middle Olifants	21 061	South Africa
21	Steelport (Olifants)	7 166	South Africa
22	Letaba (Olifants)	13 843	South Africa
23	Shingwedzi (Olifants)	10 806	South Africa, Mozambique
24	Olifants Lower	16 543	South Africa, Mozambique
25	Lower Middle Limpopo	11 637	Mozambique
26	Changane	63 533	Mozambique
27	Lower Limpopo	6 108	Mozambique

4 DATA AVAILABILITY AND CONSTRAINTS

The sub-chapters below give a motivation (and limitation) for which data and information are needed for transboundary water resources management. The chapter describes the availability of the data as well as first preliminary conclusions on quality and compatibility between countries. It further highlights the need for filling in gaps, further monitoring and harmonisation of data.

4.1 Previous studies

4.1.1 What studies are relevant for transboundary water resources management?

The Limpopo River basin, with its complexity, has been the focus for many studies related to water resources. However, many of these studies are focussed on local areas or development, such as feasibility studies or impact assessments for dams. On the transboundary scale, what is important are major studies on individual river basins or thematic studies covering the region where the river basin study is located, studies such as effects of global climate change.

4.1.2 Availability of relevant previous studies

Tables 4.1 to **4.5** below list the relevant studies identified that should provide essential input for the comprehensive study on the Limpopo River basin.

Table 4.1 Relevant river basin studies in Botswana

Title	Year	Source	Sub-catchments included
Botswana National Water Master Plan Study, SMEC & Associates	1992	DWA	Notwane, Bonwapitse, Mahalapswe, Lotsane, Motloutse, Shashe
National Water Master Plan Review, Republic of Botswana, SMEC & EHES	2006	DWA	Notwane, Bonwapitse, Mahalapswe, Lotsane, Motloutse, Shashe
Groundwater recharge studies in Botswana, by Beekman et al	1996	Botswana Journal of Earth Science	Notwane, Bonawapitse, Mahalapswe, Lotsane, Motloutse, Shashe

Table 4.2 Relevant river basin studies in South Africa sourced from DWAF

Title	Year	Sub-catchments included
Levuvhu River Basin study report. Study undertaken by HKS.	1990	Levuvhu
Letaba River Basin: Development potential and water resources management. Study undertaken by SRK.	1990	Letaba (Olifants)
Joint Upper Limpopo Basin Study – Joint Permanent Technical Committee. Study by MacDonald /Shand Consortium.	1991	Notwane, Bonawapitse, Mahalapswe, Lotsane, Motloutse, Marico, Crocodile, Matlabas, Mokolo, Lephalala, Mogalakwena, Upper Limpopo
Lephalala River Catchment Study: Water resources development study. Study undertaken by Chunnet, Fourie & Vennote.	1991	Lephalala
Water resources planning of the Mogalakwena River basin: Situation assessment and development potential.	1991	Mogalakwena
Crocodile (Western Transvaal) Catchment Study. Study undertaken by BKS & Stewart, Sviridov & Oliver.	1992	Crocodile
Water resource planning of the Sand River basin: Study of the development potential and management of the water resources.	1992	Sand
Water resources planning of the Nzhelele River basin: Study of the water resources. Study undertaken by WSM.	1993	Nzhelele
Olifants River Basin Study. Study undertaken by Theron, Prinsloo, Grimsehl & Pullen.	1991	Olifants
Hydrological Modelling of the Limpopo River Main Stem, by Görgens and Boroto	1999	All river
State of the Rivers Report: Letaba and Levuvhu river systems, WRC Report TT 165/01	2001	Letaba, Levuvhu
Groundwater use in the Limpopo, by W.H. du Toit	2003	Marico, Crocodile, Matlabas, Mokolo, Lephalala, Mogalakwena, Sand, Nzhelele, Levuvhu, Olifants
Groot Letaba water resource development bridging study. Study undertaken by BKS.	2008	Letaba (Olifants)
Water Resources of South Africa (WR2005), 2005 Study. Study undertaken by WRC.	2008	Marico, Crocodile, Matlabas, Mokolo, Lephalala, Mogalakwena, Sand, Nzhelele, Levuvhu, Olifants
Development of an Integrated Water Resource Management Plan for the Upper and Middle Olifants catchments. Study undertaken by WRP Consulting Engineers.	On-going	Olifants
Provision of general modelling and water resource	On-going	Olifants

Title	Year	Sub-catchments included
evaluation services for allocable water quantification and to support integrated water resource planning: Phase 2 for assessment of water availability in the Olifants Water Management Area by means of water resource related models. Study undertaken by Stewart Scott.		
The assessment of water availability in the Crocodile (West) River catchment by means of water resource related models in support of the planned future licensing process. Study undertaken by BKS in association with Arcus Gibb.	On-going	Crocodile
The Development of a Reconciliation Strategy for the Crocodile (West) Water Supply System. Study undertaken by BKS in association with Arcus Gibb.	On-going	Crocodile
Updating the hydrology and yield analyses in the Mokolo River catchment. Study undertaken by WRP Consulting Engineers.	On-going	Mokolo
Intermediate Reserve Determination Study for selected water resources (rivers, wetlands and groundwater) in the Crocodile West and Marico Water Management Area. Study undertaken by Zitholele Consulting in association with BKS.	On-going	Crocodile, Marico
Marico River Catchment: Updating of the Hydrology and Yield Analysis. Study undertaken by WRP Consulting Engineers.	On-going	Marico
Crocodile Mokolo Water Augmentation Project. Study undertaken by Ninham Shand and Africon.	On-going	Crocodile, Mokolo
Groot Letaba River Water Resource Development: Post Feasibility Bridging Studies. Study undertaken by Ninham Shand.	On-going	Letaba (tributary of the Olifants)

Table 4.3 Relevant river basin studies in Zimbabwe

Title	Year	Source	Sub-catchments included
Assessment of surface water resources in Zimbabwe (Blue Book)	1984	T Kabell	Shashe, Umzingwane, Mwenezi, Bubi
Bulawayo/ Matabeleland Water Supply Feasibility Study, Zimbabwe	1995	Local Government	Upper Umzingwane
Gauging and Modelling in Zimbabwe (GAMZ)	2000	DWR	Umzingwane
Assessment of surface water resources in Zimbabwe (2004)	2004	ZINWA	Shashe, Umzingwane, Mwenezi, Bubi.
Mzingwane environmental flows assessment – social issues, fisheries, invertebrates	2007	IUCN	Umzingwane

Table 4.4 Relevant river basin studies in Mozambique

Title	Year	Source	Sub-catchments included
Esquema Geral de Aproveitamento Hidráulico e Desenvolvimento Integrado Agrícola do Vale do Rio Limpopo, SELKOZPROMEXPORT	1984	DNA	Olifants, Lower Limpopo
Massingir Dam rehabilitation report, 3 volumes, WAPCOS.	1993	DNA	Olifants, Lower Limpopo
Massingir Dam rehabilitation studies, review report of WAPCOS. Study undertaken by Coyne et Bellier	1994	DNA	Olifants, Lower Limpopo
Monografia Hidrografica da Bacia do Rio Limpopo. Study undertaken by CONSULTEC.	1996	DNA	Lower Limpopo, Changane, Lower Olifants
Sedimentation Study for Corumana, Macarretane, Massingir and Pequenos Libombos Dams. Study undertaken by SWECO & Associates	2003	ARA-Sul	Lower Limpopo Lower Olifants
Telemetry for flood management of the Limpopo River. Study undertaken by DHI & CONSULTEC	2005	ARA-Sul	Lower Limpopo, Olifants
Determination of environmental flow requirements for the Elephants River. Study undertaken by Salomon & PDNA	2007	ARA-Sul	Lower Limpopo, Olifants
Salt balance study of the Lower Elephants and Limpopo rivers. Study undertaken by COBA & CONSULTEC	2007	ARA-Sul	Lower Limpopo, Olifants
Carateristicas gerais da Bacia do Rio Limpopo em Moçambique	2006	UEM	Lower Limpopo, Olifants
Integrated Water Resources Management in Mozambique: The case of the Limpopo River basin, by Rita Barros	2009	ETH, Switzerland	Lower Limpopo, Olifants

Table 4.5 Relevant thematic or basin studies for the Limpopo River basin

Title	Year	Source
Estimating transmission losses along the Limpopo River, IAHS Publication No 278, pp 1-6, by Boroto and Görgens	1999	IAHS
The Incomati and Limpopo international river basins: A view from downstream, Water Policy 2, p 99-112, by A. Carmo Vaz and A.L Pereira.	2000	DWA
An overview of the Impact of Mining and Mineral Processing Operations on the Water Resources and Water Quality in the Zambezi, Limpopo and Olifants Catchments in Southern Africa, CSIR, by Ashton et al.	2001	CSIR
Present and future vulnerability of eastern and southern Africa's hydrology and water resources, SA Journal of Science 97: 150-160, by Schulze et al.	2001	-
Rapid Environmental Appraisal of the Limpopo River basin, by SARDC/IMECSA/ZERO	2002	SARDC
Limpopo Basin Profile	2003	ARC, IWMI

Title	Year	Source
Protection and strategic uses of groundwater resources in drought prone areas of the SADC region – Groundwater situation analysis of the Limpopo River basin conducted by CSIR	2003	SADC
Assessment of Stakeholder Participation within the Limpopo River basin: Strengthening the Legal and Institutional Framework for Integrated River Basin Management of the Limpopo and Orange-Senqu Watercourse System, by J. Mushauri and H.J. Plumm	2005	GTZ
Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. WRC Draft report No. 1430/1/05, by Schulze et al.	2005	WRC
Indigenous and institutional profile; Limpopo River basin, IWMI Working Paper 112, by Earle et al	2006	IWMI
Limpopo River Basin Focal Project, Literature on Work Package 2 – Water Availability and Access	2008	FANPRAN, ARC-LNR

4.2 Maps and GIS

4.2.1 What geographical information is relevant for transboundary water resources management?

Geographical information provides a visual summary of tabulated metadata as well as additional understanding of spatial layout and trends not possible without a picture.

For basin-scale water resources management high definition geographical information focused on detail at a local scale is not essential. Geographical information that provides a picture of the whole basin is of far more value. Data of this nature will provide the following:

- A visual summary of the spatial extent and distribution of the data or attribute in question;
- A visual check of databases to help eliminate major errors; and
- An indication of the mismatches or differences in data between riparian countries with-in a basin.

For the purpose of water resources management, the following geographical data is of particular use, and can provide visual summaries of factors that impact on water resources and their availability:

<u>Topography</u>: e.g. drainage regions, rivers and elevation. Topographical data provides information on the extent and elevation of the catchment and the network of rivers that drain the basin.

<u>Climate data</u>: e.g. rainfall and evaporation. Climate and associated data determines the likely extant of rainfall runoff as streamflow.

<u>Geology, soils and vegetation</u>: e.g. generalised soil types, vegetation types and geological formations. Geology, soils and vegetation influence rainfall runoff, possible sedimentation of rivers and dams, groundwater potential and agricultural potential, amongst other things. A visual display of these attributes provides a picture of how they vary across the basin, and if any particular significant formations exist.

Cadastral: e.g. international boundaries and provincial and municipal boundaries. Geographical information of cadastral features provides a picture of the portions of the basin that are managed by different countries, provinces and municipalities or relevant authorities.

Land use: e.g. agriculture, forestry and nature conservation. Land use not only influences rainfall runoff and sediment generation in a catchment, but also indicates the extent of area that have water demands associated with a particular activity, as well as the extent of area that may result in stream flow reduction.

Infrastructure: e.g. roads, rail and pipelines. A visual summary of infrastructure provides information on where urban and industrial development and associated water demand occurs, as well as some insight into where further development and water demands are possible and likely.

4.2.2 Availability of maps and GIS data

The geographical data available in the form of GIS and maps is summarised for the four basin states in **Tables 4.6** to **4.9**. Information about other available maps in each country can be found in Annex 6.

Table 4.6 GIS and map data availability in the Botswana portion of the Limpopo River basin

Subject	Data	Region	Format	Availability	Comment
Basin characteristics					
Cadastral	National boundaries	Whole of Botswana	Shape files	Bot. PC-Atlas	
	Municipal/district boundary	Whole of Botswana	Shape files	Bot. PC-Atlas	
Topography	Rivers	Whole of Botswana	Shape files	Bot. PC-Atlas	Multiple levels
	Drainage regions	Whole of Botswana	Shape files	Bot. PC-Atlas	Primary drainage basins in Botswana
Climate	Rainfall	Whole of Botswana	Shape files	Bot. PC-Atlas	Isohyets of rainfall and rainfall variability
	Relative humidity	Whole of Botswana	Shape files	Bot. PC-Atlas	Mean monthly relative humidity for districts
	Observation stations	Whole of Botswana	Shape files	Bot. PC-Atlas	Rainfall and agromet and synoptic stations
Geology and hydrogeology	Geological formations	Whole of Botswana	Shape files	Bot. PC-Atlas	High level of detail
	Groundwater potential	Whole of Botswana	Shape files	Bot. PC-Atlas	
	Groundwater vulnerability	Whole of Botswana	Shape files	Bot. PC-Atlas	
	Groundwater levels	Whole of Botswana	Shape files	Bot. PC-Atlas	
Soils	Soil types	Whole of Botswana	Shape files	Bot. PC-Atlas	
Vegetation	Vegetation types	Whole of Botswana	Shape files	Bot. PC-Atlas	

Land use					
Infrastructure	Cities/Towns	Whole of Botswana	Shape files	Bot. PC-Atlas	
	Roads	Whole of Botswana	Shape files	Bot. PC-Atlas	
	Railways	Whole of Botswana	Shape files	Bot. PC-Atlas	Main railways in Southern Africa
	Power stations	Whole of Botswana	Shape files	Bot. PC-Atlas	
Bulk water supply	Dams	Whole of Botswana	Shape files	Bot. PC-Atlas	Existing and investigated dams (not many)
	Pipelines	Whole of Botswana	Shape files	Bot. PC-Atlas	Proposed pipeline for North South Carrier Project
	Boreholes	Whole of Botswana	Shape files	Bot. PC-Atlas	Boreholes drilled in Botswana
	Water transfer schemes	Whole of Botswana	Shape files	Bot. PC-Atlas	Proposed transfers: North South Carrier Project
Land cover/use	Mining	Whole of Botswana	Shape files	Bot. PC-Atlas	
	Agriculture	Whole of Botswana	Shape files	Bot. PC-Atlas	Various agricultural activities
	Conservation	Whole of Botswana	Shape files	Bot. PC-Atlas	

Table 4.7 GIS and map data availability in the South African portion of the Limpopo River basin

Subject	Data	Region	Format	Availability	Comment
Basin Characteristics					
Cadastral	International boundaries	Whole of Limpopo	Shape files	Yes	
	National boundaries	Whole of SA	Shape files	Yes	
	Municipal/district boundaries	Whole of SA	Shape files	Yes	
Topography	Contours	Whole of SA	Shape files	Yes	20 m intervals
	Rivers	Whole of SA	Shape files	Yes	Multiple levels
	Sub-catchments	Whole of SA	Shape files	Yes	DWAF divisions from primary to quaternary
Climate	Rainfall	Whole of SA	Shape files	Yes	Isohyets of rainfall
	Evaporation	Whole of SA	Shape files	Yes	Isohyets of evaporation
Geology and hydrogeology	Geological formations	Whole of SA	1.250 000 rectified	R 350 per digitized sheet	High level of detail
	Geological formations	Whole of SA	Shape files	Yes	Lower level of detail

	Groundwater potential	Whole of SA	1:3 000 000 map	R 30	Available from DWAF
	Groundwater levels	Whole of SA	Shape files	Yes	Data has not been verified
Soils	Soil types	Whole of SA	Shape files	Yes	
Vegetation	Vegetation types	Whole of SA	Shape files	Yes	
Land use					
Infrastructure	Cities/Towns	Whole of SA	Shape files	Yes	
	Roads	Whole of SA	Shape files	Yes	
	Railways	Whole of SA	Shape files	Yes	
	Power stations	Whole of SA	Shape files	Yes	
Bulk water supply	Dams	Whole of SA	Shape files	Yes	
	Pipelines/canals	Whole of SA	Shape files	Yes	
	Water transfer schemes	Whole of SA	Shape files	Yes	
	Sewage treatment works	Whole of SA	Shape files	Yes	
	Water purification works	Whole of SA	Shape files	Yes	
Land cover/use	Mining	Whole of SA	Shape files	Yes	
	Irrigation	Crocodile / Olifants	Shape files	Yes	Recent studies, coverage poor
	Cultivated Land	Whole of SA	Shape files	Yes	
	Afforestation	Whole of SA	Shape files	Yes	
	Conservation	Whole of SA	Shape files	Yes	

Table 4.8 GIS and map data availability in the Zimbabwean portion of the Limpopo River basin

Subject	Data	Region	Format	Availability/costs	Scale/comment
Basin Characteristics					
Cadastral	International boundaries	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000 000
	National boundaries	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad, Hard copies also available.	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
	Municipal / district boundaries	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad, Hard copies also available.	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000 000

Topography	Contours	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad, Hard copies also available.	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000 000
	Rivers	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad, Hard copies also available.	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
	Sub-catchments	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad, Hard copies also available.	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
Climate	Rainfall	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad, Hard copies also available.	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
	Evaporation			Metrological Office	
Geology and hydrogeology	Geological formations	Whole of Zimbabwe	Hardcopies available	Available: Geological Survey, range between US$3 to US$25	1 : 100,000
	GW potential	Whole of Zimbabwe	Geology maps are accompanied by booklets that explain ground water potential	Available: Geological Survey, range between US$3 to US$25	1 : 100,000
	GW levels	Whole of Zimbabwe	Geology maps are accompanied by booklets that explain GW potential	Available: Geological Survey, range between US$3 to US$25	1 : 100,000
Soils	Soil types	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000 000
Vegetation	Vegetation types	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000 000
Land use					
Infrastructure	Cities/ Towns	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000 000
	Roads	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000

	Railways	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
Infrastructure	Power stations	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available : Surveyor General map sales, cost range between US$5 – US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
Bulk water supply	Dams	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available: Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer)	1 : 5,000 to 1 : 1,000,000
Land cover/use	Mining	Whole of Zimbabwe		Geological Survey Available as industrial minerals and deposits map. Cost for map only US$7. Map & booklet US$20.	1 : 1,000,000
	Irrigation	Whole of Zimbabwe		Ministry of Agriculture	
	Cultivated Land	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Surveyor General map sales, cost range between US$5 to US$50 (US$5 for each layer), not current information	1 : 5,000 1 : 1,000,000
	Afforestation	Whole of Zimbabwe	Forestry Commission	Have not been able to get hold of Forestry Commission	
	Conservation areas	Whole of Zimbabwe	GeoTIFT, JPEG, can also convert to AutoCad	Available Department of Parks & Wildlife and Surveyor General map sales	1 : 5,000 1 : 1,000,000

Table 4.9 GIS and map data available in on the Mozambican portion of the Limpopo River basin

Subject	Data	Region	Format	Availability	Comment
Basin Characteristics					
Cadastral	National Boundaries	Whole of Mozambique	Shape files	CENACARTA	
	Municipal/district Boundaries	Whole of Mozambique	Shape files	CENACARTA	
Topography	Contours	Whole of Mozambique	Shape files	CENACARTA, on sale	1:50000, 20 m intervals
	Rivers	Whole of Mozambique	Shape files	CENACARTA and DNA	Not much detail
Climate	Rainfall	Whole of Mozambique	Shape files	DNA	Only location of rainfall stations

Geology and hydrogeology	Geological formations	Whole of Mozambique	Shape files	Direcção Nacional de Geologia	1:1,000,000 Low level of detail
	Groundwater potential	Whole of Mozambique	Shape files	Yes	Low level of detail
	Groundwater potential	Limpopo catchment	Hard copy	DNA	1:500,000
Soils	Soil types	Whole of Mozambique	Shape files	For sale	
	Soil types	Limpopo catchment	Hard copy	DNA	1:100,000
Vegetation	Vegetation types	Whole of Mozambique	Shape files	For sale	
Land use					
Infrastructure	Cities/Towns	Whole of Mozambique	Shape files	Yes	
	Roads	Whole of Mozambique	Shape files	Yes	
	Railways	Whole of Mozambique	Shape files	Yes	
	Electricity national grid	Whole of Mozambique	Shape files	Yes	
	Telecom national grid	Whole of Mozambique	Shape files	Yes	
Bulk water supply	Dams	Whole of Mozambique	Hard copy	Yes	Scale 1: 2,000,000
Land cover/use	Land use	Whole of Mozambique	Hard copy	Yes. For sale	Scale 1: 1,000,000
Irrigation potential	Classes of irrigable areas	Provinces of Maputo and Gaza	Shape files	IIAM. For sale	

4.2.3 Compatibility between data in the four countries

One of the difficulties in generating maps and geographical information databases for the whole basin is the availability of data in different formats e.g. shape files, jpeg images, hardcopy maps. A certain amount of effort will be needed to convert data into compatible formats as well as scanning and geo-rectifying hardcopies and jpeg images where shape files are not available. This is possible but apart from requiring effort and budget to do so, may result in a reduction of detail and resolution to achieve compatibility. For basin-scale studies, as discussed in Chapter 4.1.1, a loss in high detail and resolution is not likely to be a significant problem.

An additional consideration is the projection and co-ordinate systems used to generate the geographical data. Data from Botswana's National PC Atlas appears to be in a local projection and co-ordinate system that is not directly compatible with that predominantly used in South Africa and Mozambique, and Zimbabwe. Through conversions, the data can be made compatible. Some time and effort will be required to convert the data available on the Botswana National PC Atlas to be compatible. This may apply to some data from the other countries as well.

Another facet of GIS data compatibility may be the definitions or various classification systems used to categorise attributes. For example databases from the different countries use various forms of land use and vegetation type classifications. Some of the databases available have combined land use and vegetation together to into land cover, while other countries present land use and vegetation cover separately. This may result in different terms for similar attributes being presented, or in different levels of detail between the countries.

Data from Mozambique is general available with descriptions of attributes in Portuguese. If maps are to be presented in a common language, the databases of the various countries will need to be translated to so that the legends of the maps are in the common chosen language.

4.2.4 Information gaps and need for harmonisation

In some instances, particular information such as the spatial distribution of rainfall gauges in Zimbabwe is not yet attained. The generalised geographical information as discussed in Chapters 4.1.1 and 4.1.2 appears to be available, sometimes at cost, for Botswana, South Africa, Zimbabwe and Mozambique.

To create a complete set of maps of the Limpopo River basin for the various basin and land use attributes discussed in Chapters 4.2.1 a considerable effort with appropriate time allocation will be needed to:

- acquire all the data (this will require the purchasing of most of the Zimbabwe data);
- scan and geo-rectify hard copies and maps;
- convert data with different projection and co-ordinate systems so as to be compatible; and
- possible manual manipulation of some databases so as to present data at as common a level of detail and classification definition as possible, and in a common language.

4.3 Climatic data

4.3.1 What climatic information is relevant for transboundary water resources management?

The main climatic data needed for transboundary water management are rainfall and pan evaporation data that are inputs to both hydrological models and irrigation demand models. The need for long runoff records is absolutely essential for water resources management in southern Africa because of the large climatic variability. When calculating safe yields for potential dam sites or water intakes to assess drought conditions, series of 60 to 80 years are normally required in southern Africa. Since runoff observations seldom covers such long periods the only alternative is rainfall-runoff modelling to create long and concurrent runoff series.

Rainfall is required on a monthly time step for input to the hydrological and irrigation demand models. Pan evaporation is normally required as average monthly values for each month of the year, i.e. long series are not needed. The reason is that potential evaporation varies relatively little compared to rainfall. It is therefore sufficient with average values. Data on rainfall during extreme storm events are further essential to assess extreme floods. Especially important for the Limpopo River basin is statistics on tropical cyclones.

4.3.2 Availability of climatic data

Annex 2 gives a complete meta-database of rainfall stations in the four countries. In **Table 4.10** and **Figure 4.1** it can be seen that a large number of rainfall stations are available. In total more than 2,700 rainfall stations provide data on rainfall. The majority of these are farms, industries, schools, etc.

Table 4.10 Number of rainfall stations in the Limpopo River basin

Data Source	Number of rainfall stations
SADC-HYCOS	16
Botswana, Weather Services	153
Botswana, DWA	58
South Africa, Weather Services	261
South Africa, DWAF (Hydstra)	100
South Africa, used in WR2005 Study	2,009
Mozambique, INAM	21
Mozambique, DNA	76
Zimbabwe, Meteorological Services	>70

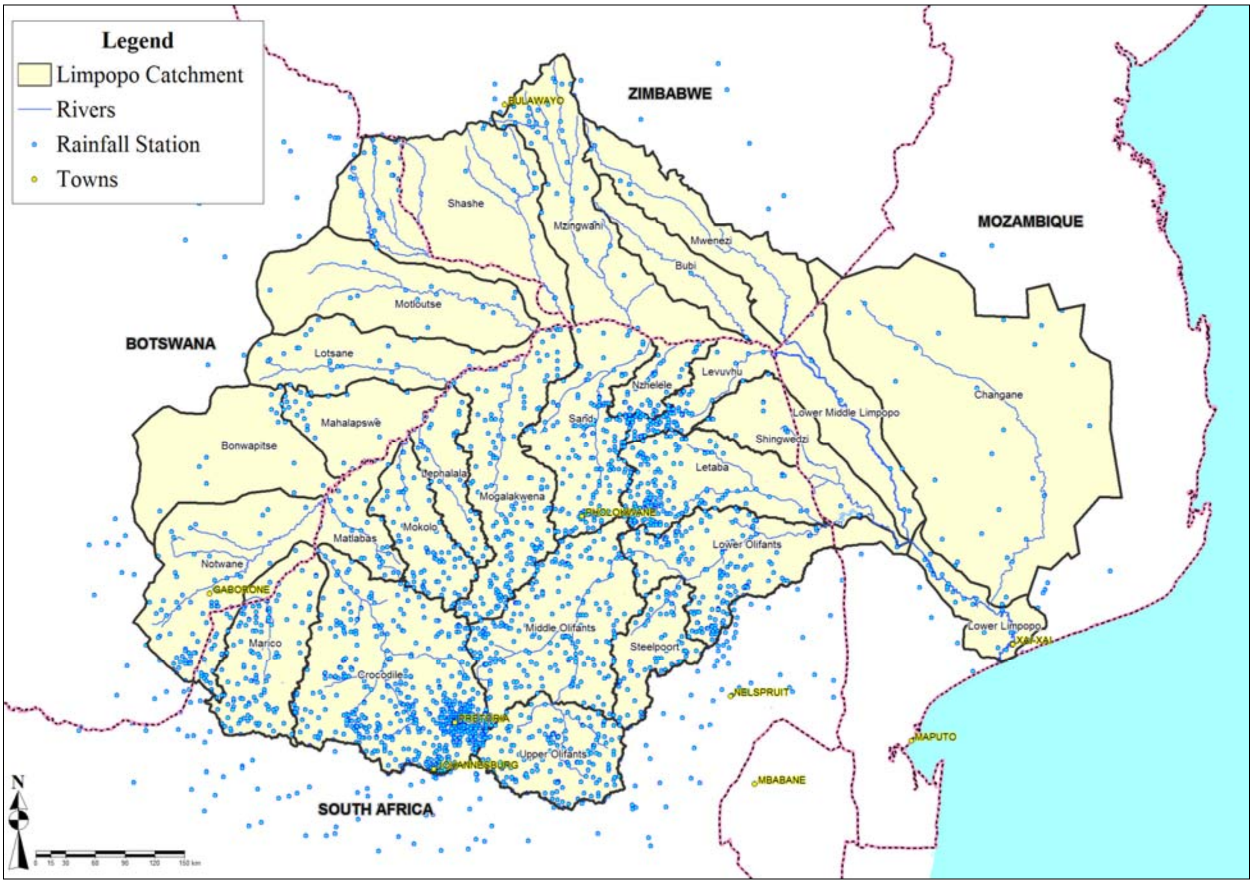


Figure 4.1 Coverage of rainfall stations in the Limpopo River basin

South Africa has the highest coverage of rainfall stations with more than 2,000 gauges. Most of the stations cover the last 40 to 50, years, while some go back all the way to the 1920s. Certain periods and areas are less covered, such as in Mozambique during the civil war years.

4.3.3 Compatibility between data in the four countries

Rainfall data are basically measured in the same way in all countries. The generally highest quality of the data is the rainfall stations run by the weather services in the four countries because they have higher requirements on equipment and observers.

The difference between the countries is therefore mainly in the coverage spatially and temporally. Through the large number of stations located in South Africa a sufficient number of stations with high quality and long records can be chosen and still the coverage is good. This situation is not the case in the other three countries, in which only a few stations show long and consistent records. Many stations operated by farms, schools, etc, in Zimbabwe and Botswana also still have the historical records in hard copy.

4.3.4 Data gaps and need for harmonisation

The Limpopo River basin most likely has a sufficient coverage of rainfall records for large-scale basin-wide water resources assessments. Problems with data gaps for extended periods and over large areas occurred in Zimbabwe and Mozambique during their civil war times.

The need for harmonisation is therefore mainly to make a thorough data quality analysis of the rainfall stations in Mozambique, Zimbabwe and Botswana to choose the best suitable records to be combined with the stations in South Africa. Long and concurrent rainfall series will be needed for all major sub-catchments as input to the hydrological modelling for water resources assessment.

4.4 Surface water data and reservoir levels

4.4.1 What surface water data is relevant for transboundary water resources management?

River runoff comprises the most essential data for water resources management. As a basis for water allocation and planning of future development of infrastructure and economic activities it is important to have information on the long term flow characteristics. Measurement of river runoff and abstractions is further required for proving compliance for agreed water allocation.

For flood management it is further essential to have real-time measurements of river runoff and water levels at key stations. Also historical records of river runoff during extreme floods are essential input for designing infrastructure and flood mitigation measures.

4.4.2 Availability of runoff data, rating curves and reservoir levels

All four countries have an understanding of how essential monitoring of river runoff is and as a result a large number of runoff stations (**Table 4.11** and **Figure 4.2**). In total some 700 stations are given in the meta-databases of the countries. Many of these stations may, however, not be functioning any longer or cover very small streams. Nevertheless, the number of major runoff stations is, in general, sufficient for transboundary river basin management. Almost all of these stations have developed rating curves based on current meter measurements or hydraulic equations.

Table 4.11 Number of runoff stations in the Limpopo River basin

Data Source	Number of rainfall stations
Botswana, DWA	44
South Africa, DWAF	545
Zimbabwe, ZINWA	85
Mozambique, DNA	17
SADC-HYCOS	16

Figure 4.2 Coverage of major runoff stations in the Limpopo River basin

The list of runoff station also includes monitored water levels and discharges at all major dams. Through water balance calculation the inflows to all major dams can therefore be estimated and used as input to the hydrological assessment of the Limpopo River basin.

The major problem of the runoff records is that many produce runoff data of poor quality. The reason for this is mainly that the rating curve (relation between river runoff and water level, which is what is monitored) is difficult to establish in rivers prone to much sediment transport. Most of the rivers in the Limpopo River basin, and especially the Limpopo itself, have generally unstable river sections which mean that the rating curves must be updated almost on a yearly basis.

A second problem is that runoff records in general have shorter coverage than the rainfall records. The runoff data are therefore mainly used as input for calibration of hydrological models for simulation of long concurrent runoff series at key points.

4.4.3 Compatibility between data in the four countries

Runoff data is basically measured in the same way in all four countries. The method is to monitor water levels at a hydraulic control section where a relationship (the rating curve) between river runoff and levels is established. The water levels are recorded on a continuous basis either through automatic mechanical recorders or data loggers. The rating curve is established trough current meter measurements in which detailed runoff measurements are made for different water levels. In Zimbabwe and South Africa many stations are also constructed weirs or flumes in which the rating curve can be calculated theoretically.

4.4.4 Data gaps and need for harmonisation

The difference in data from the countries is mainly in data quality. Because of economical constraints, especially during and after periods of the civil war, the maintenance and regular updating of the rating curves were difficult in Mozambique and Zimbabwe. These periods also often include gaps because of capturing of the data in the field was not possible.

Similar to the rainfall data, the need for harmonisation is mainly to make a thorough data quality check of the major runoff stations, to ensure that the input to river basin water resources assessment is of the same high quality for all four countries. This will entail detailed analysis of the rating curves used for the major stations.

4.5 Groundwater data and hydrogeological information

4.5.1 What groundwater data is relevant for transboundary water resources management?

Data and information on groundwater is often in abundance when it comes to boreholes. This is also the case in the Limpopo River basin where thousands of boreholes have been drilled for rural water supply or small-scale irrigation. However in very few of these boreholes continuous measurements of water levels are made. Information is most often limited to the location, depth and maybe geological characteristics. The data on boreholes are therefore not relevant for transboundary river basin management.

The major need for groundwater data for river basin management is the knowledge of interaction between surface water and groundwater. As an example, the outtake of large groundwater volumes in the vicinity of rivers affects the available surface water resources for downstream users. Similarly, the change of river runoff regime may affect the recharge of essential groundwater aquifers directly from river beds.

The most essential data and information on groundwater for transboundary river basin management is therefore the general data, such as geological and hydrogeological maps and the data on major groundwater outtakes, for an understanding of the main aquifers and their interaction with surface water. Continuous measurements of groundwater fluctuation are further of interest to assess trends in groundwater recharge and gives possibilities for groundwater model tools. In addition climatic data for calculation of groundwater recharge are valuable.

4.5.2 Availability of hydrogeological information

Table 4.12 lists the available information on hydrogeology of the Limpopo River basin. Annex 6 includes some additional information about relevant reports dealing with groundwater potential.

Table 4.12 Groundwater databases available for the study area

Data set or component	Limpopo River basin - Region			
	Botswana	**South Africa**	**Zimbabwe**	**Mozambique**
Borehole locations and status	Yes	Yes	Some	Yes (locations)
Water levels	Some	Yes	Some	No
Water quality data	Some	Yes	Some	Limited
Hydrogeological maps (GIS)	Yes	Yes	Yes	Yes
Climatic data – rainfall and recharge	Yes	Yes	Yes	Yes
Groundwater volumes used	Yes (needs verification)	Yes	Some	No
Groundwater reports	Yes	Yes		Yes
Groundwater potential areas defined	Yes	Yes		No

4.5.3 Compatibility between data in the four countries

As indicated above, the groundwater component of the comprehensive study of the Limpopo River basin, the basis should be mostly the general geological and hydrogeological information, rather than the detailed information about the thousands of boreholes. This more general information is compatible between the countries, with the same classification and information about the geological and hydrogeological formations being used.

4.5.4 Data gaps and need for harmonisation

For a comprehensive resource assessment of the Limpopo River basin, groundwater data will have to be sourced from reports produced mainly for the water management institutions in each country and also from SADC projects. Collection of data will be the most time consuming and expensive component of the project. Ample time must be allowed for the collection of and verification of data where necessary.

Resources will have to be identified and delineated. A decision must be made and motivated beforehand how the resources need to be delineated, will it be according to surface water catchments or geological units and aquifer types. The obvious route to follow is to delineate resources according to surface water catchments since groundwater tend to follow the topography and the data will be more useful for integration with surface water hydrologic inputs and requirements.

Possible groundwater pollution sources need to be identified as well as groundwater dependant ecosystems such as wetlands, springs, coastal lakes, mangroves, aquifer and cave ecosystems and certain rivers. A limited amount of work was done with the available data by the CSIR (*Protection and strategic uses of Groundwater resources in drought prone areas of the SADC region, Groundwater Situation analyses of the Limpopo Basin, Environmentek, CSIR 2003, Report no: ENV-P-C 2003-007*).

4.6 Water quality and sediment transport

4.6.1 What water quality data is relevant for transboundary water resources management?

The water quality of the Limpopo River is a function of the catchment activities that occur. Such activities often have a deleterious effect and the river's ability to assimilate these effects is dependent on the nature and extent of the activities and how they are managed. Catchment activities include urbanisation, industrialisation, agriculture and deforestation. All these activities take place in the Limpopo River catchment and thus it can be expected that water quality of the river will be affected.

The requirements of water quality depend on the purposes for which water is used. Water uses can be as diverse as drinking water, water for irrigation, industry, thermal power, fisheries, cattle, etc. Even in a category like irrigation the requirements can be quite different depending on the type of culture and on the soils. The same can be said of industrial use as some industries may have more stringent water quality requirements than others.

As a general principle, IWRM asks for good water quality at the water bodies (rivers, lakes, reservoirs, aquifers). This means that water from these sources should be possible to utilize with current treatment processes and acceptable treatment costs. This principle is becoming part of the legal framework of water management in many countries and regions, for example, in the European Union as stated in its Water Framework Directive.

For transboundary water resources management, water quality data should serve two main purposes:

- Characterize the water quality in the main rivers and tributaries, lakes and reservoirs of the various sub-catchments of the Limpopo basin; and
- Give to the four countries information on water quality at their borders.

The cost of a water quality monitoring network is high in comparison with water quantity networks. Therefore, water quality stations have to be carefully selected to take maximum benefit of the information thus obtained.

Sediment data is useful for design and operation of dams and to analyze sedimentation and erosion processes in rivers. The sediment transport may also impact on the water quality of the water bodies. In most cases, sediment data is relevant only locally. However, when large dams retain much of the sediment transported by a river system, changes in the equilibrium conditions at the lower reaches of the river and the estuary can be expected. Reservoir sedimentation may also in the long term affect the storage capacity and thus reduce the yield of dams. Olifants River in South Africa is one of the most erosion prone basin due to its intensive man-made activities and reservoir siltation is thus an essential problem.

4.6.2 Availability of water quality and sediment data

The purpose of this section is to provide an overview of the availability of water quality data for the Limpopo River catchment in South Africa, Botswana, Zimbabwe and Mozambique. Annex 5 details the methodology and results of a screening level assessment on the availability of water quality data. The data is analyzed based on the national standard guidelines defined for each country respectively. The availability of such data of each country is also defined in the annex.

The following data was summarized for every sampling point in each of the countries in question:

- Location of the point (longitude and latitude);
- Number of samples taken;
- Frequencies (Regular or Irregular) and dates of sampling; and
- The measurements taken at each point.

Available data on the water quality of the Limpopo River catchment in South Africa was collected from the Department of Water Affairs and Forestry (DWAF).

For Botswana available data on the water quality of the Limpopo River catchment was collected from the Department of Water Affairs (DWA) and complemented with data from the National Water Master Plan Review, Final Report (2006).

In Zimbabwe, water quality data was collected from ZINWA headquarters.

Mozambique data on water quality was collected from the National Directorate of Water (DNA) and from the Regional Water Administration of the South (ARA-Sul). There are some recent reports dealing with surface water quality at Massingir reservoir, as referenced in Annex 6.

Available data from all countries were used to analyse the water quality. Water quality parameters were plotted on graphs and compared to the standard guideline values of each country respectively.

Figure 4.3 presents an overview of the location of monitoring points in the Limpopo River basin. The colour coding on the map indicates the number of samples collected for each monitoring point.

Some surface water quality measurements were taken in Botswana. The exact locations of the monitoring stations are not available, but these samples are taken in the Central, South-East and Kgatleng Districts. The analysis indicates that very little data exists.

The colour coding on the map indicates whether the monitoring station is still open or closed. The analysis indicates that very little data exists in Zimbabwe. No more than 25 samples per site have been collected. The data record ends in 2006 and at some stations stretches back to 1998.

Twelve monitoring stations measuring water quality data were identified for Mozambique. These monitoring stations are indicated in Figure 4.3. Sampling frequencies were variable from 1983-2000. Since 2000 until 2008, 1-3 samples were taken each month at most monitoring stations. Older stations have more data before 2000. Some stations are new and only have data after 2006.

The following conclusions are made on each of the countries respectively:

- Extensive water quality data is available for the South African rivers. Representative stations can be selected throughout the catchment, ideally based on representivity of quaternary catchments.
- Water quality data for the Limpopo River catchment in Botswana, Zimbabwe and Mozambique is sparse. However, while longer term trends will be difficult to quantify, a snapshot of water quality can be prepared.

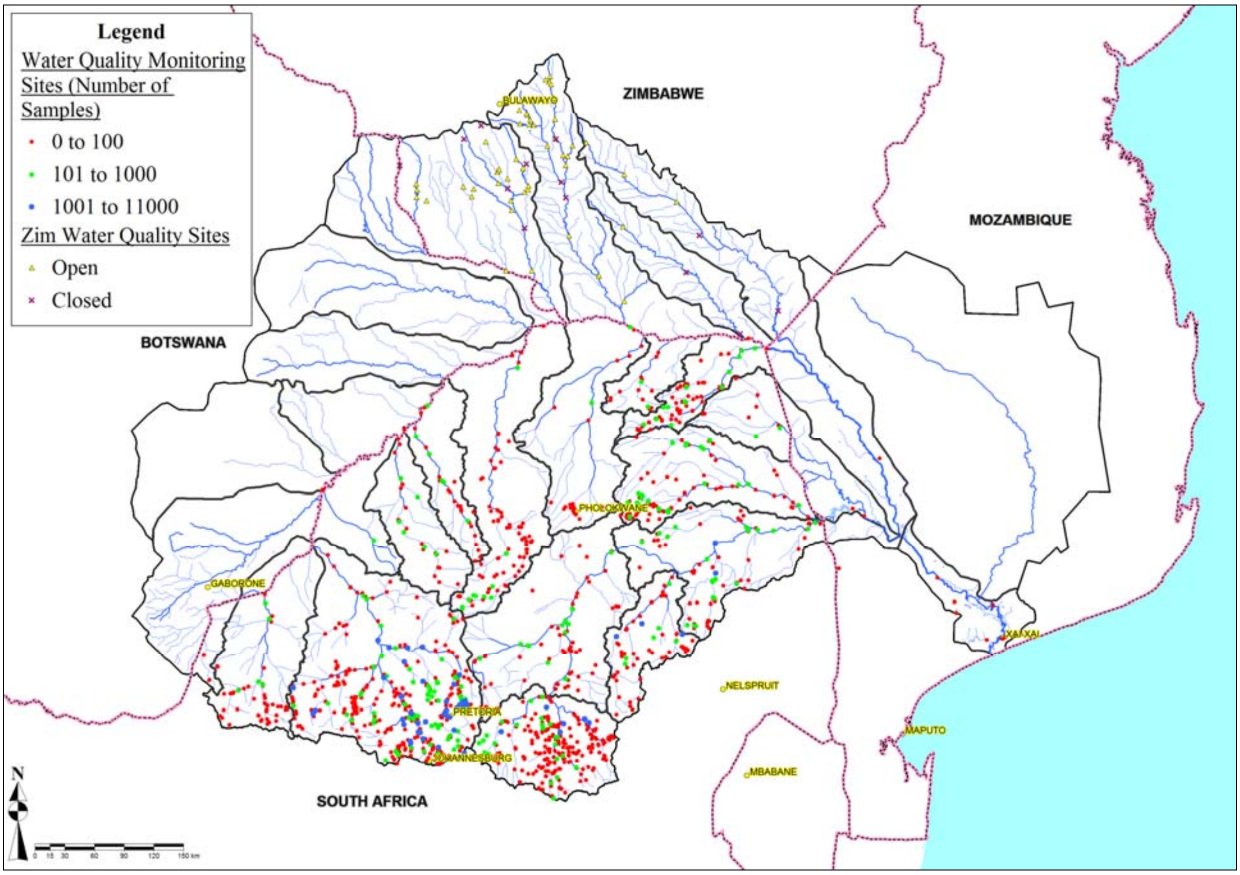


Figure 4.3 Monitoring stations of water quality in the Limpopo River basin

Suspended sediment data is one parameter that is normally analysed as part of the water quality monitoring and thus give some input to the sediment transport assessment. In both Mozambique and Zimbabwe also limited measurements of suspended sediment have been made through the depth-integrated methods at key runoff stations.

In general, however, suspended sediment gives very limited information on total sediment load because the majority of the transport occurs during extreme storms when measurements in practice are impossible. The best estimate of sediment load is therefore from reservoir surveys. By regularly surveying the reservoirs the actual siltation rate can be calculated. In South Africa all major dams are surveyed regularly by DWAF and in Mozambique a recent study in 2002 made a survey of the Massingir Dam.

4.6.3 Compatibility between data in the four countries

Available water quality data in the four countries is compatible although quality control of the data has to be conducted. The main problem is the quantity of data that is available in South Africa when compared with the paucity of data in the other three countries, both for water quality parameters and sediment transport.

4.6.4 Data gaps and need for harmonisation

Data from Botswana, Zimbabwe and Mozambique are sparse. Insufficient data for Botswana, Zimbabwe and Mozambique complicate the integration of the data from the four countries. Data from Botswana, Zimbabwe and Mozambique had few repetitions and the sampling points were not representative of the whole Limpopo catchment in these countries.

South Africa has sufficient data on the main water quality parameters. Data measurements were repeated over time and taken from representative stations over the Limpopo catchment in South Africa.

A lack of bacteriological data is found in all countries including South Africa.

Botswana, South Africa, Zimbabwe and Mozambique have separate sets of legislation for the maintenance of water quality standards. Water quality legislations and acceptable water quality standards are different for each of the countries. The four sets of legislation have similarities and differences. Differences are found on the following levels:

Water use categories: All countries specify the standard values for domestic or drinking water and discharge. South African legislation specifies the water quality standards for other water uses.

Differences are found in the parameters with available standard guideline values for the different water uses. Differences are found in the standard guideline values required for different parameters.

4.7 Water demand and use

4.7.1 What water demand data is relevant for transboundary water resources management?

Water demand data is, together with water resources data, the most essential information for water resources management as the management effort is directed towards satisfying the demand, through the increase of water availability, particularly with storage dams, and the reduction of demand, through various water demand management programs.

A distinction must be made between water demand, water licensing and water use. Water demand is a need to be satisfied, water licensing defines how much water has been allocated to a certain water user and water use is the effective use made of the water.

This distinction exists also in terms of the data that is available. Most available data refers to water demand and water licensing, resulting from studies and plans, although these may be based on field data, and from records of the water management authorities. There is much less data in relation to water use, with large differences between the various water categories. For example, urban water abstraction usually have detailed records while irrigation, in spite being a major water user, frequently does not have water meters to determine how much water is being effectively abstracted from or returned to the river.

For water resources management, water demand needs to be aggregated in terms of space and time. For spatial aggregation, water demand needs to be presented for each sub-catchment while sometimes the information is given for different geographical units. A further sub-division is required for modelling purposes, considering the location of major dams. In terms of time scale, it is sufficient to have monthly data for the water balance analysis.

Environmental flows along the various sections of the main river and tributaries, downstream of dams, and into the estuary are needed also.

4.7.2 Availability of water demand and use information

As indicated above, most of the available data is regarding to water demand and not to effective water use. Estimates of present water demand have been presented for the various countries in sub-chapter 2.4.1. Details of the water demand by sub-catchment are included in Annex 3 of this report.

Water demands in Botswana are presented in detail in the recent National Water Master Plan Review (NWMPR, 2006).

Data for Zimbabwe was obtained from ZINWA and ZINWA-Mzingwane besides other information in various reports.

Data for South Africa has been obtained from the recent studies done in the various sub-catchments of the Limpopo river basin located in the country.

Data for Mozambique was obtained from ARA-Sul and DNA as well as from reports dealing with specific issues like urban water supply.

An important source of information is population data from the official census in each country. This is essential information for the estimation of rural water supply where domestic consumption is the largest part of the demand.

There is relatively limited information on environmental flow requirements in Botswana, Zimbabwe and Mozambique, which has been summarized in sub-chapter 2.5.

Information about storage dams has been summarized in sub-chapter 2.4.2. More detailed information is included in Annex 3.

4.7.3 Compatibility between data in the four countries

There are some problems of compatibility between data in the four countries. The level of aggregation of the information differs and so, some categories are included within others (for example, industrial use as part of urban use).

Also the available information is not referred to the same base year, which makes the comparison between them more difficult.

Regarding the information on environmental flow requirements, the methods used in South Africa, Zimbabwe and Mozambique are similar, although not exactly the same, which may influence the obtained results.

4.7.4 Data gaps and need for harmonisation

Besides the problems of compatibility referred to in the previous item, there is a need for harmonization as the basis for estimates of water demand are not the same in all countries.

One example is regarding rural water supply: although population figures and its projection in the future can be obtained from the official census data in each country, not all of them include in the calculations the serious impact of the HIV pandemics (even in each country there is no consensus about the quantitative impacts in terms of the population and the water demand).

When urban water supply is being considered, a number of problems appear. For example, in general the most important component of urban water supply is domestic use, for which estimates of future water demand are made based on population growth, coverage rate, levels of service (house connection, standpost) and unit consumptions. An immediate problem when considering it under the perspective of a transboundary river basin is related to the different unit consumptions adopted in each country. A second problem relates to (physical) water losses in the system – what range of losses should be considered acceptable in a water stressed basin? A third problem is that sometimes other non-domestic uses included in the urban system (public, commercial, industrial) are taken just as a percentage of the domestic use.

Considering irrigation, there are different processes adopted in each country to arrive at the water requirements and a wide range of values used for irrigation efficiency. This last aspect, in particular, should be discussed between the water management authorities of the countries to arrive at a common basis of evaluation.

There is a significant gap between South Africa and the other three basin countries regarding studies of the environmental flow requirements. This means that some work has to be done in these countries, using scientifically sound but expedite methods like the South African Desktop Model, to obtain results that cover the whole river basin.

The estimation of the freshwater requirements for the Limpopo estuary is a more complex task, for which international and regional experience should be called upon.

4.8 Socio-economic information

4.8.1 What socio-economic data is relevant for transboundary water resources management?

The development of a transboundary water resources management strategy requires comprehensive data and information regarding population and socio-economic conditions within the study river basin. The collection of all available population and socio-economic data is an important first step. Essential information for water resources management is peoples' vulnerability to droughts and floods and the linkages between water and poverty. The data is required to allow for a macro socio-economy study of the river basin to be developed to serve as the background for the development scenarios to be considered for the basin.

4.8.2 Availability of socio-economic information

Population data for the four Limpopo River basin states is available. The population data is obtained from national censuses which are conducted every ten years in each of these states. It is from this census data that population projections have been made by Central Statistics Offices in the four countries.

Also available is socio-economic information/data for different socio-economic activities (ranging from agriculture, industry, tourism etc). This information can be obtained from national, regional, district and municipal development plans and reports. The information/data can also be obtained from reports although, in some instances, these reports just cover a portion of the basin.

One problem that deserves attention regarding the comprehensive study is that some relevant information and reports from Mozambique are available only in Portuguese, which is an obstacle in terms of access for the other countries as well as for non-Portuguese speaking consultants.

More detailed information about the socio-economic conditions in the Limpopo River basin is included in Annex 5 of the present report.

4.8.3 Compatibility between data in the four countries

In general, there are no problems of compatibility between data in the four countries, both in relation to population data and to socio-economic data.

4.8.4 Data gaps and need for harmonisation

Population data is generated from national censuses which are conducted in all the Limpopo River basin states every ten years. However, the methods of conducting censuses and types of data generated might differ from country to country. Hence the reliability of the census data might differ between countries. For Zimbabwe, population data is projected up to 2010 while for the other three basin states it is projected beyond 2020. The Zimbabwe population data need to be projected beyond 2020 to be able to compare with the other basin states. Also, like the South African population data which was projected at high and low scenarios, it might be appropriate to do likewise for the other three basin states. For Botswana and Zimbabwe population data is projected from census data obtained in the early 2000 (2001 and 2002 respectively) which is relatively old compared to Mozambique (2007) and South Africa (2005). Botswana's next census is in 2011.

With regard to other socio-economic data, almost the same variables are assessed, but different countries emphasize on different aspects of these variables. In some countries some variables are not documented e.g. community management efforts of water resources of the Limpopo River basin. There may be local institutions for water resources management and these are not adequately documented though these are critical for integrated water resources management. Issues of vulnerability and poverty are also not adequately covered across the basin states.

4.9 Legal and institutional information

4.9.1 What legal and institutional information is relevant for transboundary water resources management?

Integrated water resources management can only operate in a well-defined legal and institutional set-up that include:

- The laws and regulations of the water sector as well as those of related areas like land use, environment, mines, energy and similar;
- The policies and strategies for the water sector and its various sub-components; and
- The institutions at the various levels (national, regional, river basin, district) with different degrees of responsibilities and interventions in water management and linkages with other related sectors.

The legal and institutional set-up is already complex at the national level, taking into account that water is a cross wide issue. It becomes much more complex when it has to deal with a transboundary river basin.

Therefore, the legal and institutional information that is required for transboundary water resources management is the information from each country plus all other that links the various countries of the basin.

In the case of the Limpopo basin, it means that, besides the laws and institutions of each country, it is important to know about the bilateral and multilateral agreements between the countries, the SADC

Protocol on Shared Watercourses, other international legal and policy documents and the role of SADC Water Division. Of the utmost relevance is information about the Limpopo Water Commission (LIMCOM), the basin institution created by the agreement between the four countries in 2003, and its functioning.

However, regarding the national legal and institutional set-up, it is important to consider only those documents that have a bearing in transboundary water management at the scale of such a large river basin as the Limpopo. For example, the details of the institutional set-up to provide for rural water supply are not relevant.

4.9.2 Availability of legal and institutional information

The relevant legal and institutional information of each country and for the SADC region is available and easily accessible, be it in reference to laws and regulations, policy documents or the institutional set-up. Annex 5 includes details about the relevant available information.

The major difficulty, as it was already referred to in regard to socio-economic information, is due to the fact that many of the relevant documents of Mozambique are in Portuguese and are not translated into English (and, in what concerns legal documents, these should be official translations). This may create some difficulties with the other basin countries and also for the consultants in future studies.

4.9.3 Compatibility between data in the four countries

This is usually a difficult area as countries have different legal traditions and may follow quite different approaches in water management. Fortunately, the water laws in the various countries have been revised and sometimes profoundly reformulated in recent years, following a common basis of water being considered as a public good, with priority given to domestic use and due consideration to environmental protection.

In terms of policies regarding water resources management, also the four countries have adopted policies based on the principles of integrated water resources management, even if Botswana and Zimbabwe do not have formally approved documents of their national water policies.

The four countries also have at the national level one institution that is fully responsible for the water resources management in the whole country and South Africa, Zimbabwe and Mozambique have or are creating regional catchment management agencies.

Finally, but not less important, there is clear commitment from all the four countries to reach agreement on how to make better and equitative use of the scarce water resources of the Limpopo River basin, as translated by the creation of the LIMCOM and the activities aimed towards a far reaching agreement for the basin.

4.9.4 Data gaps and need for harmonisation

From the analysis made by the consultant, it does not appear that there are important gaps in the legal and institutional set-up that could be a problem for the comprehensive study and for reaching an agreement in water allocation and coordinated development and management of the basin.

One aspect that deserves consideration is stakeholder involvement as it is not clear how it is dealt with in each country, although it is a very important component in water resources management.

Difficulties may also arise in relation to the existing capacity in the water management institutions to deal with the demands to supervise and implement the studies and other activities for water resources management.

4.10 Conclusion on data availability

The assessment of data for river basin management in the scoping phase has generally shown that there are sufficient data available for joint integrated river basin management.

The major problem is inequality in data quantity and quality for the data in South Africa compared to the other three countries. The comprehensive study must therefore focus on extracting the most essential data from the large amount of information available in South Africa and to quality control and, if necessary, correct data for Botswana, Zimbabwe and Mozambique to produce a complete database for transboundary basin management.

Minor data gaps exist, which are of importance for the water resources management in the Limpopo River basin, such as completing ecological characterisation of all river basins, but all of these can be dealt with as part of the comprehensive study and are cared for in the scope of work described below.

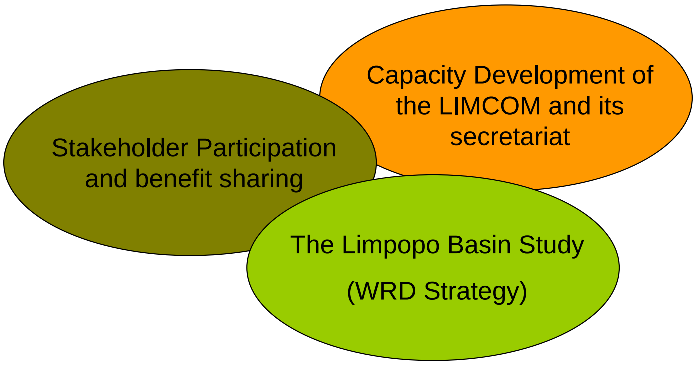
One problem that deserves attention regarding the comprehensive study is the difficulty of technical staff and stakeholders in the various countries to deal with documents written in a foreign language (Portuguese for Botswana, South Africa and Zimbabwe; English for Mozambique).

5 PROPOSED SCOPE OF WORK FOR COMPREHENSIVE STUDY

5.1 The role of the Limpopo Basin study for transboundary water resources management

The ToR states that the primary objective of the Limpopo Basin Study is to quantify the present and future water balance in the Limpopo River basin in each of the four co-basin states, and to plan future water resource development and management options so as to meet the future water demands in an optimal, sustainable and equitable way. The ToR further put much focus on the technical aspects leading to a basic understanding of key variables as water resources, water demand, infrastructural development and environmental issues.

It is thus the Consultant's understanding that the Limpopo Basin Study will form one part of the necessary measures for achieving Integrated Water Resources Management (IWRM) in the transboundary Limpopo River. Other major components are the capacity development of the LIMCOM and its secretariat as well as the stakeholder participation process and introduction of benefit sharing of the Limpopo Rivers.



All these components are on-going processes forming the transboundary water resources management for the Limpopo River basin. Furthermore, the Limpopo Basin Study must be regularly updated to accommodate the continuous development in the river basin and in the region. All components interact and cannot proceed by their own. It is for example essential that the LIMCOM Secretariat will be capacitated as soon as possible to a level where they can guide the IWRM process.

It is thus suggested that the coming year is focussed on the organisational capacity development of the LIMCOM Secretariat and that the LIMCOM develops a strategic plan for implementation of IWRM in the Limpopo River basin (**Figure 5.1**). The strategic plan should emphasise on the linkages between the different components and define LIMCOM's and the Secretariat's roles in the process.

	2010	2011	20112	2013
Strategic Plan for IWRM	■			
Capacity Development of the LIMCOM and its secretariat	■	■	■	■
Stakeholder mobilisation and introduction of benefit sharing		■	■	■
Water Resources Development Strategy (Limpopo Basin Study)		■	■	■

Figure 5.1 General plan for implementation of IWRM in the Limpopo River basin

The support to LIMCOM and its secretariat and the strategic plan will ensure that the LIMCOM will take a leading role of the coming studies and that the different water resources management components will be conducted in harmonisation.

The Limpopo Basin Study is the most advanced of the components and also an essential part of the water resources management since it will give the current baseline and potential development options for the Limpopo River basin. Because of the lack of joint baseline studies in the Limpopo River basin and the need for harmonising data and information between the four countries, as highlighted in the Scoping Phase, this study is urgently needed and will require at least a 3-year period to be completed. It is therefore advised that the procurement of a service provider for the comprehensive study will be conducted by LIMCOM during 2010 in parallel with the strategic plan. This will ensure that the Limpopo Basin Study will start as soon as possible but still under the guidance of the strategic plan for implementation of water resources management.

The objective of the Limpopo Basin Study and the general guidance from the ToR for the Scoping Phase point towards the development of a ***Water Resources Development Strategy for the Limpopo River basin***. It is thus suggested that the scope of work for the comprehensive study is structured to develop such strategy. However, it is also important to build the technical capacity for updating the strategy and to create awareness of it through public participation. The proposed scope of work therefore also includes components for technical capacity development of the LIMCOM and the water authorities of the four countries as well as for public participation. These will provide linkages to the other IWRM mechanisms that could be further developed and guided by the strategic plan.

5.2 Components of a joint WRD Strategy

A Water Resources Development Strategy should define the directions for the water institutions and should identify projects to achieve integrated water resources management and development at the river basin scale. Because Limpopo is a shared river the strategy needs to include joint principles for development and an agreed baseline such as available water resources, current and projected water demand and environmental flows. The general guidance for joint principles is the Revised SADC Protocol for shared watercourses (2002) as well as input from the stakeholder participation process where development options are part of an overall sharing of the benefits generated by the Limpopo River.

Besides the baseline and development potential studies the WRD strategy further needs guidance on how it should be regularly updated as well as developed capacity for the water institutions to run this process. Public participation is also needed to give and receive information from major stakeholders. **Figure 5.2** shows the main pillars of a joint WRD strategy for the Limpopo River basin.

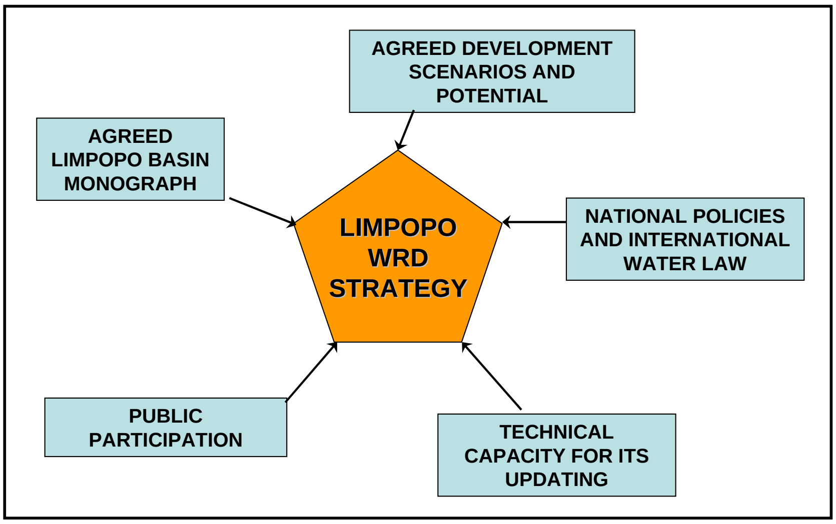


Figure 5.2 Main pillars of a Joint WRD Strategy for the Limpopo River basin

The five key pillars necessary for joint WRD in the Limpopo Rivers, which will support the four countries to jointly develop the water resources of the basin, are:

1) The Limpopo River Basin Monograph (baseline), which describes the current situation in the river basin;
2) Development Scenarios and Potential Projects in the Limpopo River basin, which describes the possible development options and the necessary measures to meet future changes within a framework of likely socio-economic development scenarios in the river basin;
3) Policies and Legal Framework, which gives an analysis of the bearing of national and international policies on the management at basin level and guides the provisions to apply for the Limpopo River basin;
4) Technical capacity and guidance for the LIMCOM, its Secretariat and the national water authorities to regularly update the WRD Strategy.
5) Public awareness and the feedback from major stakeholders on the WRD Strategy.

It is proposed that the scope of work for the comprehensive study is following four major components that are carried out in parallel:

Component 1: Development of a joint Limpopo River basin monograph (No. 1 of the five pillars). This monograph should include a detailed description of the surface and groundwater resources, existing infrastructure and socio-economic conditions, current water use and demand, and key environmental issues for the river basin.

Component 2: Development options and principles (No. 2 and 3 of the five pillars). This component shall lead to identified development options for infrastructure and economic activities, and proposed principles for its prioritisation.

Component 3: Technical capacity development (No. 4 of the five pillars). This component shall focus on developing joint capacity for updating the WRD Strategy. It includes coordinated development of joint basin tools for the water authorities of the four basin countries to monitor and update key variables for water resources development and management.

Component 4: Public participation (No. 5 of the five pillars). This component aims to build awareness and to receive feedback on the WRD Strategy from the major stakeholders of the Limpopo River basin.

It is proposed that the comprehensive study is conducted as a three-year study (**Figure 5.3**). Considering the large catchment area and vast amount of data, identified in the scoping phase, it is judged that it will take two years to make a comprehensive baseline study– the joint monograph.

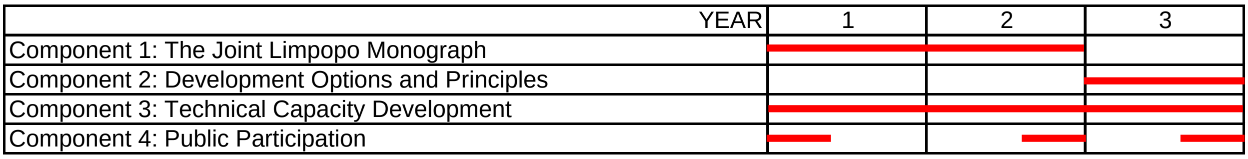


Figure 5.3 General time plan for the four components of the proposed Limpopo Comprehensive Study

In parallel with the monograph the technical capacity development shall commence. This is essential to enable understanding, ownership and acceptance of the baseline among all the basin states. It is also important since much of the compiled and analysed information and data for river basin management should be arranged, stored and presented in joint basin tools such as e.g. a GIS based database and models. The development and education of these joint basin tools must therefore be initiated at the start of the data identification part of the monograph to enable the collected data to be stored in a structured way allowing immediate access to all basin states.

Following the agreement of all parties of the monograph the component focussing on future development options and principles should commence. This component is to a large degree an iterative exercise in which the development options are tested under different regional economic development scenarios (see **Figure 5.4**). The monograph provides an essential input to this component, which is why this phase cannot start until a joint agreement has been taken by all parties on the baseline studies. Failure to agree on the baseline studies will prevent the basin states to develop a WRD strategy for the river basin.

The public participation process should be conducted in parallel with development of the WRD Strategy. However, although contacts with stakeholders are necessary to development of the monograph, the essential participation by stakeholder are necessary when the monograph, development scenarios and allocation principles are to be adopted. Without the ownership and acceptance of the major stakeholders for these principles it is almost impossible to implement. Specific focus should therefore be given to inform and get feedback from the major stakeholder at the initiation of the study and at the end of major milestones.

Both the technical capacity development and the public participation related to the WRD Strategy must be coordinated with the general implementation of water resources management in the Limpopo River basin. The scope of work for these components must therefore be carefully planned and guided by the LIMCOM and the general IWRM strategic plan.

5.3 Proposed objective

The proposed overall objective of the comprehensive study is **To develop a joint water resources development strategy for the Limpopo River basin and develop capacity for its updating**

Following the four main components the proposed specific objectives are:

- To develop a complete river basin monograph giving the baseline information for joint water resources development of the Limpopo River basin;
- To identify viable water resources development options and principles formulated in a water resources development strategy for the Limpopo River basin. The WRD Strategy will provide one of the inputs for a joint water-sharing agreement for the Limpopo River;
- To develop joint capacity of the LIMCOM secretariat and the water authorities of the four basin states to understand and take ownership of the monograph and the WRD Strategy and to update it; and
- To create awareness among major stakeholders of the WRD Strategy and to establish a forum and process for transboundary stakeholder participation.

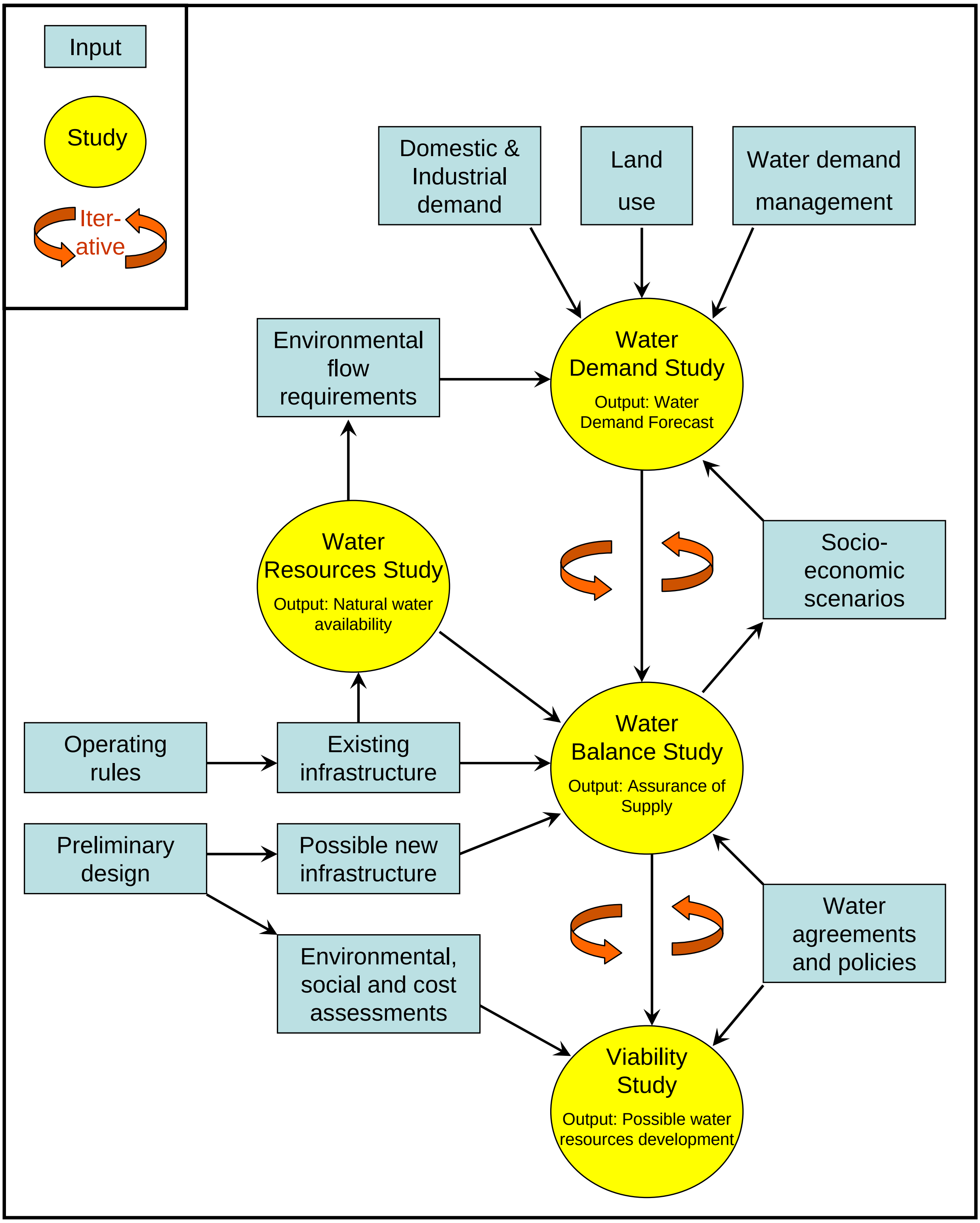


Figure 5.4 Iterative process of the development option component

5.4 Project management and supervision

The focal point institutions for the implementation are:

- The Limpopo Watercourse Commission (LIMCOM) and its Secretariat;
- The Water Resources Authorities of the four basin states, the Department of Water and Environmental Affairs (former DWAF) of South Africa, the Department of Water Affairs (DWA) in Botswana, the Zimbabwe National Water Authority (ZINWA) and the National Directorate of Water (DNA) in Mozambique.
- The local water authorities responsible for the Limpopo River basin in each country, the Limpopo CMA in South Africa, the Mzingwane Sub-Catchment Manager in Zimbabwe, and ARA-Sul in Mozambique.

The implementing agency for the comprehensive study is proposed to be the LIMCOM secretariat, while a Project Steering Committee, including representatives from each country's national and local water authorities should be established to supervise and coordinate the services provided.

5.5 Scope of Work for Component 1: River basin monograph

The River Basin Monograph forms the foundation for development and management of the Limpopo River basin and it is expected to require most of the resources of the comprehensive study. The scope of work is given below. Attention is called to the gaps and need for harmonisation in different areas that have been identified in the Scoping Phase.

5.5.1 Surface water resources assessment

Objectives

- To calculate natural river runoff for all sub-catchments and the main stem of the Limpopo River.
- To estimate flow characteristics, such as duration curves and safe yields, for all points of interest in the Limpopo River basin
- To estimate flood characteristics for the Limpopo river and it main tributaries
- To estimate the possible effects of climate change on the future surface water resources

Scope of Work

The scoping phase showed that there is a need for quality control of much of the river runoff and climatic data in especially Botswana, Mozambique and Zimbabwe, while in South Africa detailed hydrological assessment have already been conducted, e.g. by the WR2005 study. Therefore the first part of the surface water assessment should include:

- Compilation of all monthly river runoff data for Botswana, Mozambique and Zimbabwe including rating curves, current meter measurements and information on the type and characteristics of the gauging stations.
- Compilation of all monthly rainfall data for Botswana, Mozambique and Zimbabwe. This will include digitizing of rainfall data for rainfall stations in Botswana and Zimbabwe.

- A review of all previous studies on hydrology in Botswana, Mozambique and Zimbabwe, such as the surface water assessment studies in 1984 and 2004 in Zimbabwe.
- Detailed quality control of both rainfall and runoff data through visual inspections and statistical analysis. An essential part of the assessment is to analyse the rating for runoff gauging station.
- A thorough review of the WR2005 for the Limpopo River tributaries in South Africa and extraction of key stations for rainfall and runoff data.
- All data will be arranged and delivered to the GIS-based database developed in the Technical Capacity Development component.

The second part of the surface water assessment aims at calculating natural river runoff of for all tributaries in the Limpopo River basin:

- A review and if necessary correction of the catchment areas for all tributaries and the main stem of the Limpopo River basin;
- An assessment of all existing infrastructure will be made since this is a necessary input to the hydrological modelling of surface water. The major dams will be described regarding operation procedures and storage capacity /surface area in relation to water levels. Information on the minor (farm) dams will be integrated on a sub-catchment basis;
- All historical water use, return flow and interbasin transfer information will be collected for each tributary and the main stem of Limpopo River to create time series fro input to the hydrological models;
- Mass balance calculations for the large reservoirs will be conducted to calculate inflow for comparison with simulated river runoff. Observed runoff data will be prepared for the hydrological modelling for the same purpose;
- Rainfall data will be patched to provide input to the hydrological model. Care should be taken to make sure that rainfall input series are homogeneous;
- Evaporation data will be gathered and evaluated for input to the hydrological model;
- The Pitman hydrological model will be set up for all tributaries in Botswana, Mozambique and Zimbabwe, as well as the main stem of the Limpopo River;
- The previous setups used for the WR2005 study in South Africa will be reviewed, and used, if found accurate;
- The Pitman hydrological model will be calibrated, emphasising on the observed river runoff data that has been judged to have the best quality; and
- The calibrated hydrological models will be used to compute concurrent long series of natural river runoff.

Following the hydrological modelling, the computed natural runoff and the quality controlled data will be used to calculate flow characteristics:

- Statistics on the available natural water resources (MAR) will be calculated for each sub-catchment and the main river. Each country’s contribution to the virgin runoff will be calculated;
- Thematic maps of MAR and MAP will be produce; and

- Flood frequency analysis will be conducted for each tributary and the main stem of the Limpopo River basin.

As the final part of the surface water resources assessment an assessment of the possible effect of climate change should be investigated:

- Review of the most recent literature on climate change in southern Africa; and
- A sensitivity analysis in which the hydrological models and flood frequency analysis is applied to changed rainfall patterns.

The surface water resources assessment should be made in coordination with the Technical Capacity Development component in terms of improved monitoring and the establishment of a mechanism for exchange of information. The choice of river runoff stations at key points, such as borders, is an essential part of data exchange system and emergency preparedness between the countries.

5.5.2 Groundwater resources assessment

Objectives

- To describe and estimate groundwater sources on the scale of the basin or sub-basins of the Limpopo River;
- To assess water demand that is or can potentially be supplied by groundwater;
- To estimate the possible effects of climate change on the future groundwater resources.

Scope of Work

The groundwater component of the Joint Limpopo River Basin Study should focus on the regional characteristics of geohydrology in terms of significance on the scale of the basin or sub-basins. The work should be made in coordination with the development of a joint GIS-based tool in the Technical Capacity Development component. The following aspects should be addressed and described in the study:

- Hydrogeological regions and significance in terms of groundwater availability;
- Groundwater resource assessment (quantification) on a regional scale with the following components included:
    a. Rainfall distribution, variation and potential impacts of droughts.
    b. Groundwater recharge from rainfall and surface water seepages on a regional scale.
    c. Outflow components such as boreholes (regional cumulative effects), mine dewatering, basic human need, livestock use, irrigation, forestry, riparian vegetation, alien vegetation, wetlands, springs and the groundwater component of base flow.
    d. The aspect of groundwater flow losses on a regional scale.
    e. Potential groundwater yield per resource unit (e.g. primary or quaternary catchment, or aquifer unit) as motivated in the tender.
- Influence of groundwater on base flow, sustainability of aquatic eco systems and water supply;
- Assessment of the effects on groundwater recharge of decreased rainfall due to a possible climate change;
- Groundwater quality; and
- Assessment of the importance of groundwater as a resource of regional and rural water supply.

5.5.3 Land use and socio-economy

Objectives

- To collect and harmonise general geographic data for the Limpopo River basin;
- To estimate the present and historic trends in land use; and
- To provide the basic information on demographic variables, settlement patterns and socio-economic and economic development in the different parts of the basin.

Scope of Work

All work related to this task should be made in coordination with the development of a joint GIS-based tool in the Technical Capacity Development component. As part of this, compilation and analyses of information covering natural characteristics, such as Topography, Geomorphology, Geology, Soil Characteristics should be conducted and, if necessary, harmonised to create joint river basin maps.

The starting point for the work should be the data and map information collected during this scoping phase.

For the assessment of land use the following should be conducted:

- Complete compilation and analyses of information on land use and livelihood activities (agriculture, forestry, livestock, fisheries and aquaculture production and conservation areas and wildlife);
- Compilation of historic and present remote sensing data; and
- Analysis of remote sensing data to quantify different land use at present conditions as well as identifying trends.

For the assessment of socio-economy the following should be conducted:

- Compilation of demographic and socio-economic data (e.g. mapping of gender, child, poverty and health aspects) from published sources and sample surveys where necessary; and
- Use the demographic data as contained in the national censuses and updating these taking into account among others population growth, female reproduction rate and composition of the population-age distribution and HIV-AIDS.

5.5.4 Water demand and infrastructural inventory

Objectives

- To estimate present water demand for different sectors and different parts of the river basin; and
- To describe the present development of water-related infrastructure in the Limpopo River basin.

Scope of Work

The estimation of water demand and inventory of water-related infrastructure should be made in coordination with the water resources assessment and water balance studies to enable inputs for the hydrological units (see e.g. Figure 4.2) used by the hydrological and water balance models. All work related to this task should also be made in coordination with the development of a joint GIS-based tool in the Technical Capacity Development component. The starting point for the work should be the data and information collected during this scoping phase.

Present water demand data should be obtained for the following sectors:

1. Urban and rural domestic water supply
2. Agriculture, Forestry, Livestock and Fishery
3. Hydropower or other energy production
4. Industrial demand
5. Environmental flow requirements

The scope of work for the water demand assessment should comprise:

- Collection of information about present water demand from the available documentation on statistics, water permits and outtakes;
- Estimations for domestic urban and rural water demand based on population data, coverage level and unit consumption rates. Other components of urban water supply demand, like industrial, commercial and public demand, as well as leakage losses will be gathered;
- Computation of present irrigation water demand based on information on irrigated areas and crops using standard methods developed by FAO or by Universities in southern Africa;
- Water use of present afforestation will be computed through the latest developed algorithms in South Africa; and
- Water demand for other areas as livestock, fisheries, transport and navigation, and hydropower production will be assessed.

The scope of work for the water-related infrastructure task should be:

- Inventory and description of water infrastructure in the Limpopo River basin, including dams, weirs, groundwater development schemes, reservoirs, pipelines and canals, intra-basin transfer schemes, pumping stations, water tunnels, water treatment works, wastewater treatment, hydropower plants, and hazardous waste sites.

5.5.5 Environmental studies and water quality

<u>Objectives</u>

- To make a complete classifications of ecological status for all tributaries and the main stem of the Limpopo River basin;
- To calculate the environmental flow requirements for the tributaries and main stem of Limpopo River basin, with special focus on the protected areas; and
- To describe the present and historic trends in water quality for all tributaries and the main stem of the Limpopo River basin.

<u>Scope of Work</u>

The scoping phase has shown that ecological classification and determination of environmental flow requirements have been made to a limited degree in Mozambique, Botswana and Zimbabwe. An environmental assessment should therefore be carried out on terrestrial and aquatic ecology for the rivers in these countries. This process should follow the Downstream Response to Imposed Flow Transformation (DRIFT) method and includes:

- Mapping the various ecological zones within the area and identifying those zones that warrant specific management intervention in order to comply with the convention on biodiversity;
- Assessing the scope for economic use of each of the ecological zones;
- Assessing the level of direct natural resource dependence of the local population and its impacts on the environment;
- Identifying current land use practices and trends;
- Assessing the effectiveness of current management systems of the various ecological areas; and
- Assessing the potential for alternative economic development of the area.

In addition a review of the made classification in the South African Rivers should be conducted.

Environmental flow requirements will be based on the South African Desktop Model developed in South Africa. Special emphasis should be given to the protected areas and the estuarine flow requirements.

The assessment of water quality data in the scoping phase concluded that, similarly to hydro-meteorological data, the water quality data for the Limpopo River catchment in Botswana, Zimbabwe and Mozambique are sparse. However, the data is sufficient to prepare a snapshot of water quality also for these basins. Within the scoping phase also a detailed comparison of the water quality standards for the four countries were conducted and key sampling stations in South Africa were chosen to represent the water quality of the tributaries in this part of the Limpopo River basin.

With the basis of the conducted work in the scoping phase the scope of work for the water quality task in the comprehensive study are:

- Compile if possible further water quality data in Botswana, Zimbabwe and Mozambique;
- Conduct a detailed analysis of the water quality data based on all data in Botswana, Zimbabwe and Mozambique and on the key sampling sites in South Africa to assess, as much as possible, present levels and geographic and temporal trends in water quality of the main tributaries and the Limpopo River; and
- Suggest based on the national standards of the four countries one joint water quality standard to adopt for the Limpopo River basin.

The water quality task should be made in coordination with the Technical Capacity Development component in terms of improved monitoring and the establishment of a mechanism for exchange of information. The choice of water quality stations for indicator parameters at key points, such as borders, is an essential part of an data exchange system between the countries.

A special part of the water quality task is also to assess riverine sediment transport for assessment of reservoir siltation. This should include:

- Compilation and analysis of suspended sediment data; and
- Compilation and analysis of silt surveys conducted in the South African part of the river basin.

5.5.6 Water balance analysis

<u>Objective</u>

- To assess the present water balance and safe yields for the Limpopo River basin.

Scope of Work

The purpose of the water balance analysis is to compare the water requirements in the system with the water availability in the system, both for existing and future water requirements, as well as with current and possible future water infrastructure. Water balance analysis (or system analysis) is important to take into consideration the seasonal and inter-annual variation in available water resources.

Comparison of demand and supply should therefore be made month by month in the analysis to assess the risk of failure of the system. The scope of work should produce two essential outputs that are fundamental for the water management in a river basin:

1. *Historic safe yield*: the maximum annual water volume that can be abstracted without failing once over the total hydrological record length.
2. *Assurance of supply:* the percentage of time steps with fully satisfied water demand over the total hydrological record length

Historic safe yield should be calculated for all major dams and intake points and the assurance of supply should be produced for all major water users.

The scoping phase has shown that water balance modelling using the South African WRYM model has been used for all the major tributaries in South Africa. It is therefore proposed that the WRYM model is also applied for the whole Limpopo River system including all tributaries in Botswana, Zimbabwe and Mozambique.

The existing model set ups for many of the catchments, such as the Olifants and the Crocodile are very complicated and will not be feasible, which is why it is proposed to make one new setup covering the whole river basin. This will ensure flexibility to assess different scenarios of water demand that will be necessary in the Development Option component.

The scope of work for the water balance task will thus be to:

- Set up the WRYM model for the whole of Limpopo River basin based on tertiary catchments in South Africa (and for corresponding sub-division in the other three countries). The tertiary catchments will if necessary be sub-divided according to existing infrastructure (dams and transfers). The priority of water supply should follow the policies in the SADC Protocol on Shared Watercourse Systems from 2000; and
- Calculation of assurance of supply for key users and safe yield for major dams and transfers in the Limpopo River basin.

5.5.7 Legal and institutional setting

An overview of the legal setting has been conducted in the scoping phase. This will comprise the starting point for the comprehensive description of the legal and institutional setting.

For the Limpopo River basin monograph the policy and legal framework should be vertically described for the international, regional, national and local authority levels and horizontally described for inter-sectoral issues at national and local levels. At international level, relevant conventions will be identified. At regional level, the service provider should consider the broad IWRM framework for the SADC region of which the cornerstones are the Regional Water Policy (August 2005) and the Revised Protocol on Shared Watercourse Systems (2003).

5.6 Scope of Work for Component 2: Development options and principles

5.6.1 Economic scenarios and future water demand

Objective

- To forecast future water demand up to 2030 for different user sectors and different parts of the Limpopo River basin.

Scope of Work

The point of departure for the future forecast of water demand is the present water demand derived in the monograph phase. Projections for the period up to 2030 will be prepared based on the present situation, tendencies of growth and planned projects. The scope of work should be:

- Assessment of future economic and demographic scenarios based on historic changes and trends in the river basin, plus the evaluation of the most important sectors from an economic point of view;
- Projections of domestic urban and rural water demand up to 2030 based on population growth, coverage level and unit consumption rates;
- Projections of water demand for industries not served by urban water supply systems considering plans and projects defined or under consideration for the Limpopo River basin; and
- Projections of future irrigation water demand up to 2030 considering new areas to be developed according to existing plans and analysis of potential irrigable areas with suitable soils. Irrigation demand will be calculated based on areas, type of crop, irrigation method and assumed efficiency.

At least two scenarios will be prepared - high economic growth and probable economic growth - to care for the uncertainty that surrounds these projections.

5.6.2 Infrastructural development potential

Objective

- To identify future potential infrastructure development for augmentation of water resources and flood protection.

Scope of Work

The scoping study identified many studies, mainly in South Africa and Botswana on potential dam sites. Also in Zimbabwe and Mozambique a number of potential dam sites and water transfers have been identified by the water authorities. These studies and knowledge will be the starting point for the assessment of future development options. The steps to be taken are:

- A review and evaluation of previous studies on proposed new storage dams, summarising and describing the characteristics of the sites and the dams in terms of geology, foundations, type of dam, design flood, spillway and other characteristics.
- A study of new dam sites should be done at a reconnaissance level;
- Simplified designs for the dams including estimates of design floods, catchment sediment transport yields and loss of storage capacity due to sedimentation;

- A simplified costing of the alternative development schemes;
- A simplified environmental and social screening of the alternative development schemes;
- An assessment of possible multi-purpose uses, such as hydropower production or flood management; and
- Ranking of the alternative development schemes from a multi-criteria perspective.

5.6.3 Assessment of WDM and conjunctive use of groundwater

Objectives

- To assess the possibility of decreasing the future water demand in the Limpopo River basin through water demand management measures; and
- To assess possibilities for conjunctive groundwater and surface water use to increase assurance of supply.

Scope of Work

The scoping phase has identified drought mitigation as one of challenges for water resources management in the Limpopo River basin. Large parts of the Limpopo River basin are semi-arid or arid (see Figure 3.1).

The scoping study also emphasised the importance of groundwater as water supply for a major part of the river basin. In this situation the conjunctive use of groundwater and surface water is a very interesting possibility to reduce drought vulnerability. Similarly all forms of water demand management and rainwater harvesting are possible ways of augment scarce water resources in very dry areas, such as the one in the north-west part of the Limpopo River basin. These options must therefore be investigated as part of the development option component:

- Assess concrete methods for water conservation and WDM, such as improved monitoring of supply by flow meters, decreased water losses from the pipe network and more efficient irrigation methods;
- Assessment of techniques for rainwater harvesting that is implementable in driest parts the Limpopo River basin; and
- Identification of groundwater development options based on the groundwater exploitation potential and groundwater reserve estimates made in the monograph phase and the previous and parallel studies by SADC on groundwater drought management.

5.6.4 Water balance analysis for future scenarios

Objective

- To assess the water balance on a 10 year interval up to 2030.

Scope of Work

The different possible future development scenarios within the study area (and combinations thereof) should be evaluated with the WRYM model set up in the monograph phase, analysing the effect of the inclusion of new water infrastructure, WDM or groundwater sources. Input to the WRYM should be the water demand forecasts up to 2030, thus giving a water balance projection for the Limpopo River basin up to 2030. The model should be used to calculate water availability and assurance of supply to the different users under the different development scenarios.

The results of the water balance analysis for future scenarios will be used to propose limitation in allocation of water for different sectors in the four basin states within the Limpopo River basin.

5.6.5 Formulation of a Joint Limpopo River Basin WRD Strategy

Objective

- To formulate a joint Limpopo River Basin Water Resources Development Strategy up to 2030.

Scope of Work

The purpose of the WRD Strategy is to provide the LIMCOM and the basin states the proposed water resources development options to meet the future water demand for socio-economic development and poverty alleviation in the Limpopo River basin. The WRD strategy should include projected water-related development for different sectors in the four basin countries. The scope of work is thus to summarise and prioritise the different water resources development options through the following steps:

- A financial assessment, e.g. through cost-benefit analysis, of the identified development options and water demand management measures under different regional economic growth scenarios.
- Choice of three development strategies, consisting of combinations of development options, to meet different regional economic growth scenarios.
- Outline of implementation plans, including necessary preparatory studies, for the three strategies.
- Cost estimates, including Unit Reference Values for developed water, and proposed funding mechanisms for the three strategies.

The formulation of the WRD Strategy should be closely coordinated with the other IWRM mechanism implemented and guided by LIMCOM. The strategy should also be guided by feedback from the major stakeholders through the public participation process described in Component 4.

The WRD strategy should also include guidelines for its regular updating by the LIMCOM.

5.7 Scope of Work for Component 3: Technical capacity development

5.7.1 Increased human skills in water resources development

Objectives

- To increase human skill of members of the LIMCOM and the water authorities in the four countries in the field of water resources development; and
- To establish an understanding of the setting, problems and prospects of each other's countries.

Scope of Work

One of the most essential parts of transboundary river basin management is the interaction between water authorities in the other countries. Each country's institutions have their strength and weaknesses. This gives an opportunity to learn from each other's experience and knowledge. Interaction makes also the individuals involved in the river basin management to get an understanding of the other country's setting, problems and prospects, which is an essential part when agreeing on joint use of the shared water resources.

The best way of establishing this interaction between the four countries sharing the Limpopo River basin is to arrange a number of workshops, courses and training sessions related to the parallel Monograph and Development Option components. A strong coordination with the implementation of these components is therefore important to succeed with this capacity development. To increase the human skills and understanding of each others problems and prospects, the following activities should be conducted:

- Arrangements of joint workshops for key members of the LIMCOM and the water authorities related to the activities of the Monograph and Development Option components. Examples are to present the interim and final results for sector studies;
- Arrangements of courses and training sessions for key members of the LIMCOM and the water authorities related to the activities of the Monograph and Development Option components. This should include basic courses such as understanding of the IWRM concept as well as in essential sectors such as hydrology, water quality, ecology, etc.; and
- Support to individuals of the LIMCOM and the water authorities to attend international conferences and course related to water resources development and management.

The planning of the workshops, courses and training should start with an assessment of present technical development of the LIMCOM and the water authorities of the basin states. Based on this assessment and in coordination with the other components a program for the inter-action activities should be planned. The inter-action should aim at filling in gaps in knowledge and to cover the essential sector studies for water resources development. The course should as far as possible be held in the different countries on a rolling schedule to enable study and field visits within the Limpopo River basin.

The technical capacity development would be carefully coordinated with the general organisational development of the LIMCOM and its Secretariat.

5.7.2 Improved primary monitoring

Objective

- To establish a basic monitoring network for river runoff, rainfall and water quality for transboundary river basin management and development.

Scope of Work

As indicated in this scoping phase the monitoring of key variable, such as river runoff, rainfall and water quality, is sparse and in Botswana, Zimbabwe and Mozambique. It is therefore essential to already at the start of the comprehensive study to choose a number of strategically important monitoring stations, which will comprise a primary network. Strategic points are for example stations in the main tributaries close to the confluence with the Limpopo River as well as at borders. The components on technical capacity development shall therefore include support to rehabilitate, improve and if necessary construct new stations and to develop capacity for the operation and maintenance of these.

The scope of work for this task is:

- Identification of up to maximum 10 river runoff stations in each country to be key stations;

- Identification of up to maximum 10 rain gauges in each country to be key stations;
- If necessary rehabilitation of these station to ensure reliable river runoff and rainfall data, including installation of loggers. This may include current meter measurements to improve the station ratings of the river basins;
- Installation of loggers for water quality indicators, such as conductivity and pH at the runoff stations. Start up of regular sampling of key chemical parameters on a bi-monthly basis; and
- Training of personnel of the water authorities in the three countries in the operation and maintenance of the monitoring stations.

The choice of key stations should as much as possible be made utilising existing stations that are in operation. The inputs from and coordination with the Monograph component is essential for the choice of the key monitoring stations. Coordination should also be made with other regional monitoring projects, such as the SADC HYCOS.

5.7.3 Establishment of technical basin tools

Objective

- To establish essential technical tools for joint water resources development and to develop capacity in the use of them among staff of LIMCOM and the water authorities of the four basin states.

Scope of Work

Similar to a primary monitoring network for water resources management and development it is equally important to establish basic tools that will enhance the joint monitoring. The two main tools that are essential for river basin management are:

1. A GIS-based database linked to a Web-GIS
2. Hydrological and system analysis models

The GIS-based database will link all geographical information with essential data and information, such as runoff data for the primary network. It is a tool for structured storage of data, presentation of data and distribution of data. The hydrological models are used less frequently but are essential parts of estimating water resources in the river basin. The access to and understanding of these models are fundamental for the acceptance and ownership of the water resources and safe yield estimates.

Since basically all data and information compiled in the Monograph component should be stored in the GIS-Database and both hydrological and system analysis models will be used in the same component, coordination is essential. The scope of work is:

- Choice and purchase of software for the GIS database;
- Compilation and inclusion of basic GIS information for the Limpopo River basin;
- Identification of which data and in which format should be included in the GIS-Database;
- Compilation of the relevant data from the service providers conducting the Monograph component, reformatting if necessary and inclusion in the database;
- Retrieval of licences for the Pitman Hydrological model and the WRYM system analysis models; and

- Installation of the tools at the LIMCOM secretariat and development of management procedures and guidelines for the technical tools to ensure that they properly function within the organisational structures of the secretariat.
- On-the-job training courses for the staff of LIMCOM and the staff of water authorities in the four countries.

5.7.4 Establishment of Web-GIS for exchange of technical data and information

Objectives

- To establish a basic exchange of information of key data essential for Limpopo River basin management between the water authorities through a Web-GIS; and
- To define communication lines to be used in emergency situations.

Scope of Work

Linked to the establishment of a GIS-based tool for data management a mechanism for exchange of key data and information between the four basin states should be developed. The joint access to data from all basin states is very important for joint water resources development. This task is mainly focussed on technical data exchange between the national water authorities but could be combined with a general mechanism for information exchange between all major stakeholders of the basin if this would form part of the general stakeholder participation program operated by LIMCOM.

The essential tool for exchange of technical data between the water authorities in the four countries is a Web-GIS, which is linked to the established joint GIS-database. The main purpose of the Web-GIS is to disseminate information but if possible in terms of data quality assurance and internet capacity also uploading of data can be made via the Web-GIS. As suggested for the GIS-database, the Web-GIS is proposed to be hosted by the LIMCOM secretariat.

The scope of work for this task is:

- Development of a Web-GIS for the LIMCOM secretariat;
- Linkage of the GIS-database, or parts of, to the Web-GIS;
- Development of procedures for updating and quality assurance of the GIS-database; and
- Training of personnel of the LIMCOM in the basic updating of the Web-GIS.

A very essential part of the exchange of information is how to communicate during an emergency situation, either a drought or a flood. Part of this task should therefore be to develop guidelines for actions by the water authorities in emergency situations.

5.8 Scope of Work for Component 4: Public participation

The public participation should be coordinated with the general stakeholder participation process that forms part of the transboundary water resources management and which is guided by LIMCOM. The scope of work below is formulated based on the assumption that identification and mobilisation of stakeholders have been conducted by LIMCOM through other IWRM programs for the Limpopo River basin.

Objective

- To create awareness and support among the public and to get feedback on the Water Resources Development Strategy for the Limpopo River basin.

Scope of Work

The main scope of work is based on public participation through stakeholder workshops and through dissemination of information:

- Stakeholder workshops should be organised in connection with the project milestones of the parallel components on the monograph and the development options. The stakeholder workshops are good opportunity to convey the results of the studies and to get feedback from the stakeholders;
- Guiding and information material should be created and distributed to the key stakeholders. This will serve to maintain interest in the project and inform the stakeholders what is on-going; and
- Information and promotion of the Web-GIS established in the Technical Capacity Development component should be conducted.

It is foreseen that at least three major joint stakeholder workshops should be arranged: At inception, at finalisation of the monograph and at finalisation of the WRD Strategy.

5.9 Level of detail for the Scope of work

The Limpopo River basin covers a vast area and constitutes many problems and prospects. A very detailed baseline and development option study would therefore take long, which would not benefit the needed implementation of water resources management in the river basin. The following level of detail is therefore envisaged for the tasks in Component 1 and 2 (see **Table 5.1** below).

The definitions of the different level of detail follow the guidelines for other studies in the region:

1. **Reconnaissance.** When the data sets will typically be derived from mapping, imagery or existing spatial data sets with source scales of 1:250 000 to 1:1000 0000 and larger. Development of these data sets would not require fieldwork. Reconnaissance level data sets should cover the entire study area.

2. **Detailed.** The data sets are typically derived from mapping, imagery or existing spatial data sets with a source scale of 1:30 000 to 1:250 0000. The data requires considerable verification often necessitating fieldwork, but the level of detail and the accuracy is still insufficient for such purposes as detailed design. The development of detailed data sets will normally be required to improve basin-wide reconnaissance level data sets in specified sub-regions of the study area. Only where specifically requested, should detailed data sets cover the entire study area.

3. **Intensive.** These data sets will cover specific project locations, and may require field surveys where existing data is inadequate.

In the execution of the comprehensive study and production of the WRD Strategy the need for more detailed studies should be assessed and be included as recommendations for the updating of the WRD Strategy.

Table 5.1 Level of detail for the tasks in Component 1 and 2

Component 1: The Limpopo Monograph	**Level of detail**
Surface water resources assessment	Intensive
Groundwater resources assessment	Detailed
Land use and socio-economy	Reconnaissance
Water demand and infrastructural inventory	Intensive
Environmental studies and water quality	Detailed
Water balance analysis	Intensive
Legal and institutional setting	Reconnaissance
Component 2: Development options and principles	**Level of detail**
Economic scenarios and future water demand	Detailed
Infrastructural development potential	Detailed
Assessment of WDM and conjunctive use of groundwater	Reconnaissance
Water balance analysis for future scenarios	Detailed
Formulation of a Joint Limpopo River Basin WRD Strategy	Detailed

6 EXPERTISE REQUIRED AND EXPECTED OUTPUTS

6.1 Linkage between the components

It is proposed that the consultancy services for the four components are conducted by the same service provider. The knowledge attained by producing the monograph is essential input to the development options and allocation principles. The Technical Capacity Development and Public Participation components must be closely coordinated with the monograph and development option components and it is thus favourable if these are conducted by the same service provider.

6.2 Required experience

The service providers should have at least 10 years of experience in Integrated Water Resources Management and river basin planning studies for transboundary river basins in southern Africa.

The minimum list of required key expertise for Components 1 and 2 should be:

- Experienced Team Leader for Transboundary river basin studies
- Hydrologist
- IWRM Expert
- GIS and database experts
- Institutional Expert
- Hydro-geologist
- Socio-economist
- Economist
- Ecologist (terrestrial and aquatic)
- Water quality expert
- Water resources modeller
- ESIA expert
- Legal expert

6.3 Phasing

The comprehensive study should be phased in accordance with the four components. In addition the study should include an inception phase, in which the final Scope of Work should be determined and plans for the public participation and technical capacity development should be outlined. The following phases should thus be included:

- Inception Phase: Months 1-2
- Monograph Phase: Months 3-24
- Development Options phase Months 25-36

The Technical Capacity Development and Public Participation should run on an intermediate basis during al phases.

6.4 Expected outputs and reporting

The expected outputs of the Limpopo River basin would be reports, including the Monograph and the Joint WRD Strategy, increased capacity of the LIMCOM and the water authorities of the four countries and awareness of the project among major stakeholders.

Specifically the following reports should be produced

- Inception Report (Month 2)
- Progress Reports (Every 3rd months)
- Draft Monograph Report (Month 20)
- Final Monograph Report (Month 24)
- Draft Joint WRD Strategy Report (Month 32)
- Final Joint WRD Strategy Report (Month 36)
- 1st Technical Capacity Development Report (Month 24)
- 2nd Technical Capacity Development Report (Month 36)
- Public Participation Report (Month 36)

The following joint stakeholder workshops should be conducted

- Inception Workshop (Month 3)
- Monograph Workshop (Month 21)
- Joint WRD Strategy Workshop (Months 33)

The following technical tools should be developed, installed and training provided for:

- A GIS-database
- A Web-GIS
- The Pitman model set up and complete for the whole Limpopo River
- The WRYM model set up and complete for the whole Limpopo River
- 10 primary river runoff stations rehabilitated to ensure reliable continuous runoff data and equipped with loggers for water quality indicators
- 10 primary rainfall stations rehabilitated to ensure reliable daily rainfall data