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Ministry of Energy and Water Affairs

National Directorate of Water (DNA)

FINAL REPORT

National Water Sector Management Project, Activity C

A Rapid Water Resources and Water Use Assessment for Angola

March 2005

SWECO GRØNER

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1. INTRODUCTION

1.1 Study Background

The potential of renewable water resources of Angola is not known with sufficient accuracy, mostly due to lack of data. Almost all of the 189 hydrometric stations in operation at independence in 1975 were abandoned during the years of civil war. The same is the case for data on total water use, water consumption, and future water demand. Proper water development planning is thus almost impossible.

This project "A Rapid Water Resources and Water Use Assessment for Angola" is undertaken to start moving in the direction of establishing a sufficiently accurate assessment of the renewable water resources and water use that can be further elaborated and updated as data become available. As such it forms one of the steps towards achieving the goals of the Strategy for the Development of the Water Sector in Angola.

The project is Activity C of the National Water Sector Management Project (NAWASMA) being carried out as institutional co-operation between the Angolan National Directorate of Water, (DNA) (Direcção Nacional de Águas) and the Norwegian Water Resources and Energy Directorate, NVE under the financing of NORAD and covering the entire country. SWECO Grøner carried out the assessment for and in collaboration with DNA under the Ministry of Energy and Water. The development objective of the NAWASMA project is improved water sector management in Angola through a strengthened institutional capacity of DNA. Proper water management requires solid knowledge. The specific development objective of Activity C is therefore to assess rapidly the water resources, water use, and future water demand in Angola.

In addition to providing up-dated estimates of water resources and water use, the future capacity for managing and planning water resources was improved through the project by transfer of knowledge and capability to DNA. This final report of the project has been designed to enable DNA and other Angolan authorities to move on in their work with national master plans for the water sector, identifying bottlenecks for further planning and management in terms of data quality and availability. The full Terms of Reference for the assessment is included in the Appendices.

1.2 Assessment Methodology

A consultative approach was applied to the assessment in which relevant authorities and stakeholders in the water resources sector were involved in the study in order to attempt to include their knowledge and possible data. DNA was the facilitator in this respect, providing the link between the Consultant and the various authorities and bodies. Although most of this consultation work was carried out in Luanda, limited field trips were also made to some provinces where meetings were held with relevant authorities, available data collected, and some water resources developments inspected.

The challenges to obtaining reliable data on water resources and water use in Angola are many. In some sectors in fact no data is freely available at all. The importance of identifying and addressing these bottlenecks in the development of assessments for the sector cannot therefore be overestimated and has been a major activity during the assessment.

1.2.1 Establishment of clear assumptions and methodologies to be applied in assessment estimates

At the outset of the assessment the methodologies to be used as suggested in the consultant's proposal were firmed up and necessary points discussed and agreed with DNA.

An important point was the aerial resolution to be used in the study. In concurrence with the advice of Angolan experts during the project kick-off seminar in the Royal Norwegian Embassy in Luanda, the established boundaries of regions of Angola to be identified and used were adopted. These are the major river drainage basins draining to the international rivers and the coastal rivers draining to the Atlantic:

- Zaire
- Zambezi
- Okavango
- Etosha
- Coastal rivers draining to the Atlantic (including the Luando-Kwanza (Cuanza) system)

These were, however, further disaggregated into individual catchments for both the water resources and the water use assessment.

1.2.2 Estimation of Angola's renewable water resources (surface and groundwater) by river basins and aquifers

For surface water mean monthly data from the hydrology records of the NAWASMA database in DNA were transferred, assessed and used, supplemented by regional data. Monthly and yearly means were used to generate a simplified runoff map for those parts of Angola covered within the hydrometeorological network. This data was subjected to further checks before comparison with regional runoff and rainfall distribution, especially with a view to compensation for the lack of data from the eastern parts of Angola.

Meetings were held with INAMET and data was received for a selection of stations. Quality control of this data was carried out and several corrections were made, especially with respect to obvious punching errors and location of stations. Some data appears to be incorrectly punched but the values lie within probable limits. Such data values have not been adjusted. This data was then subjected to further checks before comparison with regional figures for rainfall distribution.

The data sources for the evaluation of the hydrogeology and groundwater resources of Angola are mainly the Hydrogeological map of Angola at scale 1:1.500.000 and the Geological map of Angola at scale 1:1.000.000. In addition geological and hydrogeological maps and interpretations produced as the UK contribution to the International Hydrological Programme (IHP) of UNESCO Southern Africa, and the FRIEND Phase II project were accessed. Meetings were held with HYDROMINAS, UNICEF and Direcção Provincial de Águas in Lubango, and information on groundwater registers and some groundwater data was collected. These data sources gave the possibility to indicate probable groundwater yields in most of the common aquifers, but data for estimation of the volumes of renewable groundwater resources were not accessible.

1.2.3 Preliminary estimation of sediment transport in the different river basins, and the identification of river basins where soil erosion problems are most severe

Data on sediment transport is virtually non-existent in Angola. Consequently, this is one of the major bottlenecks, which needs to be prioritised in DNA's further work on water resources.

Fortunately the Consultants were successful in obtaining a copy of a study of the sedimentation of the Cambambe Dam reservoir on the important Cuanza River[1]. The study is based on bathymetric field surveys carried out and gives estimates of the sediment volume that has accumulated in the reservoir since its implementation. Although of course not representative for other basins in Angola, it does give one data point for the important Cuanza River. Contacts were also made with institutions in neighbouring countries to seek out further possible data sources, in particular for the Okavango Delta. Internet resources were extensively researched to find any further existing relevant studies. Some limited information was found on soil erosion caused by human activity in the catchments draining to the Atlantic Ocean.

1.2.4 Development of scenarios for urban, peri-urban, and rural population growth in Angola up to the year 2025

This was one of the most complex parts of the assessment due to the lack of firm population data in Angola. The methodology was developed by gathering and comparing various available sources of population data and estimates as detailed in Chapter 4, discussing and assessing the merits and shortfalls of each one, and applying international experience combined with local knowledge. The provincial breakdown of population estimates was even more challenging. A description of the methodology and results is given in Chapter 4.

Finally, the population estimates for each province were again disaggregated into catchments populations and entered into the GIS water resources database on a catchment basis by first splitting each province up into its various catchments and, using the satellite maps of the locations of the towns, villages and settlements in each catchment, allocating first the urban and periurban figures to the correct catchment in the province. The rural population figures were then distributed to the various catchments proportionately to the intensity of settlements in each catchment as indicated by the satellite imagery. The result is a catchment distribution of the forecasts within each province. Catchments that straddle province boundaries were dealt with as sub catchments within each province, the total of the various provincial sub catchments then being summed by the GIS system to arrive at total catchment figures. Further details are given in Chapter 7.

1.2.5 Development of scenarios for growth of water intensive industrial and mining activities

Updated information on water intensive industrial and mining activities is very difficult to obtain in Angola. There is some information on the government website Angola.org, this is, however, dated from 1995. In order to secure more detailed and up-to-date information and data, meetings were planned with three main institutions:

- Ministry of Industry
- Ministry of Geology and Mines
- Endiama, the national diamond mining company

[1] Estudo de Avaliação da Sedimentação da Albufeira da Barragem de Cambambe no Rio Cuanza, PM Consultoria Obras Hidráulicas, Luanda, February 2002

At the time of writing this report, the meetings with the Ministry of Industry and Endiama were still pending. A meeting was held with the Geological Services of the Ministry of Geology and Mines but no information could be given. This was due to the Geological Services request for payment for supplying such information for which there is no facility under the Consultant's contract. This has been brought to the attention of DNA and it is hoped that this matter can be resolved in the future development of the assessment by DNA.

As a result of the general lack of data on this issue, it has not been possible to develop firm scenarios of the growth of industrial and mining industries. This is a bottleneck that should be prioritised in the further development of the assessment. One line of action for achieving this could be ministerial collaboration between the Ministry of Energy and Water and the Ministry of Geology and Mines. Mutual exchange of information and data could be beneficial to both parties in this respect.

1.2.6 Estimation of Angola's water demand for the different sub-sectors, with special emphasis on consumptive water use, and particularly the demand for full or supplementary irrigation

For estimation of the consumptive water use in the Agriculture sector, the following factors were taken into consideration: the existing and the planned irrigation schemes; the main crops grown under irrigation; and the net annual irrigation requirement. Watering of animals was also considered. For irrigation activities, year round irrigated agriculture was assumed with 365 days, while for dried periods 182 days was used. The volume of water for 2005 was assumed to be as of 2004, i.e. at the time of the study. For those irrigation schemes partially operational, it was assumed that in 2005 they would be working at 20% to 40% of their capacity, whereas in 2015 these schemes will be working at 50% to 75% of their capacity. For 2025 it was assumed that all planned irrigation schemes would be constructed and that all irrigation schemes, be they planned, partially operational or operational, would be working at 100% of their capacity.

In relation to animal watering, projections were made based on figures provided by the Department of Animal Production of the National Directorate of Livestock, a government body under MINADER, the Ministry of Agriculture and Rural Development. As the figures provided on animals are concentrated in the southern region of Angola, a certain re-distribution of animals was made for the whole country, considering those provinces with natural conditions for livestock development. In relation to poultry development it was assumed that this activity would be revitalised in those provinces where, in the recent past, a certain level of development had been reached. The annual growth of cattle was assumed to be 3%, while the annual growth of pigs, sheep and goats was assumed to be 4%. The same annual growth was assumed for poultry. The AGRODOK Series recommendations were used for daily consumptions of water for cattle, pigs, sheep and goats was taken by. The Department of Animal Production of the National Directorate for Livestock recommendations were used for daily consumptions of water for poultry.

The sum of water volumes for irrigation and water volumes for animal watering was assumed to be the total of water demand for the Agriculture sector.

For estimation of the consumptive water use in the domestic water supply sector, water use estimates and projections were developed on a per capita basis and applied to the population estimates. The methodology of this process is described in Chapter 6. The information in the existing water master plans for towns in Angola were used in this analysis.

1.2.7 Establishment of criteria and recommendations for future water resources and water use and demand assessment activities

Key to the establishment of criteria and the formulation of outline plans for maintaining and developing water resources and water use assessments is the system sustainability. It was realised at an early stage that the capacity of DNA in this respect is limited, as were the resources available to this project. Consequently focus was put on developing and handing over a system that could easily be used and updated for water resources, as well as a system that could be useful in DNA's other activities. The resulting Water Resources and Water User database and tools chosen are therefore based on the GIS system that can be easily adapted to almost any other use, and is well known in Angola, being used by NGO's in de-mining activities, the oil industry etc.

Focus was also placed on the identification of bottlenecks and gaps in the assessments due to lack of data or lack of institutional cooperation, which is addressed in the final chapter of this report, where recommendations for the dissemination of information and involvement of stakeholders in the further development of the assessments are given.

1.3 Water Resources/GIS Software and Database Tools Applied

The available hydrometeorological, meteorological and other types of data for use as input to the system are detailed in some areas and sparse or non-existent in other areas of the country. The most appropriate and sustainable methodology for establishing the water resources and water use database with such constraints was to implement an Arc-GIS database system for the entire country. The database system is raster based and the entire country is broken down into rectangular units or rasters, their size depending on the data availability for each type of data (for example with 1 km raster for rainfall data). Each data type could then be represented by one layer of rasters and the different data layers combined using mathematical algorithms to arrive at the desired data sets for use in the water resources and water use assessment.

The advantage of this system is its flexibility in that it can easily be extended or updated as new data becomes available. In addition DNA has been provided with a powerful and useful Arc-GIS software tool which will undoubtedly also be found useful in its other activities and projects. In order to obtain maximum benefit from this system a dedicated plotter for producing large-scale printouts and visualisations from the system is advisable. Consequently the Consultant has used funds from its budget for office equipment to provide such an A1 size plotter to DNA.

Recommendations have been made to immediately follow up the assessment by a stakeholder seminar in Luanda, in which the GIS database and the assessment report can be presented to key stakeholders. Such a venue would encourage the further use and development of the assessments achieved during this study.

1.4 Acknowledgements

The Consultants would like to take this opportunity to extend their appreciation and thanks to the management and staff of DNA and the Ministry of Energy and Water, without whose support this assessment would not have been possible. DNA has been the vital link between the Consultants and the stakeholders and sources of information and data in the water resources and water use sector in Angola, and has been facilitator in the stakeholder meetings held.

Furthermore, we thank the numerous officials and staff of the many ministries, directorates, government bodies and institutions as well as non-government institutions and organisations who have so enthusiastically supported our enquiries during the assessment.

Last but not least, we extend our gratitude to the NVE long-term Hydrological Adviser to DNA (the NAWASMA project) for considerable support in helping to overcome day-to-day logistics and other challenges during the assessment, to the Royal Norwegian Embassy in Luanda for provision of seminar facilities and other valuable support, and to the numerous individuals, both Angolan and foreign, who have provided invaluable information and background knowledge to the assessment team.

2. RENEWABLE WATER RESOURCES ASSESSMENT

2.1 Geography of Angola

The Republic of Angola covers an area of 1,246,700 km^2, lying between latitudes 4°22´ and 18°02´ S and longitudes 11°41´ and 24° 05´ E. Wi th the exception of the enclave of Cabinda, the country forms a square with sides about 1,250 km long, touching the Atlantic Ocean on the west (giving a total coastline of about 1 600 km) and bordering the Democratic Republic of the Congo on the north and north-east, Zambia on the east, and Namibia on the south. The Cabinda enclave covers 7,200 km^2 north of the mouth of the Congo (or Zaïre) River.

The following four major geographic regions can be distinguished:

- The coastal plain, also found in the west of Cabinda, with a width varying from 25 km in the south to 100 to 200 km in the north.
- The central highlands with an average height between 1000 and 1300 m, covering almost two-thirds of the country. They are dominated by several mountain chains forming a crescent lying in a roughly southwest to northeast direction and including the Serra Moco, the highest point in the country (2620 m). This region is one of the main sources of water for southern Africa.
- The northern foothills of the highlands toward the Congo basin, north of latitude 10°S, where most of the country's closed forests are found, the remainder being located in eastern Cabinda.
- The eastern and southern foothills of the highlands towards the central depression of southern Africa and the Kalahari basin.

Most of Angola's rivers rise in the central mountains and drain either to the Atlantic Ocean or the Congo River, but those in the southeast drain to the Okavango swamps in Botswana.

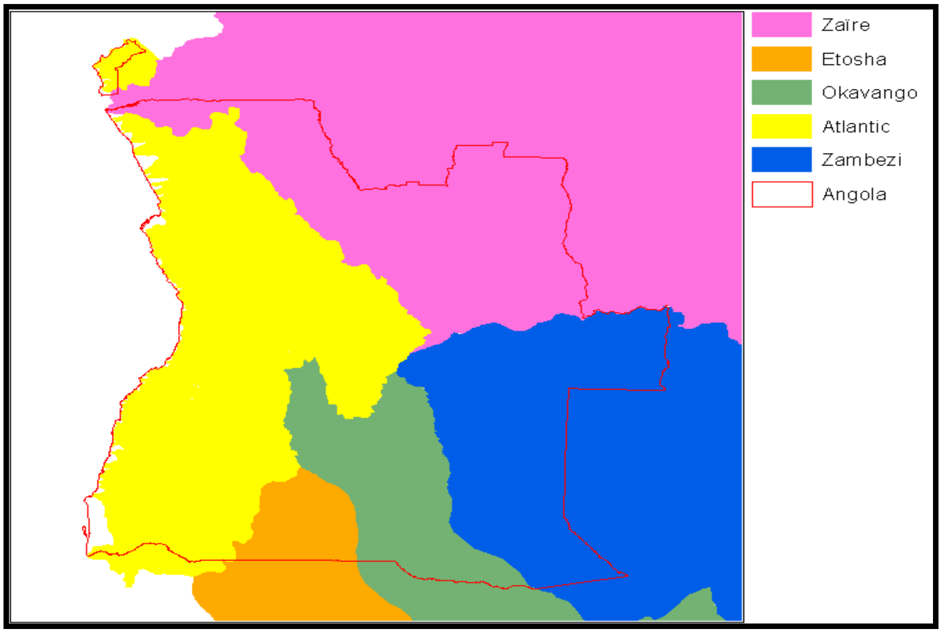
The climate is generally tropical in type, tempered by sea and altitude, but it does vary considerably depending on latitude, as well as the effects of the cold Benguela current along the coast. Rainfall reaches 1800 mm and more in inland Cabinda and decreases rapidly along the coast, dropping to under 100 mm in the south (Namibe province). It is over 1500 mm in the highest parts of the highlands, especially in Huambo, Lunda and Uige provinces. The wet season lasts from October to May. Temperatures in the coastal plain region average about 21 °C in January and about 16 °C in June. The central plateau is cooler.

2.2 Renewable Water Resources Assessment of Angolan Catchments using GIS

2.2.1 Introduction

Angola has a rich and diversified hydrological basin. The annual drainage is calculated as some 140 km^3 and is among the highest in southern Africa. There are 77 hydrological basins forming five main drainage areas: the Atlantic with 41% of the surface of the country, Zaire (Congo) with 22%, Zambezi with 18%, Okavango with 12% and Etosha with 4%. Lakes and lagoons are relatively few in number, covering a small area of land of approximately 5,500 km^2.

Figure 2.2.1 Main Drainage Areas of Angola



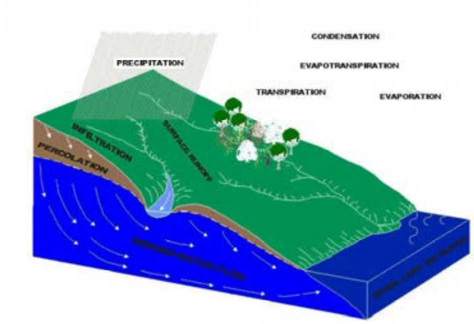
The mean annual rainfall in Angola is calculated as some 1014 mm, but exhibits great differences in spatial distribution. Along the southwestern coast, in the Namibe region, the mean annual precipitation is at its lowest with around 50 mm a year. The coastal region has a gradually increasing annual precipitation northwards and from the coastal areas and inland. The central highlands have an annual precipitation of approximately 1300 to 1400 mm and the highest precipitation is to be found in the northeastern part of the country, in the province of Lunda Norte, with approximately 1600 mm. The hydrology in Angola will generally reflect these precipitation patterns.

The use of a Geographical Information System (GIS) was considered the best tool to incorporate and validate existing data from various sources, either local Angolan data or global or regional datasets. These datasets were then used as a basis to compute and generate a surface runoff map for Angola. The basic model, the data and datasets used, and the computation and generation of the Angolan runoff map are described in the following sections.

The software used in this study is ArcGis 9.0 combined with the Spatial Analyst and 3D Analyst modules from ESRI Inc. All datasets compiled, used and generated for this study are briefly described, either in the following chapters or in the appendices, and have been delivered to DNA. A licence for the software has been purchased and delivered to DNA and training has been undertaken during the entire project.

2.2.2 Hydrological Cycle and Water Balance

The hydrologic cycle begins with the evaporation of water from the surface of the ocean. As moist air is lifted, it cools and water vapour condenses to form clouds. Moisture is transported around the globe until it returns to the surface as precipitation. Once the water reaches the ground, several processes may occur; some of the water may evaporate back into the atmosphere, vegetation uses some of the water in the process of photosynthesis and releases water back to the atmosphere as transpiration, water may runoff on the surface and into rivers and streams or water may penetrate the surface and become groundwater. Groundwater either seeps its way to the oceans, rivers, and streams, or is released back into the atmosphere through vegetation and transpiration. The balance of water that remains on the earth's surface is runoff, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again.



THE HYDROLOGIC CIRCLE

This is the general outline of the hydrological cycle. Calculating the water balance in depth means to have the full and complete accounts for amounts of water in different components of the hydrological cycle and the parameters that govern it. This is an almost impossible task in large-scale studies because several of the parameters are rarely measured and some of the processes are extremely difficult to model even in experiment setups.

2.2.3 The Water Balance Approach

The water balance equation is a modelling framework for simplifying, describing and quantifying the ‘hydrological budget’ of water exchanges in a region or catchment. Ultimately, it is regional climate that determines the amount of water in an area. Most obviously, this depends on precipitation inputs as well as other factors and processes including variations in surface temperatures which control evapotranspiration rates, amount and timing of runoff, vegetation cover, etc.

Water in the hydrological system must obey the law of conservation of mass. As such, the water balance equation is essentially a conservation equation that accounts for all water (mass) in a region and can be expressed verbally as:

“The amount of water entering a control volume during a defined time period (inflow, I), minus the amount leaving the volume during the time period (discharge, Q_{runoff}), equals the change in the amount of water stored (ΔS) in the volume during that time period.”

Or in basic form (1):

$$(\text{Inflow, I}) - Q_{runoff} = \Delta S \qquad (1)$$

In this part of the study, the main goal has been to produce a runoff map for Angola and its sub-basins. For such use, the evaporation, transpiration and groundwater seepage are not taken into account explicitly. Instead they are taken into account *implicitly* by the use of runoff coefficients. The change of mass, ΔS, is considered as 0, during the completion of a year.

2.2.3.1 Discharge (Q_{runoff})

In general, discharge (Q_{runoff}) can be calculated in several ways, one of these is by means of a soil water balance, and another by means of runoff coefficients. Calculating runoff by means of a soil water balance is a *conceptual* way of calculating runoff while runoff coefficients are obtained by comparing river discharges with precipitation *statistics*. For a basic soil water balance, it is necessary to have information on the following parameters:

- Precipitation a monthly basis or preferably at shorter intervals
- Actual evapotranspiration with the same time interval as precipitation
- Soil water storage capacity.

For more advanced soil water balances, information is also necessary on other parameters such as:

- Seepage from / to the groundwater in the saturated zone
- Land use
- Advanced soil characteristics (e.g. soil conductivity and soil moisture content at different pressure heads), necessary to calculate the water balance of the unsaturated zone.

At small scale and without data available for the whole of Angola, it was considered extremely difficult and outside the resources and timeframe of this assessment to parameterise a soil water balance. Consequently it was decided to calculate runoff using a runoff coefficient. Calculation of runoff by means of a runoff coefficient can be done according to equation (2):

$$Q_{runoff} = r * P \qquad (2)$$

where:

Q_{runoff} = runoff discharge
r = runoff coefficient
P = Precipitation

Runoff coefficients have previously been mapped for the whole world and are published on a scale of 1:20,000,000 in the Atlas of World Water Balance (1974, 1977). Data in this atlas has not been digitised, and is also very coarse and calculated for large basins.

These runoff coefficients are shown in Figure 2.2.2 and give a suggestion of what ratios one may expect in this area. The figures marked in yellow on the left are interior values; the ones on the right are coastal values. To get a better estimate for Angola, these ratios were calculated for those Angolan hydrometric basins with sufficient hydrological records. This is further described in Chapter 2.2.8.

Figure 2.2.2 Runoff/Precipitation Ratio (%), Atlas of World Water Balance (1974, 1977)

LAT	EUR	ASI	AFR	AUS	NAM	SAM	ANT	LAND	NAM	SAM	ATL		EUR	ASI	AFR		NAM	EUR	ASI	NPO		ASI	AUS	PAC		NAM	SAM	NPO	ATL	IND	PAC	SEA
	Sum Continents								EaC		WeC	EaC	WeC				NoC			SoC		EaC		WeC	WeC	WeC		Sum Coasts				
N 90-85																																-
85-80	65	61			72			66	-		-						72	65	61	66								66	-			66
80-75	64	85			70			72	-		-	-	-				70	64	85	72								72	-			72
75-70	67	62			75			62	72		72	-	-				75	67	62	62								62	72			62
70-65	75	47			53			56	72		72	76	76				52	75	47	52		85		85	-	-		52	75		85	56
65-60	65	81			83			74	67		67	71	71				81	53	85	68		81		81	105	105		68	70		92	74
60-55	57	73			49			53	35		35	57	57									73		73	87	87			43		83	53
55-50	39	39			68			50	61		61	39	39									39		39	86	86			51		49	50
50-45	28	53			53			43	47		47	28	28	-		ASI	AFR	IND		ASI	AUS	53		53	67	67			37		65	43
45-40	40	53			59			46	55		55	40	40	-		EaC		WeC	EaC	WeC		53		53	69	69			43		57	46
40-35	28	40	15		37			36	34		34	25	28	32	15							40		40	45	45			28		41	36
35-30		52	3		21			28	26		26	3	-	13	3	30		30				53		53	4	4			9	30	49	28
30-25		45	11		20			23	20		20	11			11	40	5	40				56		56	13	13			20	40	39	23
25-20		54	8		38			52	52		52	10			10	-	5	5	55	55		50		50	14	14			51	55	45	52
20-15		61	13		56			56	67		67	13			13	-	5	5	61	61		57		57	25	25			54	60	45	56
15-10		38	23		35	46		38	35	46	43	25			25	-	5	5	21	21		48		48	37	37	-		39	20	47	38
10-5		46	27		74	54		46	75	54	54	27			27	-	5	5	46	46		46		46	72	74	70		46	42	49	46
5-0		54	24			52		39		40	40	25			25		5	5	51	51		55		55	68		68		27	47	57	39
S 0-5		56	22	96		52		51		51	51	40			40	-	5	5	51	51	-	57	96	61	68		68		51	17	62	51
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15-20			21	21		26		22		26	26	8			8		22	22	14		14		23	23	30		30		22	21	23	22
20-25			26	15		37		24		37	37	8			8		27	27	4		4		21	21	30		30		33	22	21	24
25-30			8	21		44		13		43	43	2			2		13	13	3		3		30	30	60		60		10	12	31	13
30-35			21	15		25		24		25	25	48			48		17	17	13		13		28	28	65		65		25	14	39	24
35-40				17		52		29		46	46								17		17		17	17	65		65		46	17	24	29
40-45				74		48		59		37	37								-		-		74	74	58		58		37	-	68	59
45-50			-	91		51		67		45	45						-	-					91	91	53		53		45	-	72	67
50-55				-		45		45		45	45														45		45		45		45	45
55-60				-		45		45		45	45														-		-		45		-	45

Applying these calculated runoff coefficients to precipitation figures (described further in Chapter 2.2.6), according to equation (2) yielded the mean annual runoff per catchment, presented in Chapter 12.

2.2.3.2 Inflow,I

The inflow to each sub basin is composed of two elements: inflow from the upstream basin and precipitation falling in the basin.

$$I = Q_{inflow} + r * P \tag{3}$$

Under natural circumstances rivers cannot cross catchment boundaries. In some catchments, however water may not only flow in a natural direction but can also be artificially redirected through canals/tunnels towards other areas to be used for irrigation, industrial use etc. Detailed information on this for Angola has not been available and is considered negligible in this study.

The water balance of the most upstream catchments will therefore only be composed of precipitation in the basin, Q_{inflow} is zero. A value is obtained for Q_{runoff}, this value is equal to Q_{inflow} of the catchment immediately downstream of these upstream catchments.

2.2.4 Delineation of sub-basins within Angola

The water balance is calculated not for Angola as a whole but for 77 hydrological sub basins within the 5 major drainage areas in Angola.

2.2.4.1 Division of Hydrological Sub-basins Within Angola

The nomenclature and short description of 77 hydrological sub basins in Angola was obtained from a follow up of conference notes from the 1961 conference[1] in Nairobi. The drainage basins should incorporate all rivers over 50 km in length.

The nomenclature follows three divisions of order:

(i) ***Primary Division*** is the Midwestern Africa area.
(ii) ***Secondary Division*** is the division in major drainage areas shown in Chapter 2.2.1.
(iii) ***Tertiary Division*** is a consecutive number from 1 to 77 within these divisions.

Table 2.2.1 gives the numbering and names of the sub basins in Angola.

Table 2.2.1 Division of Hydrological Sub Basins in Angola

Primary Division	Secondary Division	Tertiary Division	Major Basin	Basin Name
4	40	1	S.W.Coast	Lubinda
4	40	2	S.W.Coast	Chiloango
4	40	3	S.W.Coast	Lulondo
4	40	4	S.W.Coast	Lucula
4	43	5	Zaïre / Congo	Zaire
4	60	6	S.W.Coast	Zombo
4	60	7	S.W.Coast	Luela
4	60	8	S.W.Coast	Lucolo
4	60	9	S.W.Coast	Sange
4	60	10	S.W.Coast	Lucunga
4	60	11	S.W.Coast	M'Bridge
4	60	12	S.W.Coast	Sembo
4	60	13	S.W.Coast	Loge
4	60	14	S.W.Coast	Uezo
4	60	15	S.W.Coast	Onzo
4	60	16	S.W.Coast	Lifune
4	60	17	S.W.Coast	Dande
4	60	18	S.W.Coast	Bengo
4	60	19	S.W.Coast	Cuanza
4	60	20	S.W.Coast	Perdizes
4	60	21	S.W.Coast	Sangando
4	60	22	S.W.Coast	Cabo Ledo
4	60	23	S.W.Coast	Mengueje
4	60	24	S.W.Coast	Tanda
4	60	25	S.W.Coast	Longa
4	60	26	S.W.Coast	Cutanga
4	60	27	S.W.Coast	Quiteta
4	60	28	S.W.Coast	Catata
4	60	29	S.W.Coast	Tortombo
4	60	30	S.W.Coast	Queve
4	60	31	S.W.Coast	N'Gunza
4	60	32	S.W.Coast	Quicombo
4	60	33	S.W.Coast	Dui
4	60	34	S.W.Coast	Evale
4	60	35	S.W.Coast	Balombo
4	60	36	S.W.Coast	Cuhula

[1] "Conference Interafricaine Sur L'hydrologie", Nairobi, 1961; Ordençáo das bacias hidrográficas de Angola e das estacaos hidrometricas nelas estabelecidas.

Primary Division	Secondary Division	Tertiary Division	Major Basin	Basin Name
4	60	37	S.W.Coast	Cubal Da Hanha
4	60	38	S.W.Coast	Catumbela
4	60	39	S.W.Coast	Cavaco
4	60	40	S.W.Coast	Curinge
4	60	41	S.W.Coast	Uche
4	60	42	S.W.Coast	Mormolo
4	60	43	S.W.Coast	Pima
4	60	44	S.W.Coast	Ndungo
4	60	45	S.W.Coast	Calumbolo
4	60	46	S.W.Coast	Coporolo
4	60	47	S.W.Coast	Nhime
4	60	48	S.W.Coast	Lua
4	60	49	S.W.Coast	Equimina
4	60	50	S.W.Coast	Chamanga
4	60	51	S.W.Coast	Calongolo
4	60	52	S.W.Coast	Lucipo
4	60	53	S.W.Coast	Catara
4	60	54	S.W.Coast	Cangala
4	60	55	S.W.Coast	Capim
4	60	56	S.W.Coast	Chileva
4	60	57	S.W.Coast	Carunjamba
4	60	58	S.W.Coast	Inamagando
4	60	59	S.W.Coast	Mapungo
4	60	60	S.W.Coast	Bentiaba
4	60	61	S.W.Coast	Salgada
4	60	62	S.W.Coast	Chilulo/Chapéu Armado
4	60	63	S.W.Coast	Caniço
4	60	64	S.W.Coast	Mutiambo
4	60	65	S.W.Coast	Muchimanda
4	60	66	S.W.Coast	Giraul
4	60	67	S.W.Coast	Bero
4	60	68	S.W.Coast	Changulo
4	60	69	S.W.Coast	Subida Grande
4	60	70	S.W.Coast	Metere
4	60	71	S.W.Coast	Flamingos
4	60	72	S.W.Coast	Curoca
4	60	73	S.W.Coast	Cunene
4	62	74	Zambezi	Zambeze
4	63	75	Okavango	Cubango
4	63	76	Zambezi	Cuando
4	63	77	Etosha pan	Cuvelai

Digital or even analogue map based delineations of these catchments was not possible to obtain through sources in Angola or elsewhere. Delineation was thus carried out as part of the assessment.

2.2.4.2 Topographic Base Map as Basis for Delineation of Sub-basins

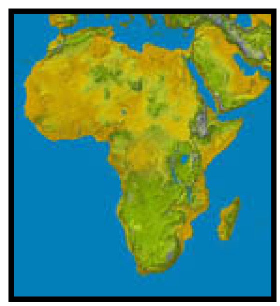
Doing basin delineation on a large scale with paper maps is a time consuming affair. With the use of GIS systems this process can be completed in a much shorter time period. Until recently good digital maps of Africa with sufficient information to generate a digital elevation model (DEM) for use in the delineation process were almost impossible to obtain. This is either because the areas have not been properly charted or because information was classified due to military reasons.

During an American NASA space shuttle mission in February 2000, this lack of data was greatly reduced. In the space of a few days 80% of the world's total landmass was mapped with Synthetic aperture radars to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry. In the following we give a short description of the methodology and data produced during the assessment, a more detailed reference is given in the appendices.

The targeted landmass consisted of all land between 56 degrees south and 60 degrees north latitude, which comprises almost exactly 80% of the total landmass of the planet.

SRTM data are delivered in individual rasterized cells, or tiles, each covering one degree by one degree in latitude and longitude. Sample spacing for individual data points outside of US territory is 3 arc-seconds, referred to as SRTM-3. Since one arc-second at the equator corresponds to roughly 30 m in horizontal extent, the sets are sometimes referred to as "90 meter" data.

All elevations are in metres referenced to the WGS84 geoid. No editing has been performed on the data, and the elevation data in particular contain numerous voids and other spurious points such as anomalously high (spike) or low (well) values. Water bodies will generally not be well-defined - in fact since water surfaces generally produce very low radar backscatter they will appear quite "noisy" or rough, in the elevation data. Similarly, coastlines will not be well-defined.



NASA released the SRTM data set for the African continent, plus the Arabian Peninsula, the Persian Gulf area, and the island of Madagascar during spring 2004. This data set represents almost a quarter of the data collected during the mission, and follows similar releases for North and South America and Eurasia.

As with the other SRTM data for regions outside the United States, the Africa set is sampled at 3 arc-seconds, which is 1/1200 th of a degree of latitude and longitude, or about 90 m (295 feet).

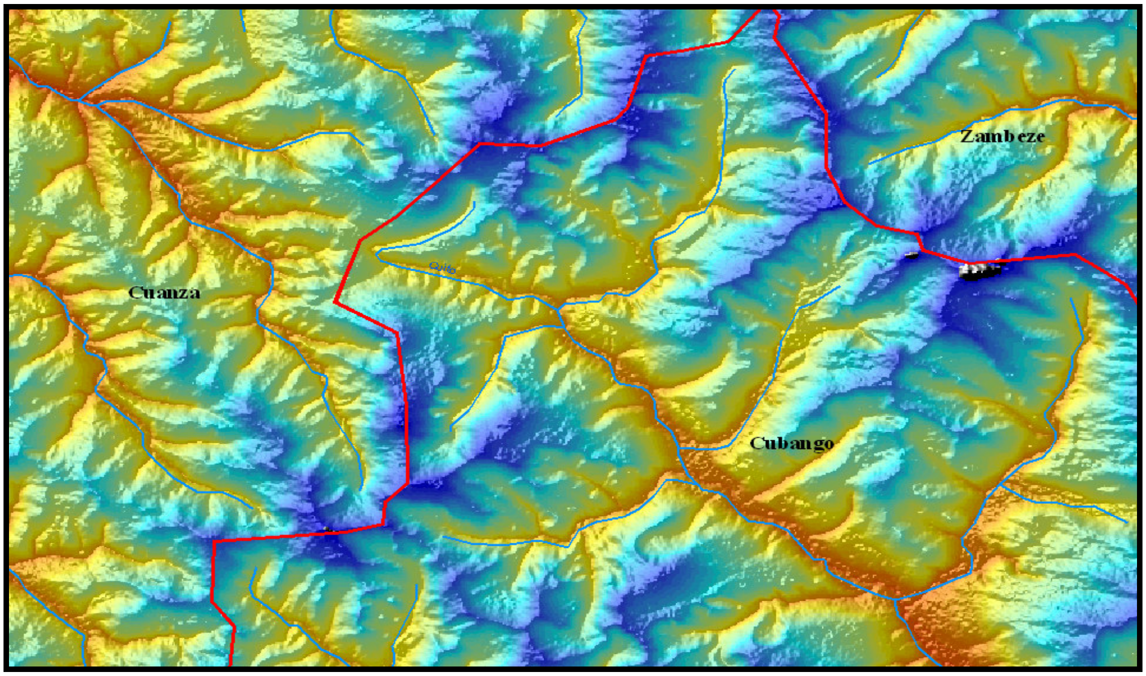
Because of persistent cloud cover or inhospitable terrain, Africa has been one of the most poorly mapped regions of the planet. Thus the SRTM data reveal, in most areas for the first time, an enormous diversity of landforms including the deserts and mountains of the north, the tropical forests and rift valley of central Africa, and the plateaus and coastal plains of the south.

2.2.4.3 Delineating Angolas Hydrological Basins

Using this digital elevation model (DEM) from the SRTM mission together with the hydrographic features obtained from the DCW[2] data set, the delineation was done by digitising along the catchment boundaries as shown in Figure 2.2.3. The use of hill-shade gives a three-dimensional effect that makes such delineation easier.

[2] The Digital Chart of the World contains data for the world at a scale of 1:1,000,000. There are various thematic layers including: political/oceans, populated places, roads, railroads, utilities, drainage, hypsography (elevation), land cover, ocean features, aeronautical, cultural landmarks, transportation structure, and vegetation. More detail of these datasets is given in the appendix.

Figure 2.2.3 Basin Boundary Delineation with use of 3D Hill Shade Topographic Effects

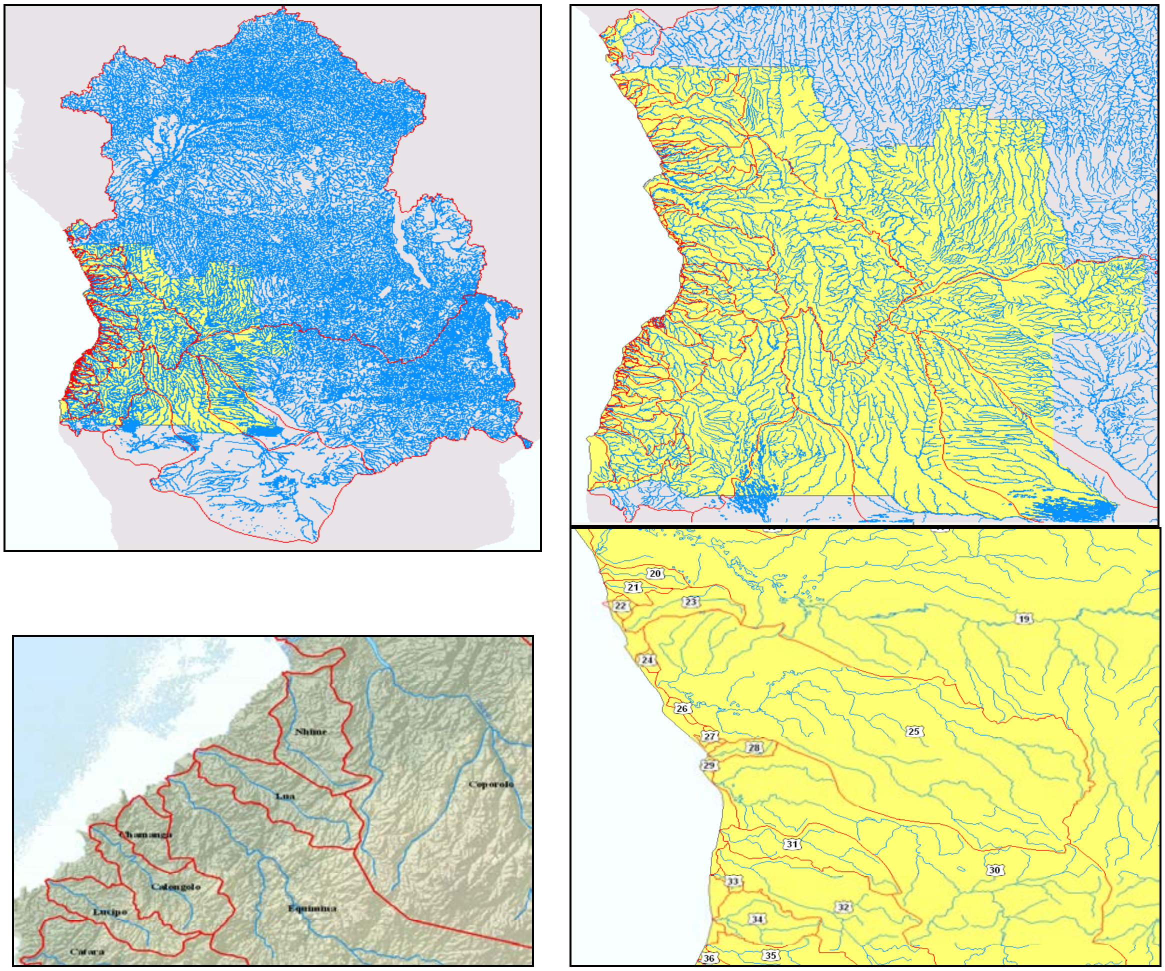


In total, 77 drainage basins were delineated, out of which 70 are totally within the borders of Angola. Figure 2.2.4 shows the drainage basins in different zooming levels or detail.

For later use we recommend that DNA also digitise and delineate the sub-basins of the basins that are not completely contained within Angola's borders. This should be done to ease the calculations of water balance for smaller areas and/or sub basins within these often large basins.

In this assessment, delineation of basins and calculation of water balance has been carried out for the original 77 basins.

Figure 2.2.4 Angolan Drainage Basins in Various Degrees of Detail



It should also be mentioned that with the use of GIS software this process of delineation can be done in an automatic and mathematical way. Such an approach could not, however, be applied in the rapid assessment partly because:

1) The size of the original digital elevation model (DEM) (496 Mb) requires extremely powerful PC's to be done in a reasonable amount of time.
2) The calculations are prone to errors in areas where differences in height are minimal.
3) The output of the model has to be revised to check for these errors. Such revision is time consuming, compared to the relative ease with which experienced hydrologists can do this kind of work.

Earlier experience with the use of such modelling and a comparative check of the results of the automatic delineation of the Africa Basins in the Hydro1K dataset confirmed this decision. However a short description of the method is given here for future reference.

The method used to delineate the basins is described by Maidment et al. (1997). The basis upon which the sub-basins are delineated is a digital elevation model (DEM) of reasonable resolution, the smaller the catchments, the more the detail required in the DEM. Delineation of catchments from a digital elevation model (DEM) can be done in the GRID-package of the Geographical Information System (GIS) software Arc-INFO or in the hydrology module of the Spatial Analyst extension of ArcGIS 9.0 as follows:

- The digital elevation model (DEM) is checked for the occurrence of fictitious "pits" due to minor errors in the DEM;
- The depressions which are regarded as mistakes are filled to a corrected digital elevation model (filled DEM);
- From this filled DEM the flow direction of each cell of the model is identified;
- Given the flow direction of each cell, flow accumulation is calculated, it indicates for each cell how many cells are situated upstream of this cell;
- Whenever the flow accumulation of a certain cell exceeds a user defined threshold value, the cell is regarded as part of a stream, if the threshold value chosen is to be 500 square kilometres; this means that the automatically delineated catchments are generally larger than 500 square kilometres.

After automatic delineation of the catchments, the resulting map should be compared to the stream pattern derived from either the local map data or some international dataset such as the Digital Chart of the World (DCW). As natural streams cannot cross boundaries of catchments, the automatically generated catchment map has to be corrected manually. Unfortunately, the DCW does not differentiate between natural flowing rivers and dug canals. In contrast to rivers, canals can cross borders of catchments. Therefore other sources of information such as the Times Atlas of the World can be used to differentiate artificial flows from natural flows in the flow pattern of the DCW. At this point, the automatically delineated catchments must be corrected manually to match the natural flow pattern. After corrections a final map with catchments is obtained.

2.2.5 Hydrological measurements

Besides drainage basins and their subsequent area values, both hydrological information and measurements of precipitation are necessary to calculate the aforementioned runoff coefficients.

No global or regional datasets are however available with the necessary resolution and detail needed for use in the drainage basins. Discharge from the hydrometric basins must therefore be calculated from local data.

A Hydrometric network existed in Angola earlier. In 1975 it comprised of 189 stations, which assured the gathering of a hydrometric database. With the war the hydrometric net was almost totally destroyed and inaccessible.

The “National Water Sector Management” (NAWASMA) project, carried out since 2002 as an Institutional Co-operation between the Angolan National Directorate of Water, DNA (Direcção Nacional de Águas) and the Norwegian Water Resources and Energy Directorate, NVE, has been carefully reconstructing and quality checking the hydrometric data from the pre-war period. Some stations have been reconstructed and their operation resumed.
Reports generated from this reconstructed database show that the period from 1960/1965 to 1975 is suitable to describe the Angolan data (Bjøru, 2003).

To use the discharge data directly into the GIS system to generate a runoff map of Angola at least three parameters had to exist for the data in the Hydata database generated by the NAWASMA project:

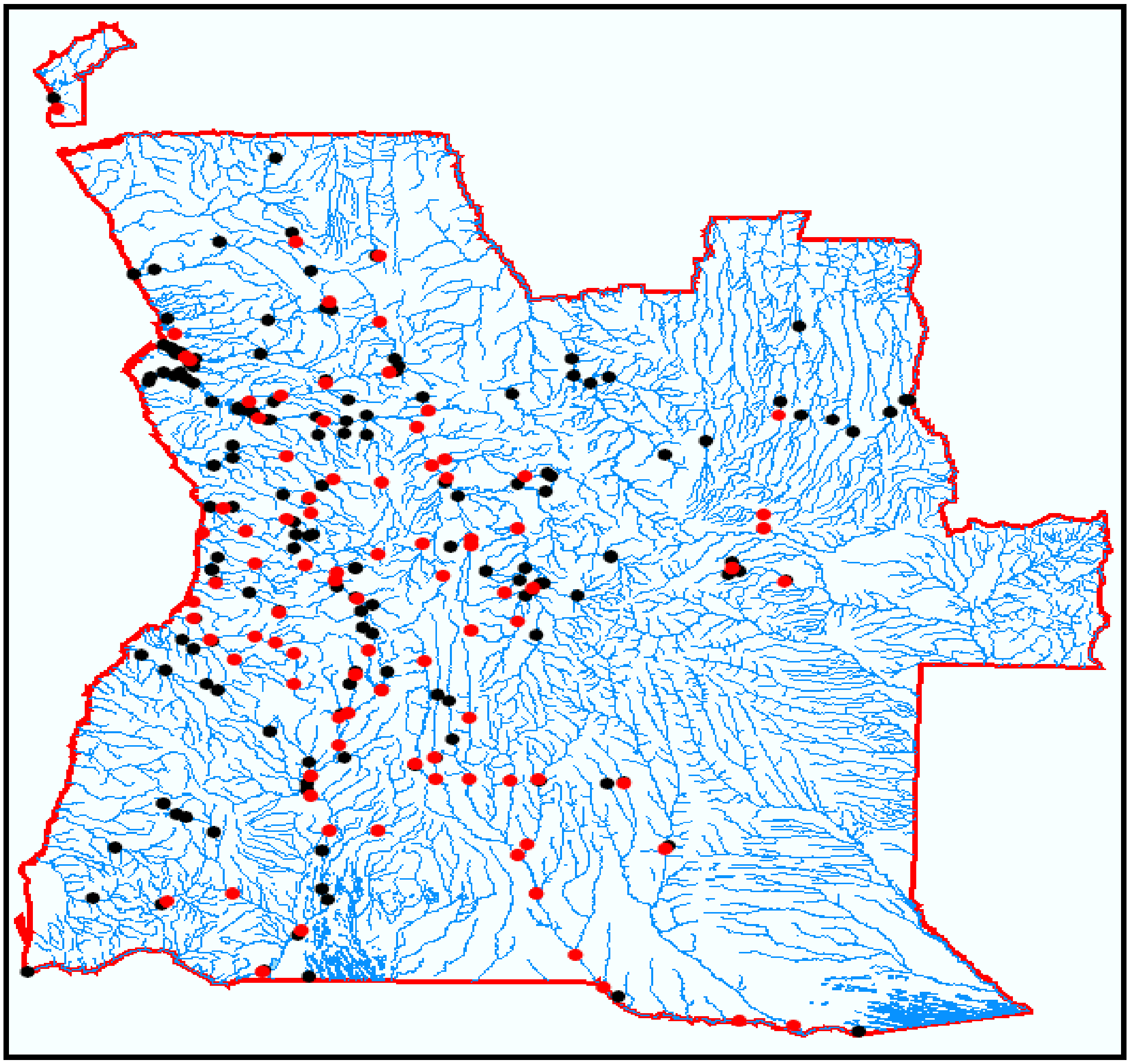
- Annual discharge data
- Location of measurement points
- Upstream area of measurement points

All three parameters seemed in general to be existence in the database, but the first plotting showed that there were clearly some errors in the two latter parameters; location and area.

It was also clear that even with the use of measurements from every location large areas of Angola would still not be covered by hydrometric measurements. This became even clearer with the use of the selected hydrometric stations as shown in Figure 2.2.5.

Figure 2.2.5 Hydrometric Stations in Angola.

(Red dots are selected stations for use in the study.)



The only dataset with complete coverage of Angola was the precipitation coverage, and hence the reason for using calculation of runoff coefficients. Spatial distribution of this runoff parameter could then be utilized together with the precipitation coverage to calculate specific discharge for the whole of Angola.

DNA supplied the project with data from a selected range of hydrometric stations (99). Data from these stations was considered of good quality and of sufficient length of data series to make a standardized year. In addition, data from four Namibian hydrometric stations was supplied.

The hydrometric stations were plotted and clearly erroneous locations were corrected with the assistance of DNA staff. For all hydrometric stations, monthly and annual average values for the longest possible time period were calculated. For most data series this was the period 1967 to 1974. Some stations have longer periods of data and some shorter. In order to have a reasonable amount of hydrometric stations to use in the generation of a runoff map, it was necessary to use most of the data and not only the periods where all stations had overlapping data periods. If this were to be done, too few stations would have been left for the analysis. During this process some hydrometric stations were omitted due to too short a period of time. For the remaining stations annual specific discharge (litres*km²/sec) was calculated and plotted in the GIS system.

An analysis of the distribution of values for specific discharge showed that there were clearly some errors in the area values of the data. To still be able to make use of the data, these area values had to be corrected and new values for specific discharge calculated. The only way to obtain this was to start delineating the catchments of the hydrometric stations. In all, 93 catchments containing hydrometric stations were delineated and the areas were calculated during this process. Comparison with the area values given from the Hydata database records is given in Table 2.2.2. The delineated catchments are shown in Figure 2.2.6.

Area data from the hydrological database in relation to the calculated area data from the delineation of drainage basins for the selected hydrometric stations, shows for several stations a great deal of inaccuracy. This caused the problems with calculation of correct area specific discharge values for use in the generating of runoff map. The values were corrected and new values for specific discharge were calculated and plotted together with their corresponding catchment area. This gave a seemingly more correct result.

Figure 2.2.6 Delineated Catchments with Hydrometric Measurement Stations

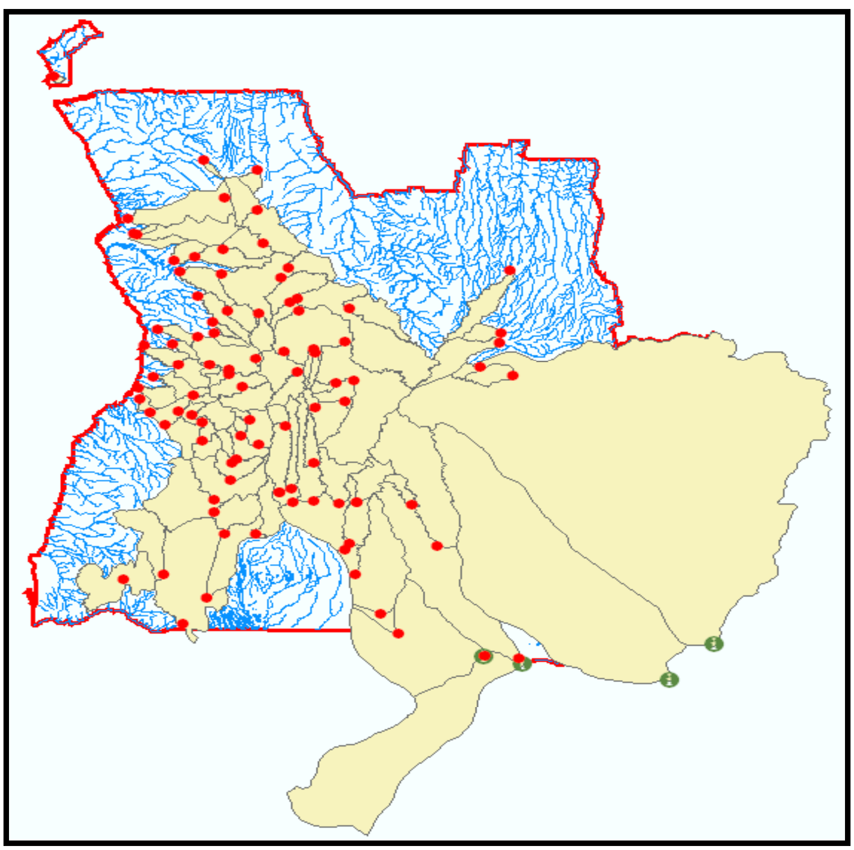


Table 2.2.2 Comparison of Calculated Area Values from GIS System to Hydata Database Records

STATION NUMBER	HYDROMETRIC STATION NAME	AREA IN KM² FROM HYDATA DATABASE	AREA IN KM² FROM GIS DELINEATION	DIFFERENCE KM²	DIFFERENCE %
400401	N'HAMA - LUCOLA - CABINDA	354	357	-3	-0.8 %
430501	ZAIRE - CHIUMBE - DALA	2100	2136	-36	-1.7 %
430502	ZAIRE - CHICAPA - SAURIMO	6250	5792	458	7.9 %
430503	ZAIRE - CASSAI - PONTE	5400	6920	-1520	-22.0 %
430504	ZAIRE - CUILO - PONTE	1400	1446	-46	-3.2 %
601101	M'BRIDGE - LOA - FAZENDA LOA	484	518	-34	-6.6 %
601701	DANDE - PORTO QUIPIRI	10660	10902	-242	-2.2 %
601804	BENGO - CABIRI	8053	10016	-1963	-19.6 %
601806	BENGO - LALAMA	6364	7572	-1208	-16.0 %
601906	CUANZA - CAUISSO	62790	61175	1615	2.6 %
601908	CUANZA - CAMBAMBE	121470	115658	5812	5.0 %
601913	CUANZA - LUCALA - CATECO CANGOLA	4140	4248	-108	-2.5 %
601916	CUANZA - CUNHINGA - CAPEIO	996	1009	-13	-1.3 %
601917	CUANZA - CUTATO - CUTATO ANDULO	7033	7936	-903	-11.4 %
601920	CUANZA - CUQUEMA - CHAVAIA	941	968	-27	-2.8 %
601921	CUANZA - CUQUEMA - CHIMBUNDE	8202	8913	-711	-8.0 %
601929	CUANZA - GANGO - GANGO	2691	2737	-46	-1.7 %
601930	CUANZA - LUCALA - Km 34	25290	22619	2671	11.8 %
601931	CUANZA - LUCALA - LUCALA	19450	15748	3702	23.5 %
601935	CUANZA - LUANDO - LUCUNGA	29290	27776	1514	5.5 %
601942	CUANZA - N'HAREA	38270	35679	2591	7.3 %
601943	CUANZA - CUNJE - CATABOLA	942	958	-16	-1.7 %
601944	CUANZA - CANGANDALA	96740	93169	3571	3.8 %
601946	CUANZA - CUIJE - PONTE DO CUIJE	3200	3777	-577	-15.3 %
601951	CUANZA - LUCALA – P.VIEIRA MACHADO	15000	11656	3344	28.7 %
601953	CUANZA - LUCALA - PONTE PINHEIRO CHAGAS	23270	20208	3062	15.2 %
601954	CUANZA - COQUEMA - PONTE DA CAMBANDUA	5943	5987	-44	-0.7 %
601955	CUANZA - QUISSAQUINA	116400	111279	5121	4.6 %
601956	CUANZA - CUNE - QUEDAS DO LAU LAU	1007	1014	-7	-0.7 %
601957	CUANZA - CUTATO - QUEDAS	2909	2982	-73	-2.4 %
601958	CUANZA - JOMBO - RIMBA LUQUEMBO	5150	5573	-423	-7.6 %
602501	LONGA - NHIA - BUIA	1264	1240	24	2.0 %
602503	LONGA - CARIANGO	2610	2573	37	1.4 %
602506	LONGA - QUISSUCA	6332	6300	32	0.5 %
602508	LONGA - CATOFE - FABRICA	3676	868	2808	323.7 %
603001	QUEVE - ALTO HAMA	2887	4577	-1690	-36.9 %
603003	QUEVE - CAIOVOLE	9887	9407	480	5.1 %

STATION NUMBER	HYDROMETRIC STATION NAME	AREA IN KM² FROM HYDATA DATABASE	AREA IN KM² FROM GIS DELINEATION	DIFFERENCE KM²	DIFFERENCE %
603004	QUEVE - CACHOEIRAS DA BINGA	20352	20077	275	1.4 %
603006	QUEVE - CUCHEN - CATATO	789	934	-145	-15.6 %
603008	QUEVE - COVELE - GONGO	727	686	41	6.0 %
603009	QUEVE - GINGA	18304	18341	-37	-0.2 %
603016	QUEVE - CUVIRA - TRANGALA	372	322	50	15.6 %
603101	N'GUNZA - GANJA	1176	1055	121	11.4 %
603201	QUICOMBO - CATANDA	3473	3156	317	10.0 %
603202	QUICOMBO - QUICOMBO	5581	5668	-87	-1.5 %
603501	BALOMBO - CAPECO	871	881	-10	-1.1 %
603502	BALOMBO - CANJALA	3842	3689	153	4.2 %
603701	CUBAL DA HANHA - HANHA	2119	2602	-483	-18.6 %
603801	CATUMBELA - BIOPIO	15829	15802	27	0.2 %
603802	CATUMBELA - CAIAVE	14982	14874	108	0.7 %
603803	CATUMBELA - CUIVA - CUIVA	3157	3266	-109	-3.3 %
603804	CATUMBELA - CUBAL DA HANHA - CUBAL	3653	3809	-156	-4.1 %
603806	CATUMBELA - CHICUMA	2128	2122	6	0.3 %
603807	CATUMBELA - LUPOMBA	3424	3397	27	0.8 %
603808	CATUMBELA - LOMAUM	8296	8270	26	0.3 %
607202	CUROCA - PEDIVA	1	11456	-11455	-100.0 %
607303	CUNENE - CACULUVAR - COVA DO LEAO	8063	7827	236	3.0 %
607304	CUNENE - COLUI - CATEMBULO	4510	4527	-17	-0.4 %
607308	CUNENE - IACAVALA	86188	87038	-850	-1.0 %
607310	CUNENE - CALAI - CHISSOLA	837	842	-5	-0.6 %
607312	CUNENE - GOVE I	4811	4623	188	4.1 %
607314	CUNENE - JAMBA IA HOMA	8637	8599	38	0.4 %
607315	CUNENE - JAMBA IA MINA	13817	13767	50	0.4 %
607316	CUNENE - LUCEQUE	18849	22588	-3739	-16.6 %
607317	CUNENE - CUANDO - LUCUNDE	1480	1435	45	3.2 %
607320	CUNENE - MATUNTO	41034	41102	-68	-0.2 %
607322	CUNENE - XANGONGO	53254	53648	-394	-0.7 %
607324	CUNENE - VILA FOLGARES	35636	35510	126	0.4 %
607345	CUNENE - CUNHANGAMUA - GONGOINGA	537	610	-73	-12.0 %
627401	ZAMBEZE - LUMEGE - CANHANGUE	1044	1077	-33	-3.1 %
627402	ZAMBEZE - LUENA - CHAFINDA	2970	3149	-179	-5.7 %
637501	CUBANGO - CAIUNDO	38650	38210	440	1.2 %
637503	CUBANGO - CUEBE - CAPICO	10020	10088	-68	-0.7 %
637504	CUBANGO - CACUCHI - CAMUE	262	2685	-2423	-90.2 %
637505	CUBANGO - CUTATO - CUTATO	3720	3692	28	0.8 %
637506	CUBANGO - CUCHI - CUCHI	9430	9205	225	2.4 %
637507	CUBANGO - CUITO - CUANAVALE	27100	26093	1007	3.9 %

STATION NUMBER	***HYDROMETRIC STATION NAME***	***AREA IN KM² FROM HYDATA DATABASE***	***AREA IN KM² FROM GIS DELINEATION***	***DIFFERENCE KM²***	***DIFFERENCE %***
637508	CUBANGO - CHINHAMA	1520	1597	-77	-4.8 %
637509	CUBANGO - CHISSOMBO	71960	71589	371	0.5 %
637510	CUBANGO - CUITO - DIRICO	59170	59785	-615	-1.0 %
637511	CUBANGO - FOZ DO CUATIR	70080	69497	583	0.8 %
637512	CUBANGO - MUCUNDI	50330	50385	-55	-0.1 %
637513	CUBANGO - MUMBA	12570	12634	-64	-0.5 %
637514	CUBANGO - CUELEI - MISSAO VELHA	5230	5814	-584	-10.0 %
637515	CUBANGO - QUIRIRI - PONTE	1770	1941	-171	-8.8 %
637516	CUBANGO - SAMBIO	86800	109125	-22325	-20.5 %
637517	CUBANGO - CUEBE - NENONGUE	4520	4548	-28	-0.6 %
637518	CUBANGO - LUAHUCA - SERPA PINTO	1100	1000	100	10.0 %
637540	CUBANGO - V.ARTUR PAIVA	7320	7381	-61	-0.8 %

The delineation of the hydrometric catchments made it possible to look at the relative contribution from each sub-basin for those catchments with successive measurement stations downstream in the rivers. This gives a better possibility to identify any sub-basins or hydrometric stations with non-consistent data or errors.

For each sub-basin downstream the discharge was calculated according to (4):

$$Q_{sub\text{-}basin} = \Sigma Q_{in} - Q_{out} \qquad (4)$$

During this process a few additional hydrometric stations were omitted from the material, especially due to inconsistency in data periods in upstream or downstream catchments, and based on a review of the comments made by NVE staff during revision and control of the database.

In all 79 hydrometric stations were included in the final preparation for the runoff map of Angola.

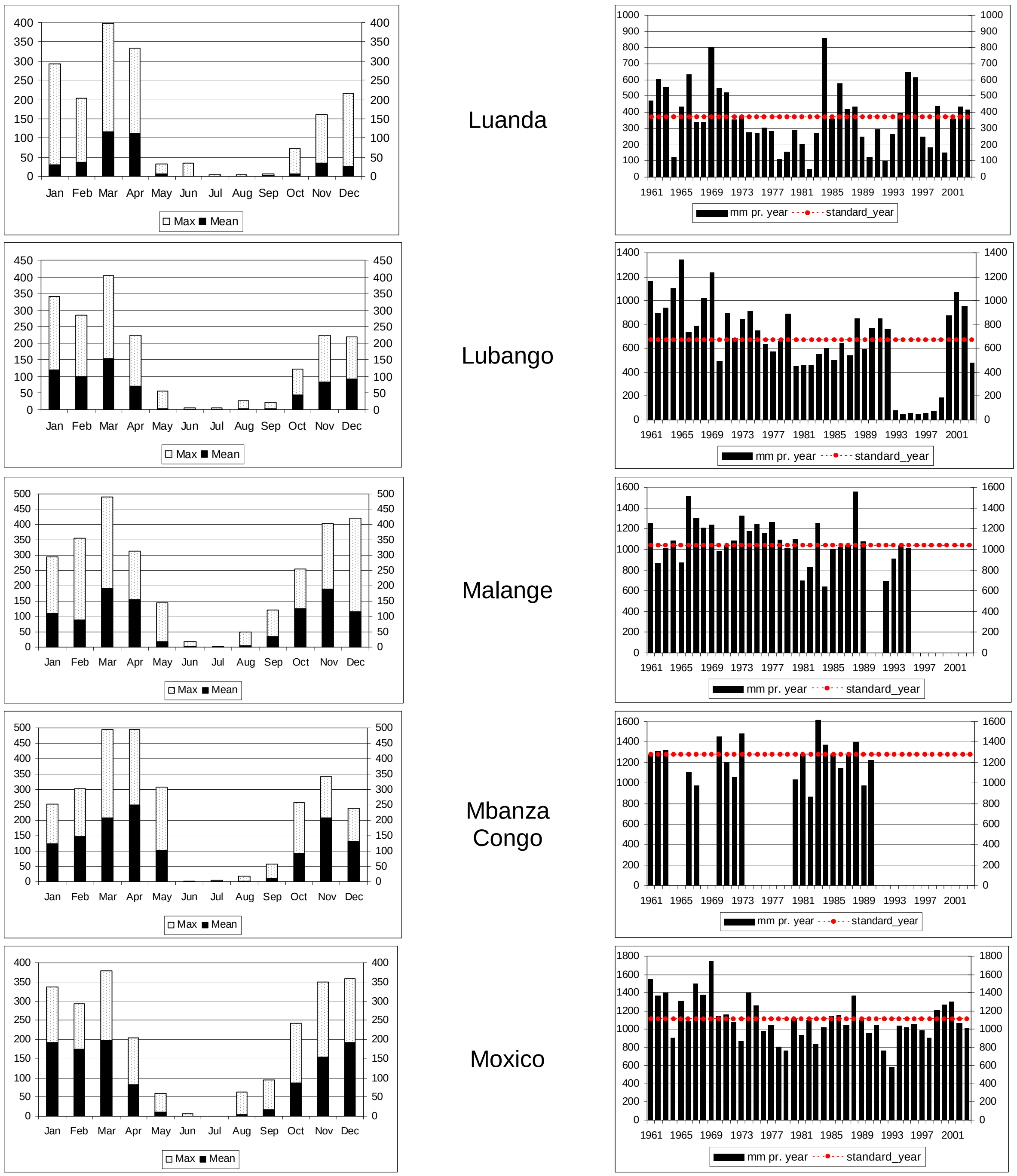
2.2.6 Precipitation

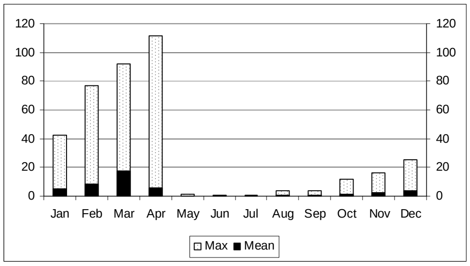
Precipitation data was obtained through several sources. Digital data of this type are freely available in abundance on the Internet due to several major research projects especially regarding climate change.

Climate data was also available through the governmental organization INAMET who handle meteorological investigations in Angola. This data was only partly digitised and was for just 15 locations. The precipitation data had some missing years but not in the same magnitude as the hydrological data. Data from INAMET was digitised and summarized, location of the measuring points were localized and the data used for verification and control of the precipitation coverage obtained from WORLDCLIM. The monthly and annual precipitation data from INAMET is figuratively shown in Table 2.2.3 and the location of the measuring points in Figure 2.2.7.

A regional precipitation dataset was obtained from WORLDCLIM. (WORLDCLIM is a set of global climate layers (grids) on a square kilometre grid.) The last version released (March 2004) is Version 1.2. (Hijmans, R.J., S. Cameron, J. Parra, 2004) The data layers were generated through interpolation of average monthly climate data from weather stations on a 30 arc-second resolution grid (often referred to as "1 km^2" resolution). Variables included are monthly total precipitation, and monthly mean, minimum and maximum temperature, and 19 derived bio-climatic variables.

Table 2.2.3 Average Mean and Maximum Monthly and Annual and Average Annual Precipitation for Measurement Locations obtained from INAMET (All values in mm)





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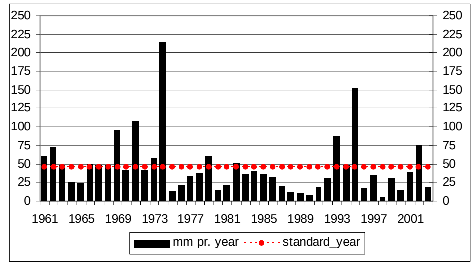

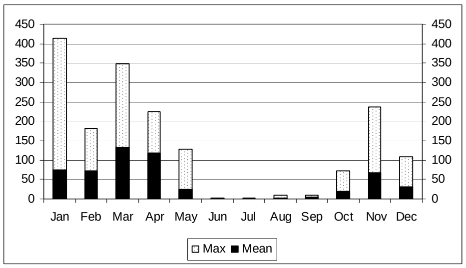

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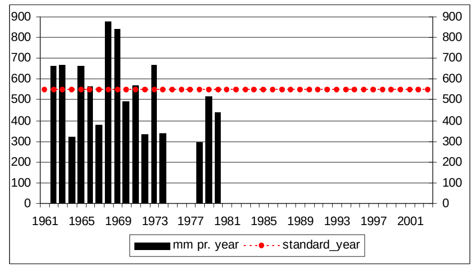

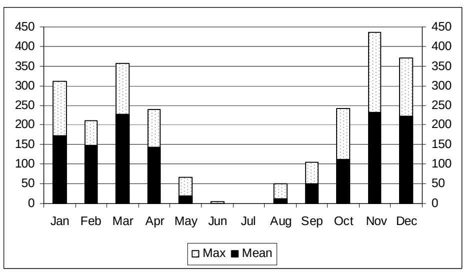

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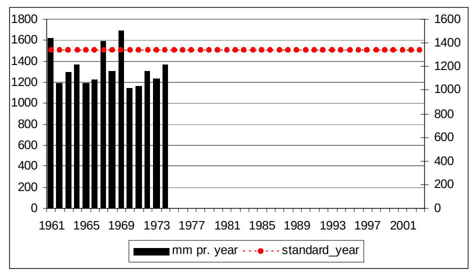
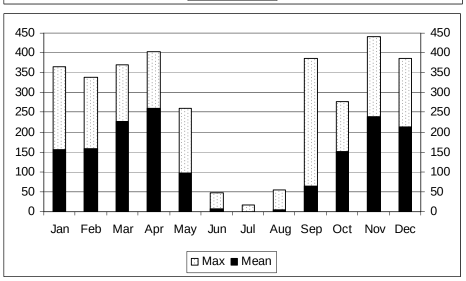
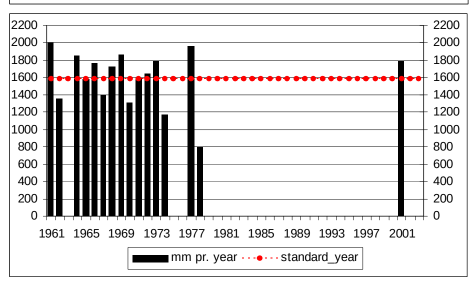
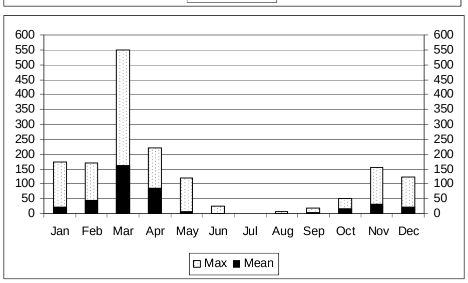




Uige





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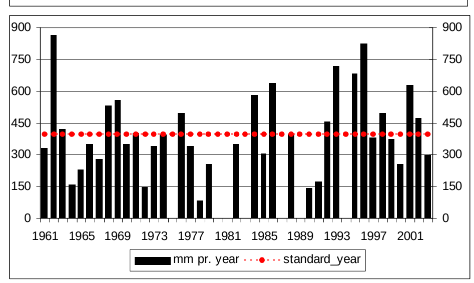
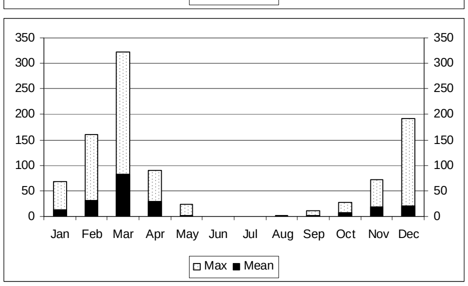
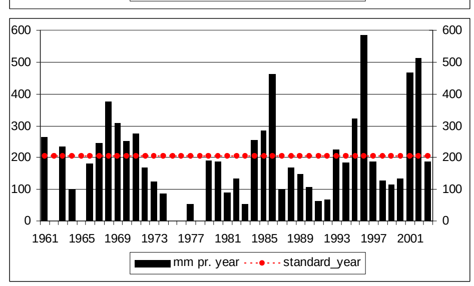
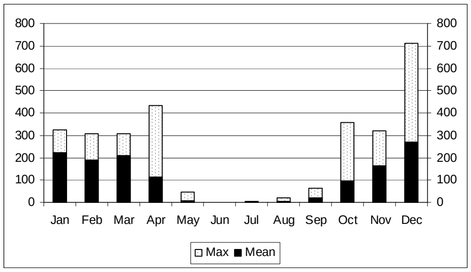


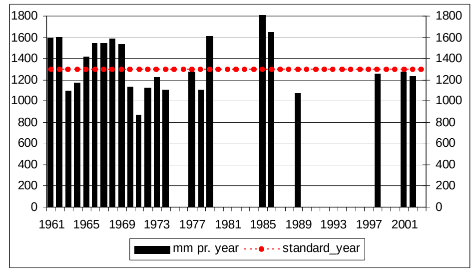


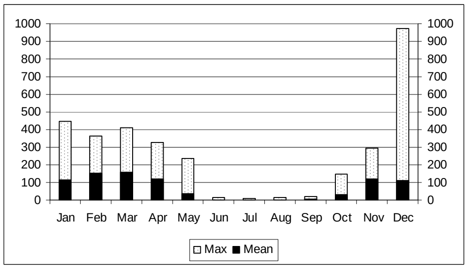
Benguela



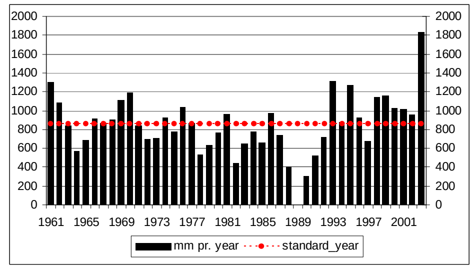


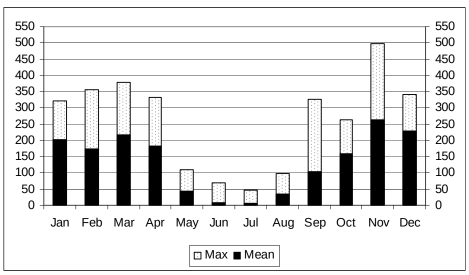
Bie



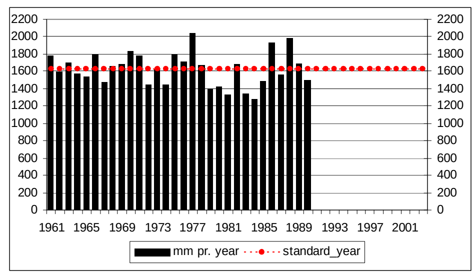


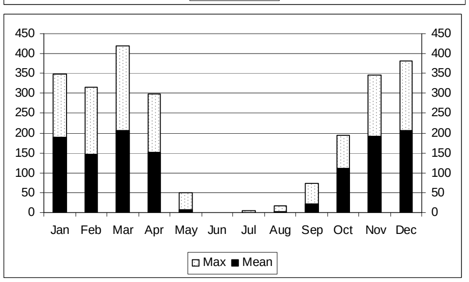
Cabinda



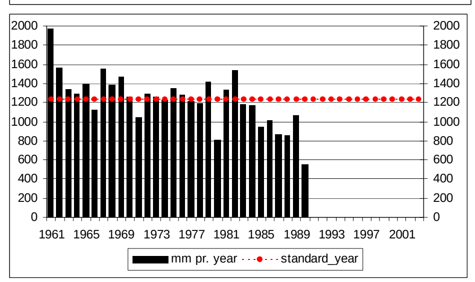


Dundo





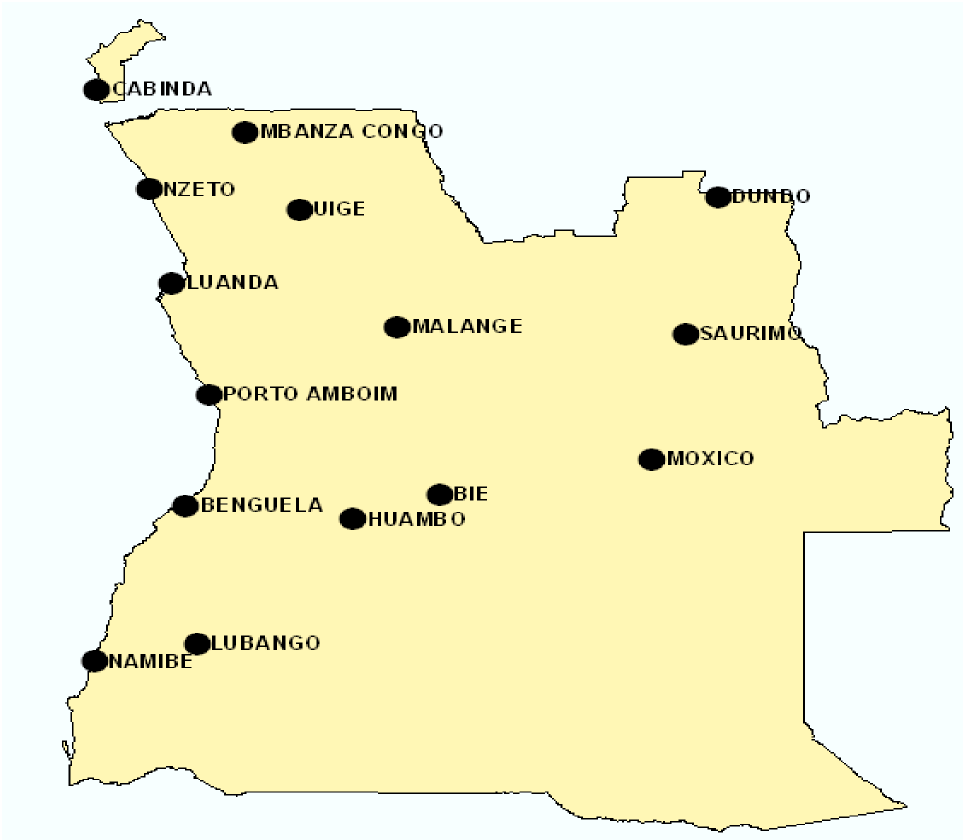
Huambo



A study of the potential impacts of climate change on freshwater resources in southern Africa predicts an overall reduction in rainfall, by as much as 10 per cent across the whole sub-region, and up to 20 per cent in parts of South Africa (WWF 2000). Evaporation rates will increase by 5–20 per cent, as a result of raised temperatures, which will reduce run-off, and decrease water security and agricultural potential.

Some stations in the INAMET datasets seem to conform to these results, but we have little knowledge of other factors behind the data collected by INAMET that may influence measurement results and trend analysis could not be carried out on these data.

Figure 2.2.7 Location of INAMET Precipitation Measurement Stations



The WORLDCLIM interpolated climate layers were made using:

- Major climate databases compiled by the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Centre for Tropical Agriculture (CIAT), R-HYdronet, and a number of additional minor databases for Australia, New Zealand, the Nordic European Countries, Ecuador, Peru, Bolivia, amongst others.
- The SRTM 30 arc-minute elevation database.
- The ANUSPLIN software.

For stations for which there were records for multiple years, averages were calculated for the 1960-1990 period. Only records for which there were at least 10 years of data were used. In some cases the time period was extended to the 1950-2000 period to include records from areas for which there are few recent records available (e.g., DR Congo), or predominantly recent records (e.g., Amazonia).

The calculations were started with the data provided by GHCN because of the high quality of that database. Additional stations were then added from other databases. Many of these additional databases had mean monthly values without a specification of the time period. Despite this, these records were also added to obtain the best possible spatial representation, reasoning that in most cases these records will represent the 1950-2000 time periods, and that insufficient capture of spatial variation is likely to be a larger source of error than in high resolution surfaces than effects climatic change during the past 50 years. Figures 2.2.8, 2.2.9 and 2.2.10 show the spatial distribution of the climate stations for which data exists.

Figure 2.2.8 Locations of Climate Stations with Precipitation Data

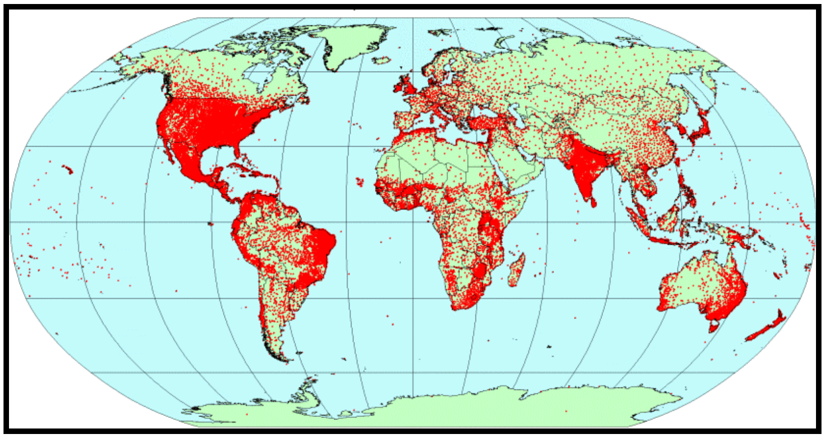


Figure 2.2.9 Locations of Climate Stations with Mean Temperature Data

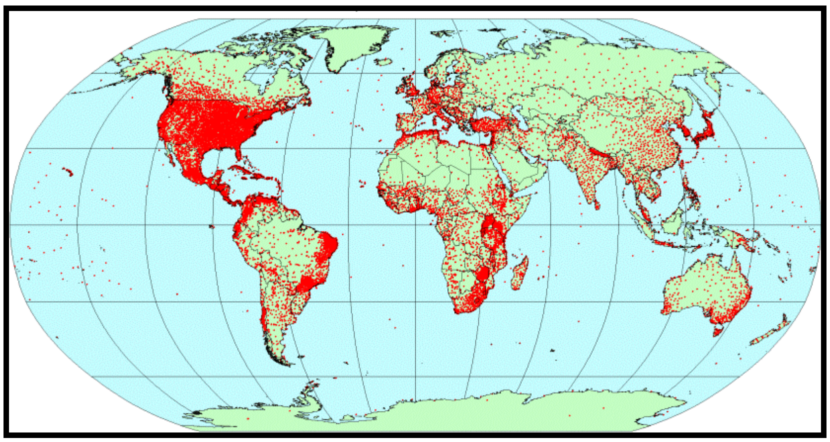
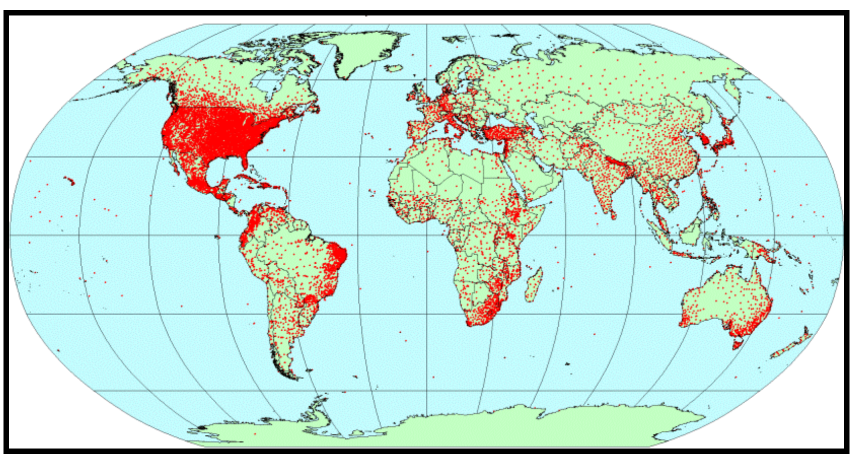


Figure 2.2.10 Locations of Climate Stations with Temperature Data



Temperature data was also obtained from WORLDCLIM, but even if not used primarily in this project, the GIS files were delivered to the client for use in future development of the assessment. Comparison of the two datasets from INAMET and WORLDCLIM gave very promising results. Comparing all points together the sum of differences was just above 2%, and gave no reason to discard the use of the precipitation dataset from WORLDCLIM in further calculations. The comparison of the measurements and dataset is shown in Figure 2.2.11 and the country covering dataset from WORLDCLIM is shown in Figure 2.2.12. This dataset was used for calculating runoff coefficients together with the discharge data from the selected hydrometric measurement stations.

Figure 2.2.11 Comparison of INAMET Measurements and WORLDCLIM Dataset

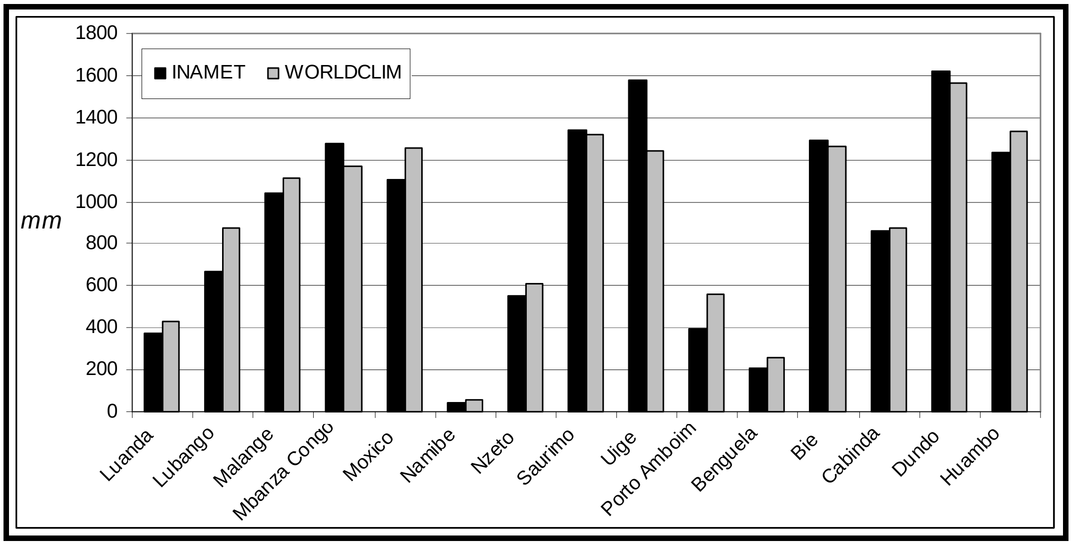
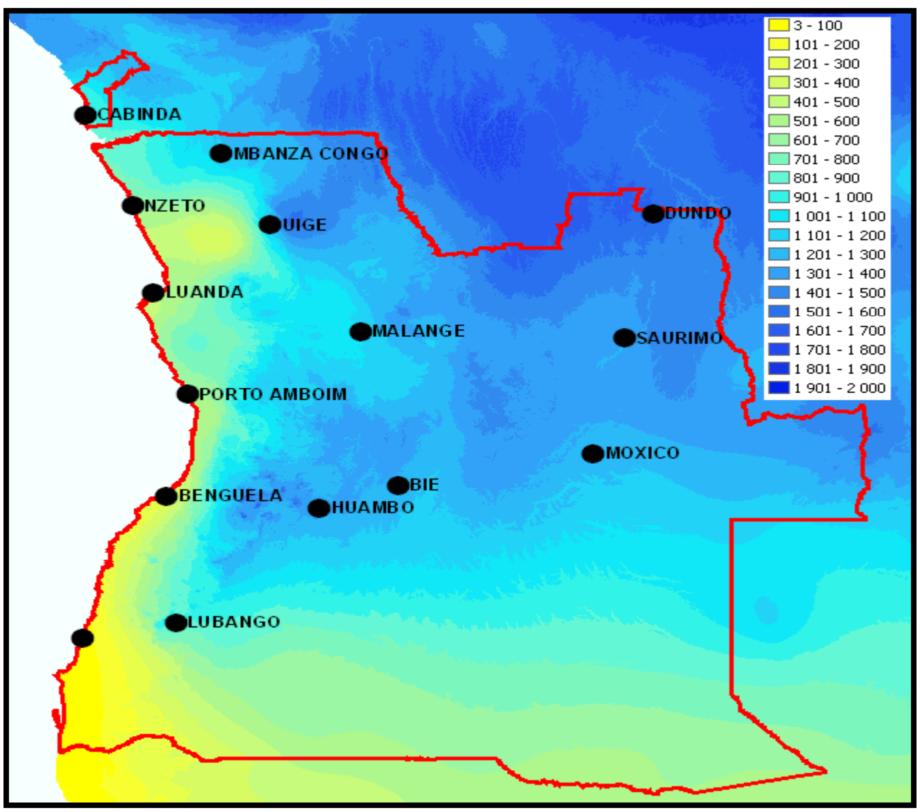


Figure 2.2.12 Precipitation in Angola - Data from WORLDCLIM (2004)



2.2.7 Potential Evaporation

Point measurements of potential evaporation data were also obtained from INAMET and plotted together with a countrywide dataset provided by the Climatic Research Unit (CRU) at the University of East Anglia (UK), made for the Southern Africa FRIEND Phase II project.

Measurements made by INAMET are mostly made using US Class A pans but some stations use Piche evaporimeters which makes comparison of data difficult.

The other dataset of mean annual and mean monthly potential evaporation data was estimated by the Penman method, and averaged over the standard period 1961 to 1990. The gridded values were calculated by applying a spline function to data collected at national meteorological stations, (Fry et al. 2001) and delivered as a polygon half-degree grid coverage of Penman potential evaporation data for the SADC region.

Data from INAMET measurement stations is shown figuratively in Table 2.2.4. Comparison of data from the two sources is shown in Figure 2.2.13 and the gridded dataset in Figure 2.2.14.

The comparison shows that data from CRU is generally lower (30%) than data from INAMET, and that both datasets generally show that potential evaporation exceeds or is near yearly values for precipitation.

Figure 2.2.13 Comparison of Measurements from INAMET and CRU Dataset

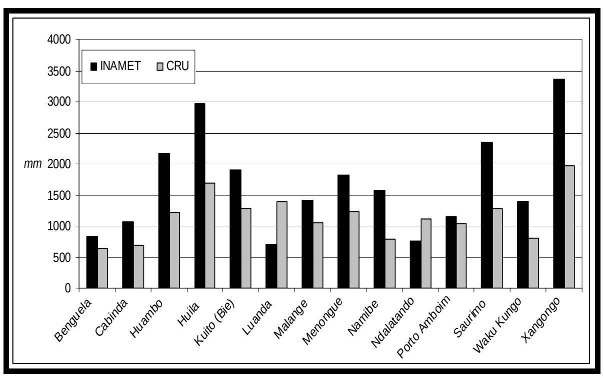
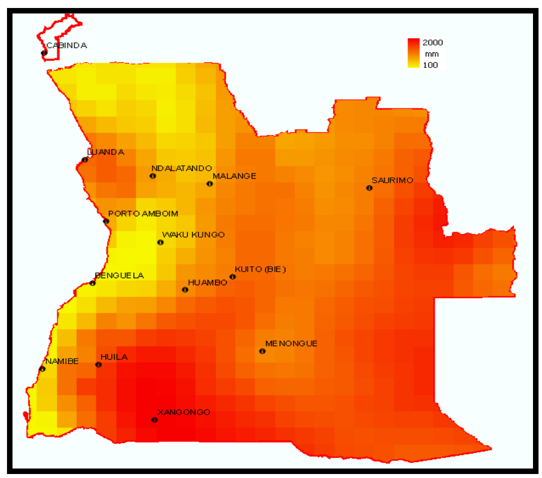
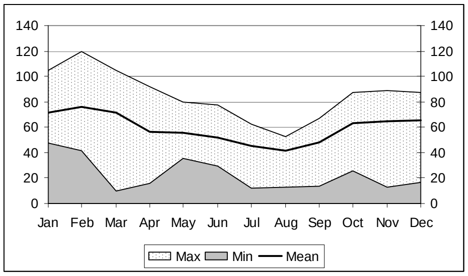


Figure 2.2.14 Mean Annual Potential Evaporation (Penman Calculation)

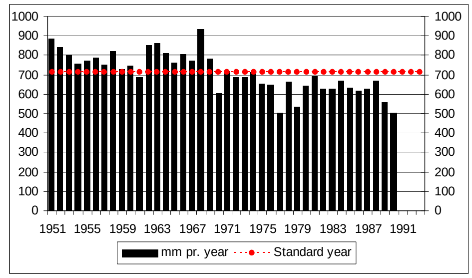


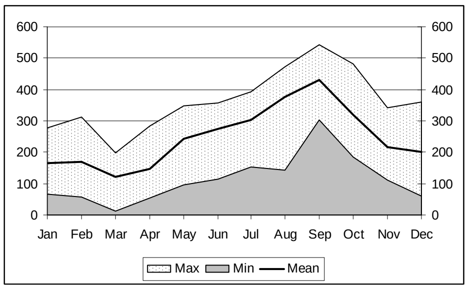
This data was not used in the study because of the choice of estimation method, i.e. the use of runoff coefficients. The data is, however, valuable in the overall evaluation.

Table 2.2.4 Average Mean, Minimum and Maximum Monthly and Annual and Average Annual Potential Evaporation for Measurement Locations Obtained from INAMET (All values in mm)

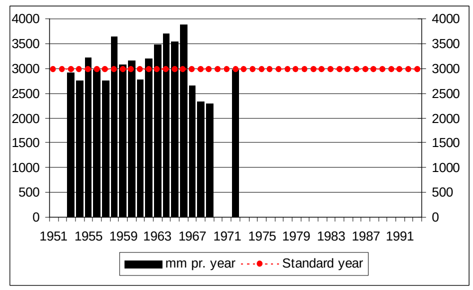


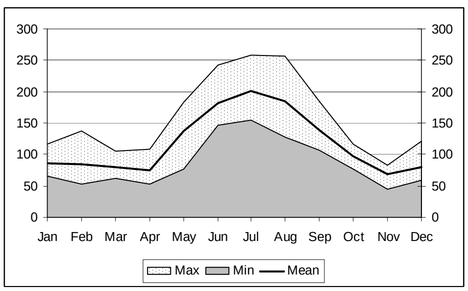
Luanda



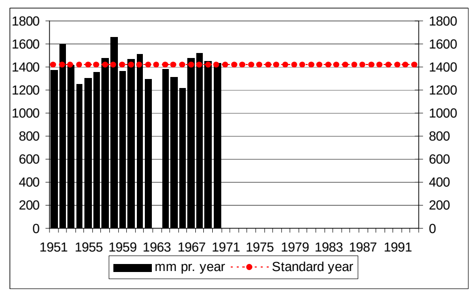


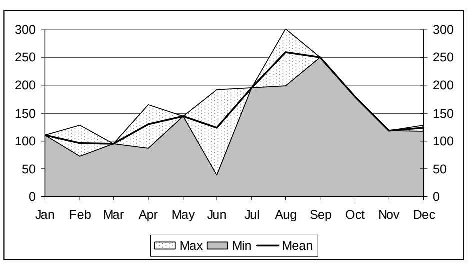
Huila



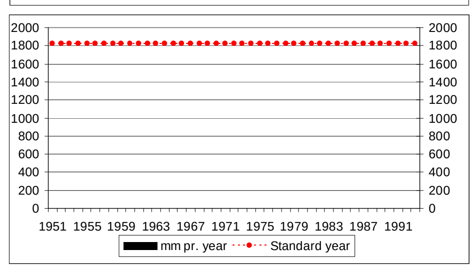


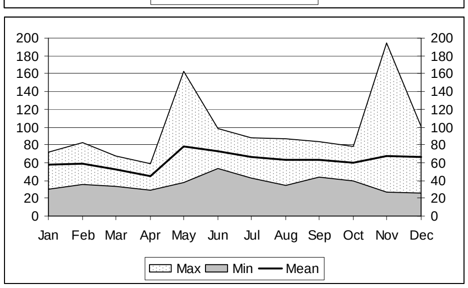
Malange



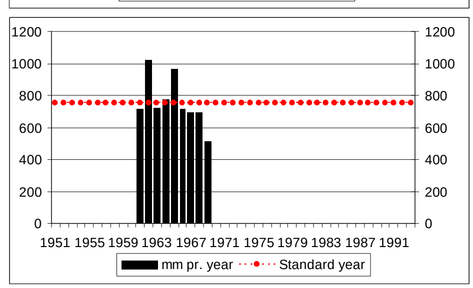


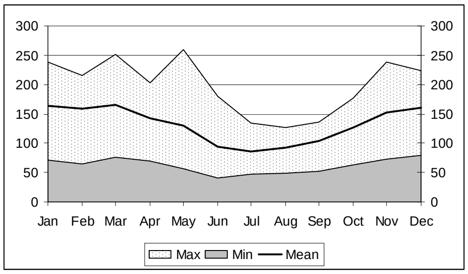
Menongue
(*Very sparse with data, no full years*)





Ndalatando





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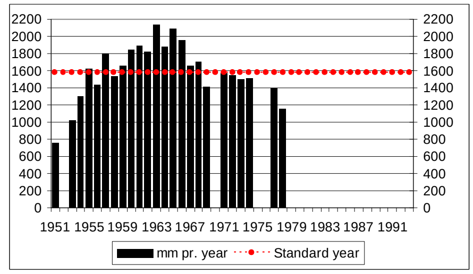
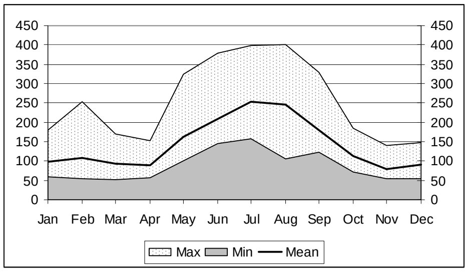
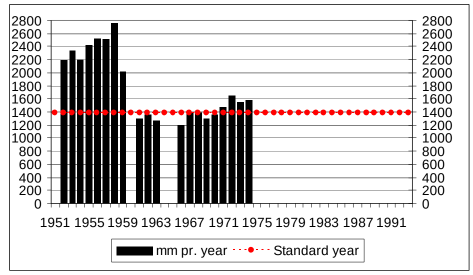
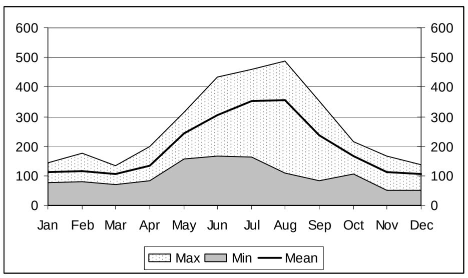




Waku Kungo





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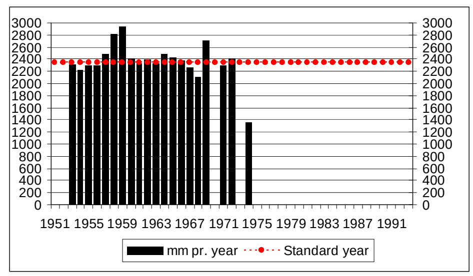

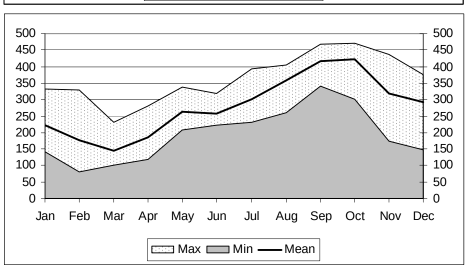

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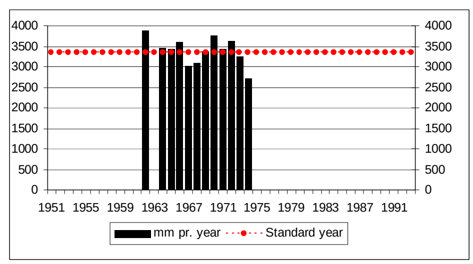

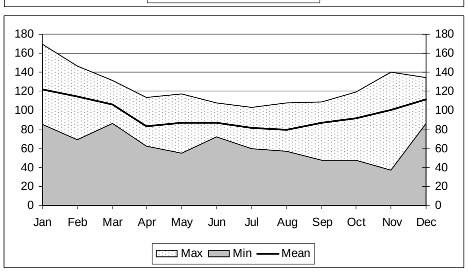

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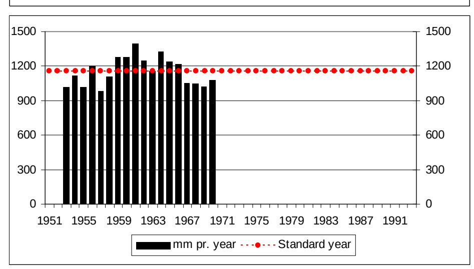
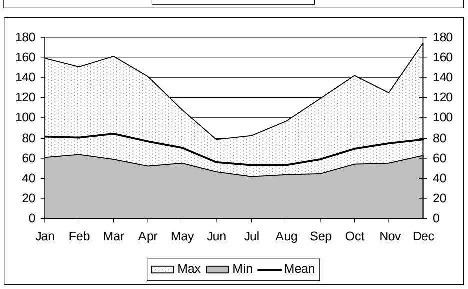
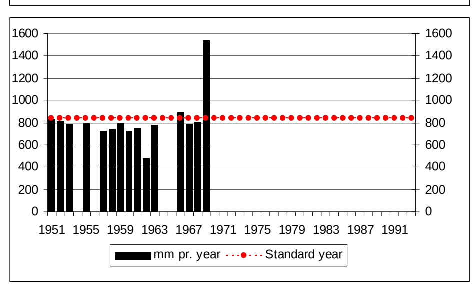
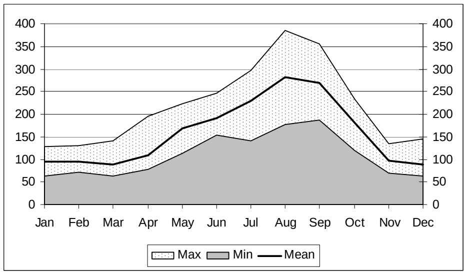


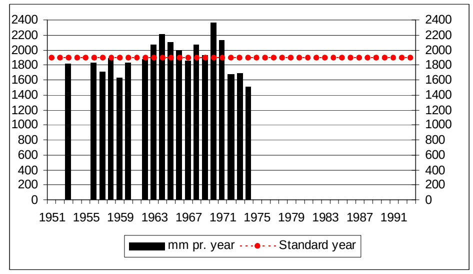


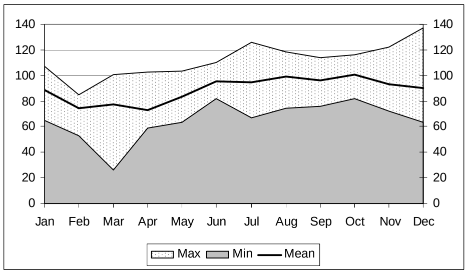
Benguela



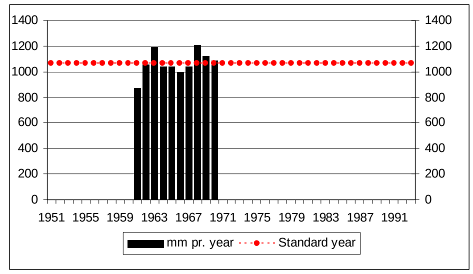


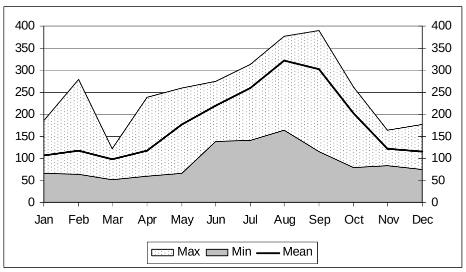
Kuito (Bie)



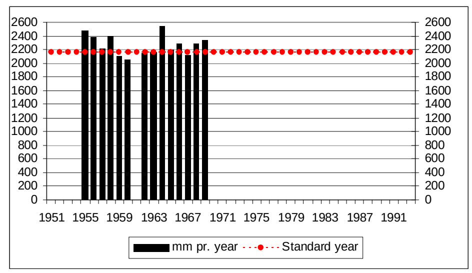


Cabinda





Huambo



2.2.8 Determination of runoff coefficients

Calculation of specific precipitation ($l\ s^{-1}\ km^{-2}$) was made for the same catchments described in Chapter 2.2.5 and shown in Figure 2.2.6. Together with the calculated specific discharge from the same selected catchments, the runoff coefficients for the catchments were calculated according to equation (5):

$$r = q_{runoff} / p_{spec} \tag{5}$$

where:

r	=	Runoff coefficient
q_{runoff}	=	Specific discharge
P_{spec}	=	Specific precipitation

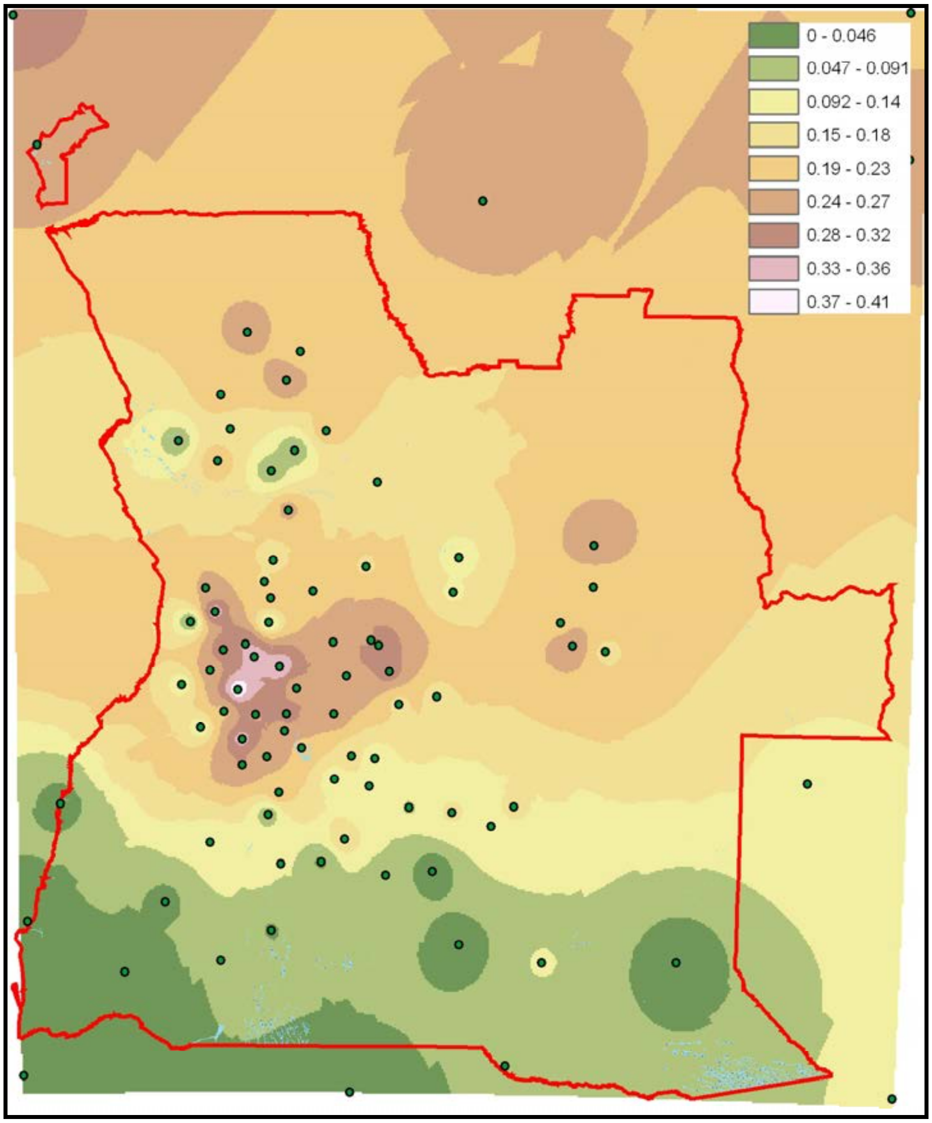
For some areas, especially along the southern coast and the northeastern part of Angola, some points had to be supplied with estimated values. This was done visually and with the calculated values from the Atlas of World Water Balance in mind.

2.2.9 Generation of a run off map for Angola

With Angola now “speckled” with polygons and points with calculated runoff coefficients, a complete coverage was interpolated with the use of a method called inverse distance weighted interpolation. Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable. IDW lets the user control the significance of known points on the interpolated values, based on their distance from the output point. By defining the higher {power} option, even more emphasis can be put on the nearest points. Thus, nearby data will have the most influence, and the surface will have more detail (be less smooth). Specifying a lower value for power will provide a little more influence to surrounding points a little farther away.

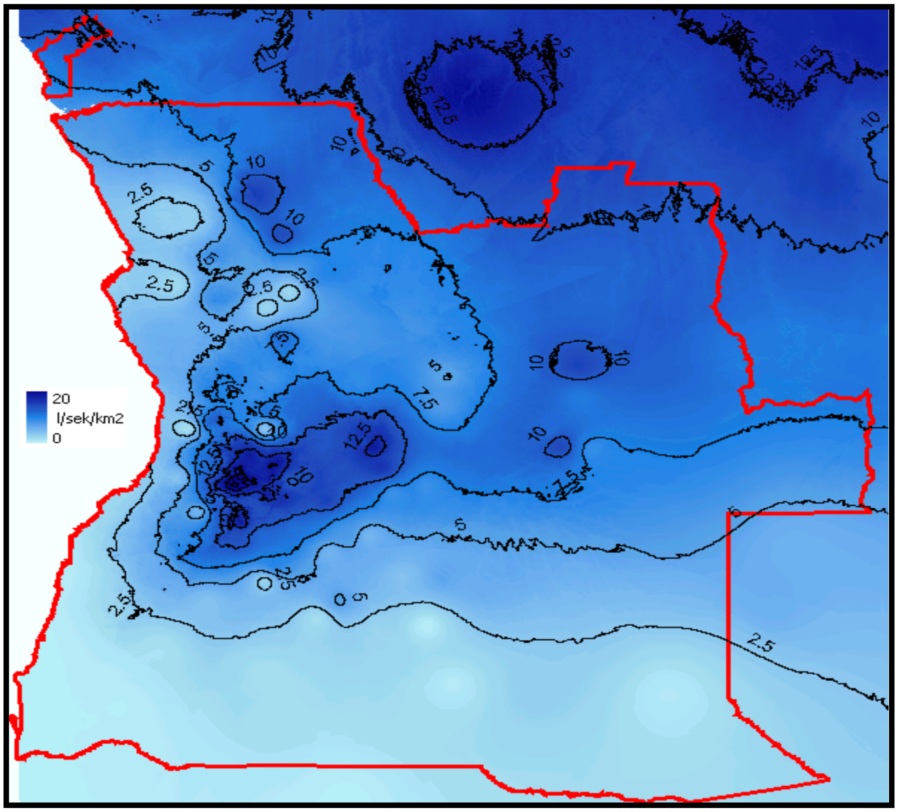
The characteristics of the interpolated surface can also be controlled by limiting the input points for calculating each interpolated point. The input can be limited by the number of sample points to be used or by a radius within which there are all points to be used in the calculation of the interpolated points.

Figure 2.2.15 Runoff Coefficient Map of Angola



This procedure generated complete coverage with runoff coefficients of Angola and to some extent into bordering countries as shown Figure 2.2.15. By multiplying this coverage with the specific precipitation cover, a runoff cover of Angola resulted with values as specific runoff (l s^{-1} km^{-2}). The entire map is shown in Figure 2.2.16 and in detail for each basin in Angola in Chapter 12. All generated GIS data have been transferred to DNA.

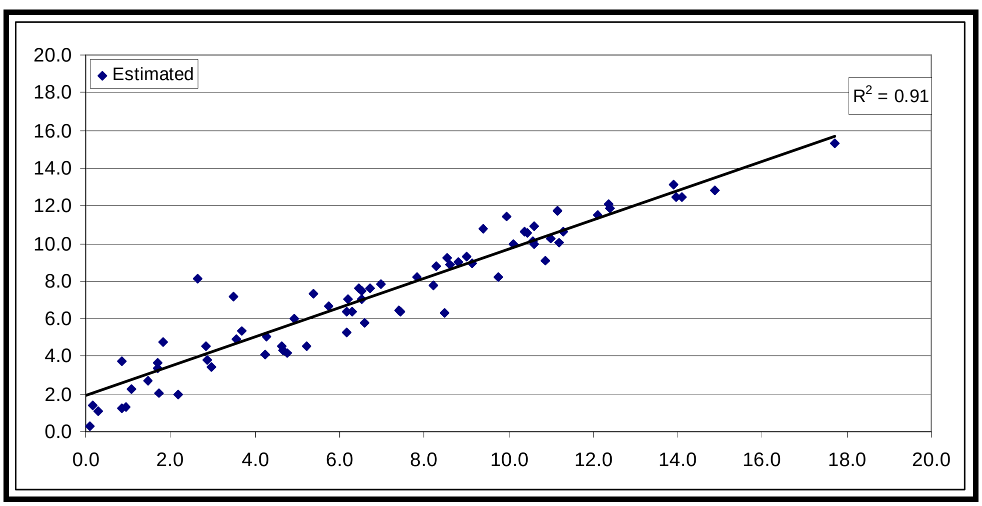
Figure 2.2.16 Runoff Map of Angola. Values as Specific Discharge in l s^{-1} km^{-2}



2.2.10 Check Against Measured Data

Control of calculated runoff values based on the new runoff map against observed values from measurements at the hydrometric stations gave very good results, with a correlation coefficient of $R^2 = 0.91$. Figure 2.2.17 shows the estimated values plotted against observed values. There seems to be some slight overestimation when calculation is done on small catchments. This is considered normal with the use of runoff maps.

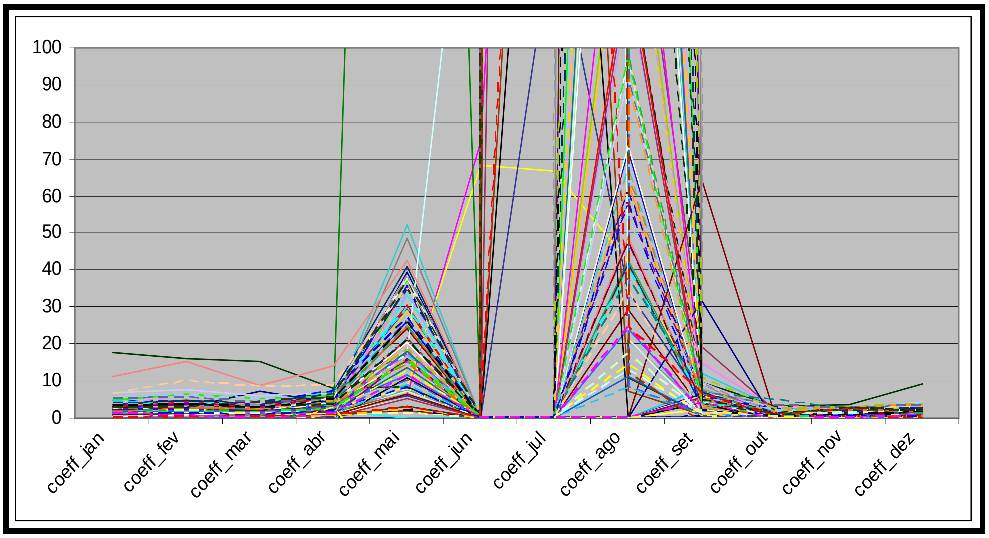
Figure 2.2.17 Calculated Values of Runoff Plotted against Observed Values from Catchments with Hydrometric Stations. (Values in m³/s, observed values on x-axis)



2.2.11 Runoff Variations Throughout the Year

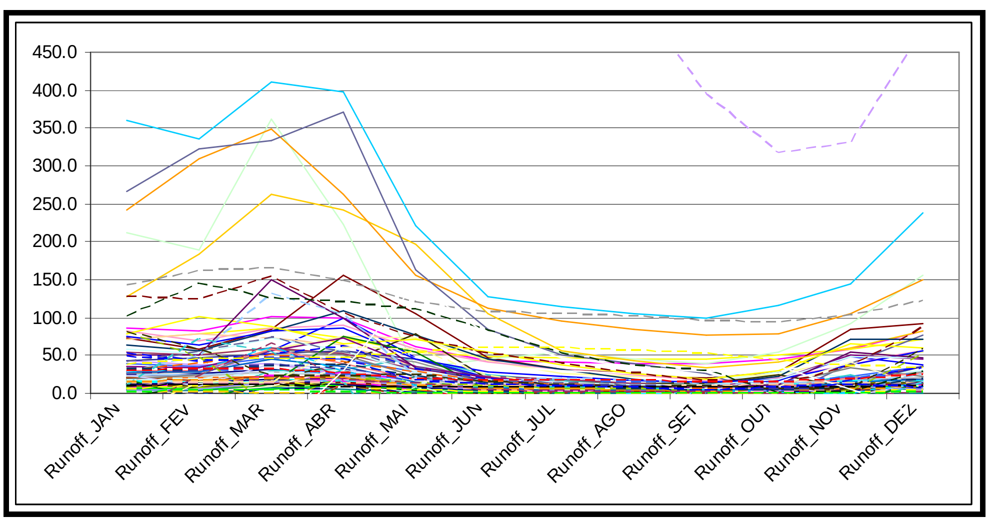
Annual values of runoff do not always give the information needed to find deficits in the water balance. Surface water tends not to be evenly distributed in time. Periodic or constant use of this resource for domestic water use, irrigation etc. can surpass the resource base in periods of low flow. To find out if there are periods of deficit even though they do not exist on an annual basis, the estimated annual runoff values for each catchment has to be distributed in time. Making runoff maps for each month with the use of runoff constants was not possible. The existence of very dry periods with little or no rain makes this ratio difficult to establish. As can be seen in Figure 2.2.18, runoff constants for the months with sufficient rain are fairly constant. In periods of drought, however, this constant goes off the scale.

Figure 2.2.18 Monthly Calculation of Runoff Constants for the Selected Catchments



As can be seen in Figure 2.2.19, the runoff varies during the course of a year in a seemingly similar pattern. Such patterns can be used to distribute in time the calculated annual values for runoff in each of the Angolan catchments. If possible the use of hydrographs from nearby hydrometric stations should be used. (The high values in October and November are runoff in Zambezi that is so high it exceeds the used scale)

Figure 2.2.19 Monthly Runoff in the Selected Catchments (Values in m³/s)



To attain an easy method of such distribution, the percentage of mean annual runoff was calculated for each month in the runoff series selected for the study and plotted. During this assessment, the country has been divided into five runoff regimes; Northwestern coast, southwestern coast, southern area draining into Namibia, Zambezi and the Congo. For each of these regions, except the southwestern coast, a mean curve of time distribution of runoff was established. For the southwestern coast, were the rivers run totally dry for long periods of time, precipitation distribution in time gave this distribution.

The distributions are showed in figuratively and numerically in Figures 2.2.20 to 2.2.24 and in Tables 2.2.5 to 2.2.9.

Figure 2.2.20 Monthly Percentage of Mean Annual Discharge at the Northwestern Coast

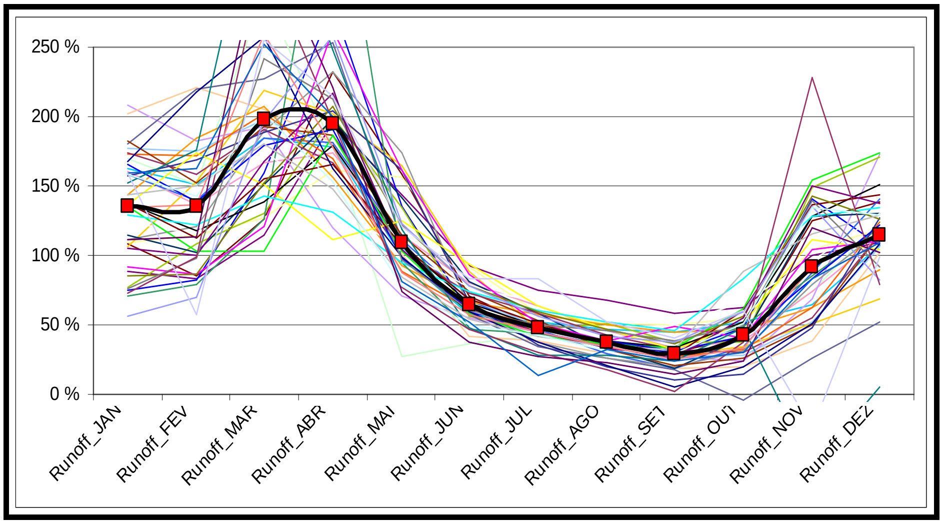


Table 2.2.5 Monthly Percentage of Mean Annual Discharge at the Northwestern Coast

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
135 %	135 %	198 %	195 %	109 %	64 %	48 %	37 %	30 %	43 %	92 %	115 %	100 %

Figure 2.2.21 Monthly Percentage of Mean Annual Discharge at the Southwestern Coast

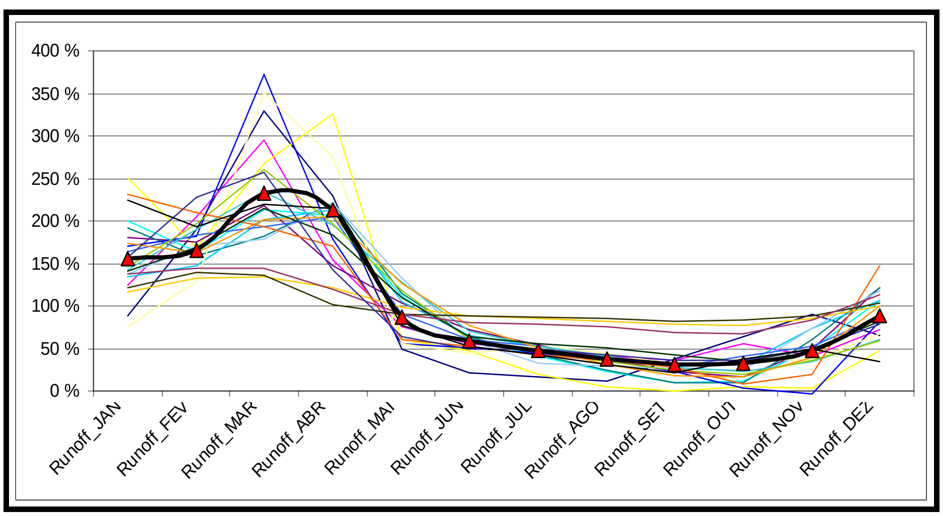


Table 2.2.6 Monthly Percentage of Mean Annual Discharge at the Southwestern Coast

Jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Annual
155 %	166 %	233 %	212 %	87 %	59 %	48 %	38 %	31 %	32 %	48 %	89 %	100 %

Figure 2.2.22 Monthly Percentage of Mean Annual Discharge draining into Namibia.

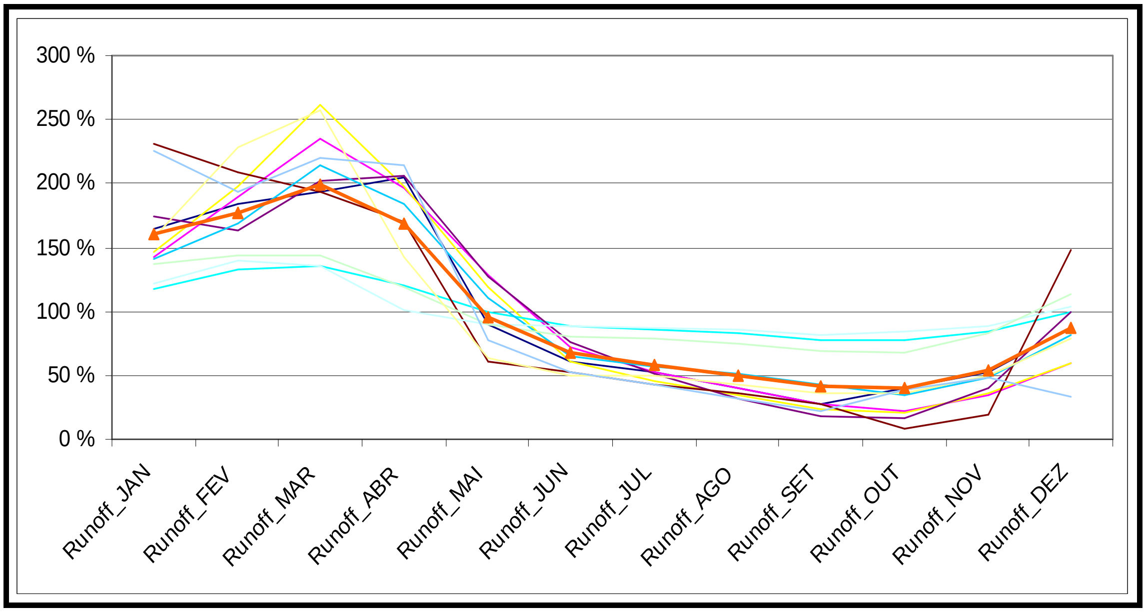


Table 2.2.7 Monthly Percentage of Mean Annual Discharge draining into Namibia

Jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Annual
160 %	177 %	199 %	169 %	96 %	68 %	59 %	50 %	41 %	40 %	53 %	88 %	100 %

Figure 2.2.23 Monthly Percentage of Mean Annual Discharge in Upper and Lower Zambezi

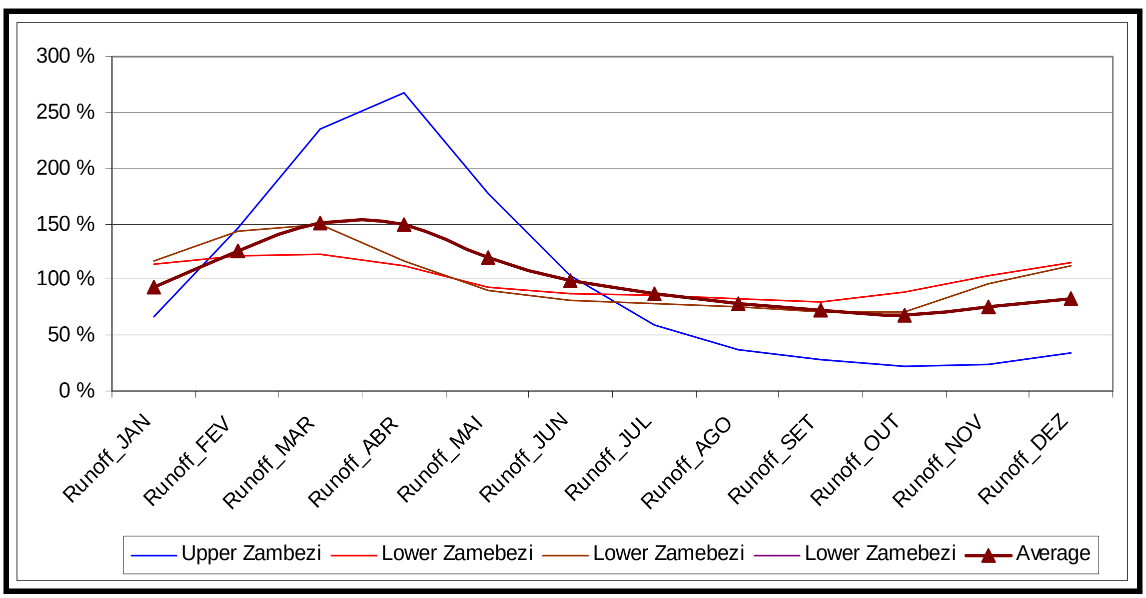


Table 2.2.8 Monthly Percentage of Mean Annual Discharge in Upper and Lower Zambezi

Jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Annual
93 %	126 %	151 %	149 %	119 %	100 %	87 %	79 %	72 %	68 %	75 %	83 %	100 %

Figure 2.2.24 Monthly Percentage of Mean Annual Discharge in Upper Congo

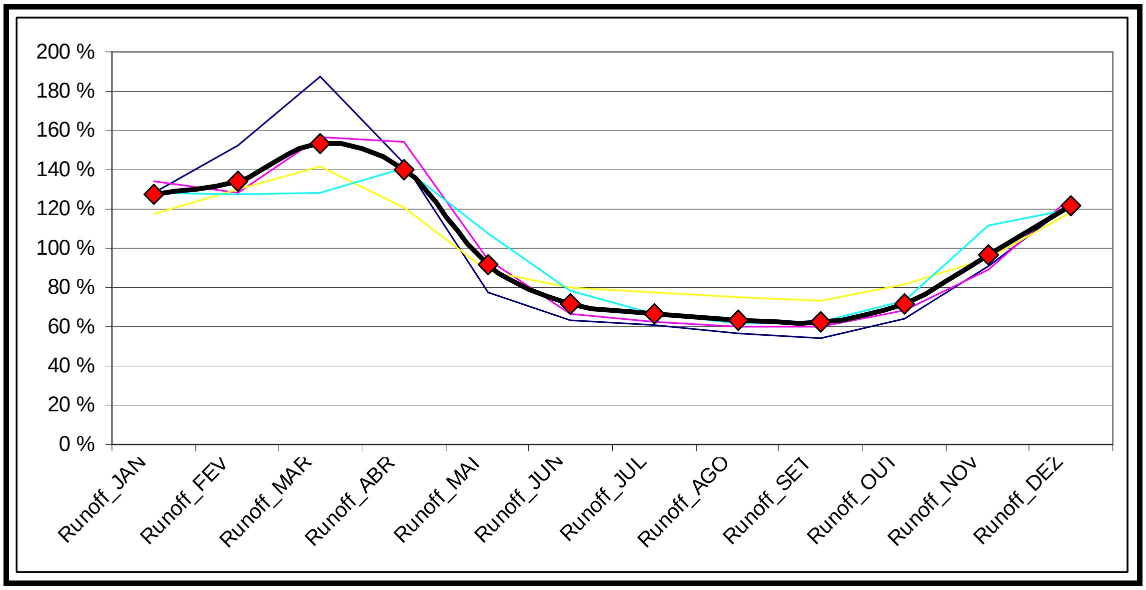


Table 2.2.9   Monthly Percentage of Mean Annual Discharge in Upper Congo

Jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Annual
127 %	135 %	154 %	140 %	92 %	72 %	67 %	63 %	62 %	72 %	97 %	122 %	100 %

2.3 Groundwater Assessment

2.3.1 Knowledge on Geology and Hydrogeology

The geology of Angola is rather well known in the western part of the country, but less known to the east. The hydrogeological characteristics of the rocks of Angola are best known in the southwestern provinces of Huila, Namibe and Cunene, where many wells have been drilled and reported. There are probably data reports from several of these wells in the archives of some official and/or scientific institutions in Angola, but they have not been available for use in this study. In the hydrogeological map of Angola the depth of a number of wells are shown and their capacity is given in the intervals: < 1 l/s, 1-5 l/s, and > 5 l/s. In addition the main aquifer type is shown:

- Porous rocks with primary porosity and permeability
- Good aquifers in fissured an carstic hardrocks
- Low productivity aquifers with limited or no groundwater potential

Each of these groups is divided into 2 or 3 subgroups with indications of probable well yield.

The maps from the FRIEND program are probably based on the same data, but the presentation is adjusted to the standard UNESCO legend of Hydrogeological Maps, as the program covers eleven nations in the South African SADC-region. To describe the aquifer types the terms I = Intergranular, F = Fissured and L = Local are used. There are also maps presenting a national aquifer yield categorisation (in units of litres per second), with each polygon assigned values for lower, mid and upper yields. A unified geological classification, developed by the British Geological Survey for the whole of Southern Africa is also introduced.

In the maps of "National yield categorisation" made by the FRIEND project a few rocks and sediments are shown to have a much higher yield than in the hydrogeological map of Angola. This is probably caused by misinterpretations or misprints in the production of the FRIEND maps, as the project probably had no other data resources than the hydrogeological map of Angola.

2.3.2 Interaction between Groundwater and Surface Water

To understand the process of groundwater recharge it is important to realize that groundwater regeneration does occur in periods of high precipitation even if the catchment could have a negative annual water balance. Thus there is some groundwater even in the dry areas in Namibe province, but it is easily overexploited. Because of the high evaporation in areas with low precipitation, the mineral content is often too high for use as drinking water.

An unknown part of the freshwater resources of Angola is shared between groundwater and surface water. In principle a large withdrawal and use of groundwater for agricultural purposes will increase the evapotranspiration and could reduce the run-off in the rivers. The use of groundwater for other purposes is normally less than for agriculture, and except for discharge along the coast, wastewater will return to groundwater or rivers.

The groundwater yield of most of the rocks in Angola is rather low, and it could only in a few hardrock areas be practically possible to use so much groundwater that river run-off was substantially reduced. If the use of groundwater for agricultural purposes is maximized from the good hardrock aquifers in the northern basins of M'Bridge, Loge, Dande and Bengo, some influence of the rivers in dry periods could probably be seen. In the basins of Rio Cuanza and Rio Cunene, tributary rivers could perhaps be influenced in the same way, but any effect on the main rivers would hardly be traced. In the southern basins of Sao Nicolau, Bero, and Curoca the precipitation is low, and groundwater withdrawal from Pan-African rocks of high yield in the inland areas could probably reduce the river run-off in the dry season.

Groundwater wells in the alluvial sediments along the rivers could produce large amounts of groundwater, and the groundwater would be renewed by bank infiltration from the rivers. Large withdrawals will influence the river run-off, and the consequences should be evaluated in each case to decide the acceptable amount of groundwater to be used.

2.3.3 Main Geological Units

An overview map of the geology of Angola is presented in four foldout A3 sheets at the end of this chapter as follows:

Figure 2.3.1 a – Geology of Angola (north-west)
Figure 2.3.1 b – Geology of Angola (north-east)
Figure 2.3.1 c – Geology of Angola (south-west)
Figure 2.3.1 d – Geology of Angola (south-east)

Rocks of the Precambrian basement are exposed in large parts of Angola. The basement rocks represent a series of orogenic sequences from the Limpopo-Liberian orogen with an age of nearly 3000 million years to the youngest Pan-African orogen that ended at the beginning of the Palaeozoic time. Except for in the coastal area there are Precambrian basement rocks in most of the western part of the country.

To the south and east, Palaeozoic and younger continental sedimentary rocks and Quaternary sediments overlay the basement. The oldest mapped rocks are of Carboniferous age, while most of the Cambro-Silurian rocks seem to be missing in the sequence. In the central part there are many Precambrian inliers among the sedimentary rocks, and in the eastern part of the Moxico province there are large areas of basement rocks. To the north Precambrian rocks are found in places in the deeply eroded river valleys as well.

Along the coast there are marine sedimentary rocks and sediments, mainly of Cretaceous to Quaternary age. The largest extension of these is in the western parts of the Cabinda, Zaire, and Bengo provinces. South of N'Gunza, there are also mapped several outcrops of eruptive rocks of Mesozoic age, mainly among the Mesozoic sediments.

There are recent alluvial sediments along the large rivers such as the Cuanza, Zaire and Cunene; both in flood plains and deltas in the lower parts near the coast, but also in the inland river valleys.

2.3.4 Hydrogeological Characteristics of the Geological Units

2.3.4.1 General Comments on the Groundwater Potential

When evaluating the groundwater potentials of Angola it is important to emphasise the limited knowledge of the origin of the data, such as if the yields are based on a real test pumping or not. Probably most of the information on expected yield etc. are based on data from a few provinces in the southwest.

For some of the rock groups there are probably only a few well data. A few favourable results, for example caused by wells in favourable fault or fissure zones, could then cause a very high average yield. However the median yield, indicating the most probable yield of a new well, will be much lower. In addition it should be emphasised that in the FRIEND maps the values for "middle yield" seem to be calculated as the middle value between the obtained highest and lowest yield, and not even the middle yield of all the wells.

In most cases it seems reasonable to account for these factors by reducing the expected water yield compared to the values given in the hydrogeological maps. This is partly done in table 2.3.1 and in the short summary of the individual river basins given in section 2.3.8, but however there are probably too high estimations for the water yields in some of the hardrocks.

2.3.4.2 Precambrian rocks

In the Precambrian basement there are a large variety of rock types that, according to the hydrogeological maps, have quite different hydrogeological properties. The hydrogeological characteristics of some of the main groups are mentioned here.

According to the maps, granites, granitic gneisses and migmatites are common rocks in most of the orogenic sequences. The legend of the hydrogeological map of Angola indicates yields of 1-3 l/s and a success rate of 50-70%, but only 30-50% in some regions. However, according to the wells shown in the map, the most common yields of granites and gneisses are less than 1 l/s. This value corresponds better to the general experience of the yield of Precambrian basement rocks. It should be emphasised, however, that most of the wells in these rocks are drilled to a rather shallow depth (15 to 40 m), and probably the total capacity could be increased if they were extended to for example 70 or 100 m. Some wells with a very high yield are known from Angola, but based on knowledge from other Precambrian areas common water yields of more than 1 l/s should not be expected.

Basic rocks in Angola such as gabbros and norites are probably better aquifers, and in the hydrogeological map of Angola their yields are often indicated to be 3-5 l/s with a drilling success rate of 70-80%. In our opinion these are unexpected and very good results for basic deep-seated rocks. With reference to the comments in section 2.2.4.1 we indicate a mean yield of 3 l/s in the summary of the hydrogeology of the individual basins. Basic intrusive rocks are found both in northern and southern parts of the country.

There are also groups of volcanic rocks in the Precambrian basement that are supposed to have an average yield of 3 l/s. The largest area of these rocks is found along the borders between the Bengo, Cuanza Norte, and Uige provinces. In addition there are a lot of large doleritic dyke swarms running WNW-ESE in the western part of the country south of N'Gunza. In the same areas series of fissure and fault zones are shown. Perhaps these zones occur elsewhere in the country as well, in areas that are yet not detailed mapped.

Among the older Precambrian rocks of sedimentary origin there are a few groups that probably are good aquifers. The rocks include old quartzites of the Limpopo-Liberian orogen and a group of metasediments mainly consisting of quartzites, sandstones and conglomerates that are probably somewhat younger. These rocks are scattered over most of the Precambrian districts, especially in the southwestern part of Angola. Average groundwater yield is estimated to 3 l/s, but this value may be too high.

Rocks of the Pan-African orogen are the youngest and best aquifers of the Precambrian rocks. The group of Chela, with sandstones, siltstones and volcanics is the oldest group of the orogen. Average groundwater yield may be as much as 6 l/s. The Chela group is found in an area south and west of Lubango, and also further south in the Namibe province. In the north of the basin, and to the east of the volcanic rocks of Bengo, Cuanza Norte, and Uige provinces, there are large areas of sedimentary rocks, including sandstones, geyvackies, limestones, dolomites and several others. The average water yield is supposed to be 3-6 l/s in most of the rocks in this district. Sandstones and related rocks of this orogen are also found east in the Moxico province and in smaller areas at several sites elsewhere in the country.

2.3.4.3 Mesozoic and Quaternary Sediments and Rocks along the Western Coast

According to information in the hydrogeological map of Angola the probable groundwater yield in the areas dominated by Quaternary sediments is estimated to 1 l/s.

The groundwater potential of the Mesozoic rocks along the coast is also probably low. The average yield of porous rocks is estimated to 1 l/s, while some of the fissured or carstic Cretaceous and Tertiary rocks probably have some higher groundwater potential.

2.3.4.4 Mesozoic Eruptive Rocks.

The eruptive rocks along the coast probably have a better groundwater potential than the surrounding sedimentary rocks. This is only partly shown in the hydrogeological map, but in general young volcanic rocks and small intrusive bodies are quite good aquifers. Many of these small bodies are situated in southwest part of the coastal zone where the groundwater is known to have a high mineral content, and the water may be unsuitable as drinking water.

2.3.4.5 Areas of Kalaharian Sand

The groundwater potential of the large areas of continental Mesozoic and Cenozoic sediments and sedimentary rocks in the western and southern part of Angola is not well known. In the hydrogeological map a medium yield of 1 l/s is indicated. Some of the sandstones, conglomerates and a few limestones could give higher yields, and a maximum yield of 5 l/s is obtained.

2.3.4.6 Quaternary Alluvial Sediments

The recent alluvial sediments along the rivers are definitely the best aquifers of the country. In the hydrogeological map water yields from 15 to 50 l/s are reported. In the largest alluvial plains composed of sand from the erosion of granitic and other quartz rich rocks even higher yields could probably be obtained from correctly constructed wells.

Only the largest alluvial plains in the western part of the country are shown in the small-scale maps. Most of them are along the lower part of the river courses and less then 100 km from the coastline. There are probably a lot more alluvial deposits that could be used for groundwater supply both for villages and towns. The largest aquifers of this category are found in the provinces of Huila, Benguela, Cuanza Sul, Bengo and Zaire. In the hydrogeological maps no wells are presented in these deposits, but other well data that is not available for this study probably exists.

Some of the groundwater in the alluvial plains is reported to have too high contents of iron and sulphate. High mineral content in the groundwater should not be unexpected in areas of low precipitation and high potential evapotranspiration. In addition iron problems is often caused by the lack of circulation in deep groundwater basins.

In some of the deltas and in lower parts of the alluvial plains the groundwater quality is influenced by saline water. The tidal reach in some of the rivers like Rio Cuanza can be traced tens of kilometres upstream from the sea.

The rivers of the small catchments along the coast dry up in periods of low precipitation, and the groundwater will also probably vanish. No information was available about the groundwater potentials of these alluviums in the dry season.

2.3.5 Structures of Hydrogeological Importance

In addition to rock type, several geological structures such as dikes, faults and fissures are important for the groundwater storage and water yield. Even in rocks with primary porosity secondary fissures often account for an important part of the transportation of water and sometimes for the storage capacity as well.

The larger geological structures such as fault and fissure zones are important for conducting water during long-duration pumping of wells. Dykes of intrusive rocks often have highly fissured "chilled margins" caused by the rapid cooling against the side rock. In hardrocks that are sparsely fissured these zones and dykes can give the only possibility for groundwater supply.

In the southwestern parts of the Precambrian rocks of Angola many dikes, faults and fissure zones are mapped. The use of these zones, and probably also a lot of smaller zones not shown in the map, could be very important to obtain maximum groundwater yield.

2.3.6 Mineralised Water and Saltwater Intrusion

Mineralised water is reported along the coast south of Benguela, and inland in the southwest part of Angola. Both water yield and mineral content often increase with depth. Groundwater in these areas is seldom, if ever, usable for drinking water.

Along the entire coast intrusion of seawater can be a problem for wells pumped with high capacity over long periods. In the alluvial plains salt water lies underneath the fresh water, often up to several tens of kilometres from the river mouth.

2.3.7 Water Demands and Groundwater Supply

The use of groundwater for irrigation is important in the coastal area and in the southwestern provinces, especially in the basins of Dande, Bengo, Cuanza, Longa, Queve, Cunene and Cubango. The rainfall is not sufficient for the crops, and groundwater from alluvial plains is used when the rivers dry up. The irrigation may use a substantial part of the water in the rivers, and water taken from the alluvium after the rivers have dried up must be refilled by river water in the beginning of the next precipitation period. As we do not have the geological information necessary to estimate the volume of these alluviums, we do not know the volume of accessible groundwater. In some basins agriculture will probably use all accessible groundwater.

According to the data of the hydrogeological maps the groundwater potential is sufficient to supply most of the villages in the rural districts of Angola. In fact, groundwater is the main source of drinking water outside the towns. The water demand in the rural districts is today probably no more than 30 l/capita/day. The necessary volume for a village of 1.000 inhabitants should thus be achieved by a very few drilled wells, even if the success rate is less than 50%.

For denser populated areas and towns more detailed evaluations have to be made. Table 2.3.1 indicates the water demands for villages and towns of different size and the necessary number of wells in different hydrogeological regions. The basis for this table is the estimates of future water demands for towns given in Chapter 7 and Table 7.2 in this report and the indications of low, middle and high yield given in the hydrogeological map of Angola and maps from the FRIEND II project. The yield values from the maps are reduced as explained in section 2.2.3.1. In the table more probable average values for a limited number of wells based both on the given values for low, middle and upper yield are used as well as general experience of groundwater yields from the actual rock types and sediments.

It should be remembered that alluvium aquifers sometimes have unsatisfactory water quality.

Table 2.3.1. Estimated Wells Necessary for Future Town Water Supplies

City population and water demands		Indication of the necessary number of wells		
Town Population/ Year	Water demand (l/s) (Table 7.2)	Alluvium of high permeability. Medium yield estimated as 30 l/s	Fissured and carstic rocks of high permeability. Medium yield estimated as 6 l/s	Fissured rocks of medium permeability. Medium yield estimated as 3 l/s
10.000 capita/2015	18	1	3	6
10.000 capita/2025	25	1	5	9
20.000 capita/2015	36	2	6	12
20.000 capita/2025	50	2	8	17
50.000 capita/2015	90	3	15	Groundwater supply seems not to be realistic
50.000 capita/2025	125	5	21	
100.000 capita/2015	180	6	Groundwater supply seems not to be realistic	
100.000 capita/2025	250	9		
500.000 capita/2015	900	30*		
500.000 capita/2025	1250	42*		

* For larger towns it is hardly realistic to drill 30 or 40 wells in these aquifers. It is more reasonable to search for the localities with maximum permeability and/or to use the alluvium as a filter for infiltrated water at a part of a treatment process for drinking water.

2.3.8 The River Basins

2.3.8.1 Basin 1 Lubinda

In the Lubinda basin there are mainly Quaternary sediments and sedimentary rocks of marine origin and varying degree of consolidation (sand, clay, claystones, and laterites). In the hydrogeological map of Angola the water yield of these rocks are said to be rather small, 1 l/s as an average, but the yield is sometimes increasing with depth. The thickness of the Quaternary sediments is unknown, and underlaying Tertiary or Cretaceous aquifers could cause the increase in water yield. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably a misinterpretation.

Occurrences of alluvial deposits to the south could give large amounts of water, but the groundwater here is probably saline. In this basin groundwater could probably only give supply to villages in rural districts. Filtration of water in the alluvium could perhaps be used as part of a water treatment process for large populations.

2.3.8.2 Basin 2 Chiloanga

In the northeast part of Chiloango basin the average water yield of the fissured sedimentary rocks is supposed to be high (6 l/s). In the central part there are fissured and sedimentary rocks of medium water yield (3 l/s).

To the south there are mainly Quaternary sediments and sedimentary rocks of marine origin and varying degree of consolidation (sand, clay, claystones, and laterites). In the hydrogeological map of Angola the water yield of these rocks is said to be rather small, 1 l/s as an average, but the yield sometimes increases with depth. The thickness of the Quaternary sediments is unknown, and the increase in water yield could be caused by underlying Tertiary or Cretaceous aquifers. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably a misinterpretation.

Along Rio Chiloanga there are recent alluvial sediments of high groundwater potential. However, along the lower part of the river the groundwater is probably saline.

In the northeastern part of this basin groundwater from fissured rocks could supply both villages and towns of a size of 10 to 20.000 inhabitants. In the southwestern areas groundwater could probably only supply villages in rural districts unless freshwater is found in the alluvium. Filtration of water in the alluvium could perhaps be used as one element in a water treatment process.

2.3.8.3 Basin 3 Lulondo

In the Lulondo basin there are mainly Quaternary sediments and sedimentary rocks of marine origin and varying degree of consolidation (sand, clay, claystones, and laterites). In the hydrogeological map of Angola the water yield of these rocks is said to be rather small, 1 l/s on average, but the yield sometimes increases with depth. The thickness of the Quaternary sediments is unknown, and the increase in water yield could be caused by underlying Tertiary or Cretaceous aquifers. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably a misinterpretation.

Some coastal sediments probably contain saline groundwater. In this basin groundwater could probably only supply villages in rural districts.

2.3.8.4 Basin 4 N'Hama

In the basin of N'Hama there are mainly Quaternary sediments and sedimentary rocks of marine origin and varying degree of consolidation (sand, clay, claystones, and laterites). In the hydrogeological map of Angola the water yield of these rocks is said to be rather small, 1 l/s on average, but the yield sometimes increases with depth. The thickness of the Quaternary sediments is unknown, and the increase in water yield could be caused by underlying Tertiary or Cretaceous aquifers. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably a misinterpretation.

In the area south of the town of Cabinda, large areas of coastal sediments probably contain saline groundwater. In this basin groundwater could probably only supply villages in rural districts.

2.3.8.5 Basin 5 Zaire

The Angolan part of the Zaire basin is one of the largest river basins in Angola and most of the main rock groups of the country are represented here. To the west in the Soyo municipality of the Zaire province there are Mesozoic and Cenozoic sedimentary rocks and sediments of marine facies. In the hydrogeological map of Angola the water yield of these rocks is said to be rather small, 1 l/s on average, but the yield sometimes increases with depth. The thickness of the Quaternary sediments is unknown, and the increase in water yield could be caused by underlying Tertiary or Cretaceous aquifers. Based on the maps from the FRIEND project an average water yield of 3 l/s could be more reasonable, but this is probably a misinterpretation.

East of the this area, in the Nóqui municipality, there are Precambrian rocks, both granites and gneissic rocks of low groundwater potential, and volcanic and associated rocks that commonly give a higher yield (3 l/s on average). In the M'Banza Congo and Cuimba municipalities there are mainly sedimentary rocks of the Pan-African orogen with a high average water yield of probably some 6 l/s. In the western part of the basin sedimentary rocks of the Pan-African orogen are also found as a belt running southwards through the Uige and Malanje provinces. The average water yield of these rocks is said to be lower, probably 3 l/s.

In the eastern part of the Uige and northeastern part of the Malanje provinces there are mainly rocks of Upper Cretaceous to Quaternary age. The groundwater potential of these rocks is not well known, and according to the hydrogeological map the average yield is no more than 1 l/s. According to the FRIEND project a rather high water yield (probably 3 l/s on average) is obtained in highland areas from porous aquifers in the upper part of this sedimentary sequence, while Cretaceous rocks in valleys and lowland areas give much less water. We believe this is a misinterpretation.

In the valleys of Rio Cuango and Rio Lui along the eastern borders of the Uige and Malanje provinces there are also older Mesozoic rocks. These rocks are also found in the eastern part of the Lunda Norte province. The groundwater potential is reported to be low. However, as the rocks obviously are not detailed mapped, this is probably too simple a conclusion. In some of the valleys in the eastern part of the Luanda Norte province, especially in an area east and northeast of the town of Cuango, the rocks are eroded down to the Precambrian basement. According to the geological maps the complex of Achaean gabbro-norites and charnocites are represented here, as well as younger rocks of the Pan-African orogen. These Precambrian rocks probably have a higher groundwater potential.

The rest of the western part of the basin in the Luanda Norte and the southern part of Luanda Sul provinces are covered with Tertiary and Quaternary continental sediments described as Kalaharian sand in the hydrogeological map. The groundwater potentials of these areas is unknown but probably low.

In the eastern part of the Luanda Norte province and in the northern part of the Luanda Sul province the river valleys are eroded down through the younger sedimentary rocks, and here several Precambrian rocks are exposed. Some of these could be quite good aquifers.

Along Rio Zaire and the tributary rivers there are large alluvial deposits, and probably a lot more than those marked in geological and hydrogeological maps. These recent sediments could probably supply large towns with groundwater if the quality is good enough. Groundwater from recent alluvial deposits could perhaps be the main water source for most of the population living in the river valleys.

Groundwater form fissured rock could supply villages and smaller towns in part of the Noqi municipality and even lager populations in the M'Banza Congo and Cuimba municipalities. The smaller areas of fissured rocks in Malanje and valleys in Luanda Norte and north-eastern parts of Luanda Sul provinces could probably also supply water to villages and towns with as much as 10.000 inhabitants.

In the areas covered with Cenozoic rocks groundwater probably could only supply villages in rural districts.

2.3.8.6 Basins 6-9 Zombo, Lulea, Luculo and Janube

In these basins there are mainly Quaternary sediments and sedimentary rocks of marine origin and varying degrees of consolidation (sand, clay, claystones, and laterites). In the hydrogeological map of Angola the water yield of these rocks is said to be rather small, 1 l/s on average, but the yield sometimes increases with depth. The thickness of the Quaternary sediments is unknown, and the increase in water yield could be caused by underlying Tertiary or Cretaceous aquifers. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably a misinterpretation.

In these basins groundwater could probably supply only villages in rural districts.

2.3.8.7 Basin 10 Lucunga

West of Rio Lucunga, and also east of the southern part of the river, there are Cretaceous rocks. In the hydrogeological map of Angola the rocks west of the river are indicated to have a secondary porosity caused by fractures, while those to the south are said to have a primary porous permeability. Neither the fractured nor the porous rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably a misinterpretation.

East of this zone there are mainly acidic and gneissic rocks with a low groundwater potential. In the eastern part of the basin there is a small area of fissured and carstic sedimentary rocks of the Pan-African orogen (quartzites, limestones etc.) with a medium or high medium water yield (average yield estimated to 3 to 6 l/s).

Along Rio Lucunga there are recent alluvial sediments of high groundwater potential. However, along the lower part of the river the groundwater is probably saline, and parts of the river could be dry in seasons of low precipitation.

The area seems to be sparsely populated, and groundwater could probably supply all the people living in the villages and rural districts of the Lucunga basin. However, in the gneissic and granitic rocks some unsuccessful boreholes could be expected.

The sedimentary rocks of the Pan-African orogen are probably the only rocks that could supply groundwater to small towns.

2.3.8.8 Basin 11 M'Bridge

In a rather small area near the coast there are Cretaceous fractured and carstic rocks, probably of low or medium water yield. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable, but this is probably too much, and the evaluation is probably caused by a misinterpretation. East of this zone there is a belt of mainly acidic and gneissic rocks with a low groundwater potential. In the eastern and largest part of the basin there are fissured and carstic sedimentary rocks of the Pan-African orogen (quartzites, limestones etc.) with a medium or high water yield (average yield estimated to be 3 to 6 l/s).

Along Rio M'Bridge there are recent alluvial sediments of high groundwater potential. However, the groundwater in alluviums along the lower part of the river is probably saline.

According to the present knowledge of the groundwater potential there should be enough groundwater to supply the population in most of the eastern part of this basin. In the gneissic and granitic rocks some unsuccessful boreholes should be expected, and there will probably not be enough groundwater for medium sized villages unless a large number of wells are drilled. To the west there will probably be too little water to supply the city at the mouth of Rio M'Bridge, unless freshwater is found in the alluvium. Filtration of water in the alluvium could perhaps be used as one part of a water treatment process.

2.3.8.9 Basin 12 Sembo

In most of the Sembo basin there are gneissic and granitic rocks with a low groundwater potential. Only in a small eastern part are there sedimentary and volcanic rocks of the Pan-African orogen that give a medium to high water yield (estimated as 3 to 6 l/s as an average).

The coastal delta of Rio Sembo probably contains only saline water.

Except for in the eastern part, groundwater in this basin could probably only supply small populations in rural districts.

2.3.8.10 Basin 13 Loge

In the western part of the Loge basin there are mainly acidic and gneissic rocks with a low groundwater potential. In the eastern and largest part of the basin there are fissured and carstic sedimentary rocks of the Pan-African orogen (quartzites, limestones etc.) with a medium or high water yield estimated as 3 to 6 l/s on average.

The coastal delta of Rio Loge probably contains only saline water.

In the eastern part of this basin groundwater from fissured rocks could supply both villages and towns of 10 to 20.000 inhabitants. In the western part of this basin groundwater could probably supply only small populations in rural districts, unless freshwater is found in the alluvium. Filtration of water in the alluvium could perhaps be used as one part of a water treatment process.

2.3.8.11 Basin 14 Uezo

The rocks of this basin are mainly acidic and gneissic rocks with a low groundwater potential. In the eastern part of the basin there is an area of fissured volcanic rocks of the Pan-African orogen with a medium water yield, estimated to 3 l/s on average.

The coastal delta of Rio Uezo probably contains only saline water.

The area seems to be sparsely populated; and groundwater could probably supply all the people living in the rural districts. However, in the gneissic and granitic rocks some unsuccessful boreholes could be expected.

2.3.8.12 Basins 15-16 Onzo and Lifune

Along the coast of these basins there are Cretaceous rocks described as sand, silt and claystones with beds of limestones, marl and gypsum. Neither the fractured nor the porous rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. The maps from the Friend project indicate an average medium water yield of 3 l/s caused by the primary, intergranular porosity in a Cretaceous sandstone, but this is probably a misinterpretation.

In the eastern part of the basin there is an area of fissured volcanic rocks of the Pan-African orogen with an estimated average water yield of 3 l/s.

The coastal deltas of Rio Onzo, Rio Ió, and Rio Lifune probably give possibilities for groundwater supplies, but could contain only saline water. The run-off in the dry seasons is probably low and if the rivers dry up, the groundwater may vanish as well.

These basins seem to be sparsely populated, and groundwater could probably supply all people living in smaller and medium-sized villages in the rural districts. However, in the gneissic and granitic rocks some unsuccessful boreholes should be expected.

To the east even small towns could probably be supplied by groundwater.

2.3.8.13 Basins 17-18 Dande and Bengo

In the western part of these basins there are Cretaceous and younger rocks, and east of these there are old Precambrian migmatites. To the east there is a zone of volcanic rocks followed by a zone of sedimentary rocks that overly the older Precambrian basement. Both of these belong to the Pan-African orogen.

The youngest Quaternary sediments and Mesozoic rocks are found west of a NW-SE striking fault striking in the direction NW-SE near Caxito town. Neither the fractured nor the porous rocks are described as good aquifers, but there could be layers of sandstones and limestones with better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable in some of these rocks, but this is probably a misinterpretation.

The Precambrian migmatites in the central part of the basins also have a low groundwater potential.

The rocks of the Pan-African orogen are heavily fissured, and in the eastern part carstic limestones are reported. As a result the average water yields are relatively high, estimated as 3 l/s in the volcanics and 6 l/s in the sedimentary rocks.

Along Rio Dande and Rio Bengo there are recent alluvial sediments of high groundwater potential. However, the groundwater in the lower part of these alluviums is probably saline.

In the eastern part of these basins groundwater from fissured rocks could supply both villages and towns of more than 20,000 inhabitants, but for the largest populations a large number of wells would have to be drilled, and the transport systems for water could be rather expensive.

In the area of Precambrian migmatitic rocks and in the areas of Mesozoic and younger rocks groundwater could probably supply only small populations in rural districts.

If good quality freshwater is found in the alluvium along the lower parts of Rio Dande or Rio Bengo, groundwater supply of large towns could be possible. Filtration of water in the alluvium could also perhaps be used as one part of a water treatment process.

2.3.8.14 Basin 19 Cuanza

The Cuanza basin is one of the largest river basins in Angola and most of the main rock groups of the country are represented here.

In the lowland in the western part of this basin there are Mesozoic and Cenozoic sedimentary rocks and sediments of marine facies. Neither the fractured nor the porous rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in some places a little more could be expected. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable in some of these rocks, but this is probably a misinterpretation. Thus probably only villages and inhabitants of rural districts can be supplied by groundwater from these aquifers.

East of the town of Dondo there are old Precambrian rocks (gabbros, norites and charnocites) and younger Precambrian gneissic and granitic rocks covering large areas. The granites and gneissic rocks with low groundwater yield are found in the western part of the basin. The basic rocks and the ultrametamorphic charnocites with an average yield estimated to 3 l/s occur in the central part. In this central part of the basin due east of Dondo there are also sedimentary rocks of the Pan-African orogen. The latter mentioned rocks are heavily fissured, and based on data from the FRIEND project the average water yield could be estimated to 6 l/s.

The southern and eastern parts of the basin are mainly covered with continental sediments and sedimentary rocks of Mesozoic and Cenozoic age. These areas are marked as Kalaharian sand in the maps, and the groundwater potential is said to be low or unknown. An average yield of 1 l/s is estimated in the legend of the hydrogeological map of Angola. There are also a few outcrops of Precambrian rocks in these areas. In the eastern part of the basin these Precambrian rocks are mainly sedimentary rocks of the Pan-African orogen, while older granitic and gneissic rocks are more common to the south. As mentioned above, the water yield of the granitic rocks are rather low, while the rocks of the Pan-African orogen may be quite good aquifers.

If the assumed high water yield of the rocks of the Pan African orogen is correct, groundwater from fissured rocks could supply towns of up to 20.000 inhabitants in some central parts of the basin. The basic rocks and the ultrametamorphic charnocites with an average yield estimated to 3 l/s could supply villages and smaller towns.

The granitic rocks in the western and southern part of the basin are said to have a lower groundwater potential, with an average yield of 1 l/s, and a drilling success rate of no more than 50%. However, villages with low water demands in rural districts could be supplied with groundwater from these rocks.

Along Rio Cuanza there are large alluvial deposits, and probably a lot more than those marked on the geological and hydrogeological maps. These recent sediments could probably supply large towns with groundwater if the quality is good enough. The river is tidal up to about 70 km from the coast. The groundwater in the alluvium plains along the lower part of the river is thus probably saline.

2.3.8.15 Basins 20-24 Perdizes, Sangando, Cabo Ledo, Mengueje, and Benbeje

In the Perdizes basin there are mainly Quaternary sediments and sedimentary rocks of marine origin and varying degree of consolidation (sand, clay, claystones, and laterites). According to the hydrogeological map of Angola the water yield of these rocks is rather small, 1 l/s on average. Based on the maps from the FRIEND project an average water yield of 3 l/s in the areas of Quaternary sediments seems more reasonable but this is probably a misinterpretation.

In this basin groundwater probably could supply only villages in rural districts.

2.3.8.16 Basin 25 Longa

The lower part of the Longa basin lies in the area of Mesozoic and Cenozoic sedimentary rocks. Most of the surface rocks are Upper Cretaceous and Lower and Middle Tertiary. Neither the fractured nor the porous rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. Based on the maps from the FRIEND project an average water yield of 3 l/s seems more reasonable in some of these rocks, but this is probably a misinterpretation.

In the eastern part of the basin there are mainly granitic and gneissic Precambrian rocks with low groundwater potential and an average water yield of no more than 1 l/s. Some areas with Precambrian sedimentary rocks occur, and in these rocks an average water yield of 3 l/s is reported.

Along the Rio Longa and tributary rivers there are large alluvial deposits, and probably a lot more than those marked in geological and hydrogeological maps. These recent sediments could probably supply large towns with groundwater if the quality is good enough. The river is influenced by the tidal water sveral km from the coast. The groundwater in the alluvium plains along the lower part of the river is thus probably saline.

In most of the other areas of this basin only villages in rural districts can be supplied by groundwater. Some Precambrian fissured rocs in the south-eastern part of the basin could give water to small towns.

2.3.8.17 Basins 26-29 Cutanga, Quiteta, Catata, and Tortombo

In the Cutanga basin neither the fractured nor the porous rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. Based on the maps from the FRIEND project an average water yield of 3 l/s in the areas of Quaternary sediments and in some of the rocks seems more reasonable but this is probably a misinterpretation.

In this basin groundwater could probably supply only villages in rural districts.

2.3.8.18 Basin 30 Queve

The rocks of the Queve basin are mainly Precambrian granitic and gneissic rocks with a low groundwater potential, an average yield of 1 l/s and a drilling success rate of no more than 50%. However villages with low water demands in rural districts could be supplied with groundwater from these rocks.

Most of the Precambrian rocks in the southern and eastern part of the basin are covered with continental sediments and sedimentary rocks mainly of Cenozoic age. These areas are marked as Kalaharian sand in the maps, and the groundwater potential is said to be low or unknown. An average yield of 1 l/s is estimated in the legend of the hydrogeological map of Angola. There are however a few outcrops of Precambrian rocks in these areas, and some of them belong to a series of old sediments that are supposed to have a higher yield than the rest of the Precambrian rocks in the area. An average yield of 3 l/s is estimated.

The eastern area of the basement is densely populated, but in most of the area groundwater can supply only villages and inhabitants in rural districts. Small towns can perhaps obtain groundwater enough from the above-mentioned outcrops of Precambrian sedimentary rocks.

Near the coast to the west there are Mesozoic and Cenozoic sedimentary rocks and sediments of marine facies. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. Based on the maps from the FRIEND project an average water yield of 3 l/s in the areas of Quaternary sediments seems more reasonable but this is probably a misinterpretation.

Large alluvial deposits are shown on the maps along the Rio Oueve, Rio Caninda, and Rio Cussol. There are probably also a lot of smaller alluvial deposits that are not shown in the maps. These recent sediments could probably supply large towns with groundwater if the quality is good enough. The rivers are probably tidal up to several kilometres from the coast. The groundwater in the alluvium plains along the lower part of the river is thus probably saline.

2.3.8.19 Basin 31 N'Gunza

Most of the rocks in the N'Gunza basin have a low groundwater potential. Along the coast there are Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part there are mainly Precambrian granites and gneisses with a low groundwater potential. An average yield of 1 l/s or less, and a low drilling success rate could be expected. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells will occur.

In the western part of the Precambrian rocks there is an area of Mesozoic volcanic rocks that is supposed to be a rather good aquifer with an estimated average yield of 3 l/s. Further to the east there are also areas of old Precambrian sediments that are supposed to have an average yield of the same size. These rocks could supply groundwater to towns with a few thousand inhabitants.

In the eastern part of the basin a small area of Quaternary alluvial sediments is shown in the map, and there are probably more along Rio N'Gunza. These recent sediments could probably supply large towns with groundwater if the quality is good enough.

2.3.8.20 Basin 32 Quicombo

Along the coast of the Quicombo basin there are Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part there are mainly Precambrian granites and gneisses with a low groundwater potential. These rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

In the western part there are two areas of Mesozoic volcanic rocks that are supposed to be a rather good aquifer with an estimated average yield of 3 l/s. These rocks could supply groundwater to towns with a few thousand inhabitants.

Further to the east there is an area of recent alluvial sediments. The maps from The FRIEND project indicate a relatively low water yield of 3 l/s, but according to the hydrogeological map of Angola the yield could be higher, and groundwater supply for towns could be possible.

2.3.8.21 Basin 33 Dui

The groundwater potential of most of the rocks in the small Dui basin are low. Along the coast there are Lower and Middle Cretaceous sedimentary rocks. In the eastern part there are granitic gneisses and migmatites. All these rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

There is also an area of Mesozoic volcanic rocks in the basin that is supposed to be a rather good aquifer with an estimated average yield of 3 l/s. These rocks could supply groundwater to towns with a few thousand inhabitants.

There are alluvial sediments along the river. The water yield is probably high in the wet seasons, but the river and probably also the alluvium are dry during most of the year.

2.3.8.22 Basin 34 Evale

Most of the rocks in the Evale basin have a low groundwater potential. Along the coast there are Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part there are mainly Precambrian granites and gneisses with a low groundwater potential. These rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful boreholes should be expected.

In the middle of the basin there is a North-South running belt of Mesozoic volcanic rocks that is supposed to be a rather good aquifer with an estimated average yield of 3 l/s. These rocks could supply groundwater to towns with a few thousand inhabitants.

At the southern end of the volcanic belt there are alluvial deposits supposed to have a rather high water yield in the wet seasons, but the river and probably also the alluvium could be dry for most of the year.

2.3.8.23 Basin 35 Balombo

Most of the rocks in the Balombo basin have a low groundwater potential. Along the coast there are Lower and Middle Cretaceous sedimentary rocks. None of these are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in some places a little more could be expected. In the eastern part there are mainly Precambrian granites and gneisses with a low groundwater potential. These rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

There are alluvial sediments both along Rio Balombo and its tributary rivers. Two of them are shown in the geological and hydrogeological maps. The water yields could be quite large here. Aquifers in alluvial sediments have the largest groundwater potential in the basin, and some of them could probably supply towns with several thousand inhabitants. However, there is no information about the water situation in the dry season.

2.3.8.24 Basin 36 Cuhula

Most of the rocks in the Cuhula basin have a low groundwater potential. Along the coast there are Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with better potential. An average water yield of 1 l/s and a little more in places could be expected. In the eastern part there are mainly Precambrian granites and gneisses with a low groundwater potential. These rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However, villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

2.3.8.25 Basin 37 Cubal Da Hanha

Most of the rocks in the Cubal Da Hanha basin have a low groundwater potential. Along the coast there are Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part there are mainly Precambrian granites and gneisses with a low groundwater potential. These rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

Along the coast there are some shore deposits, and one well with water yield between 1 and 5 l/s is reported. There is probably a risk of saline intrusion after long time pumping in this coastal zone.

2.3.8.26 Basin 38 Catumbela

Along the coast of the Catumbela basin there are Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In most of the basin east of the narrow zone of Mesozoic rocks there are Precambrian granites and gneisses. These rocks are supposed to have an average yield of 1 l/s or less, and a low drilling success rate. However, villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

Most easterly in the basin there are several outcrops of the Precambrian sedimentary sequence that are supposed to give an average yield of 3 l/s. Small towns could probably be supplied from these rocks.

In the maps large alluvial deposits are shown along Rio Catumbela and tributary rivers, both near the outlet to the sea and in the upper part of the rivers. There are probably also a lot of smaller alluvial deposits that are nor shown in the maps. These recent sediments could probably supply large towns with groundwater if the quality is good enough. The groundwater near the river mouth could be saline.

2.3.8.27 Basin 39 Cavaco

Most of the rocks in the Cavaco basin have a low groundwater potential. Along the coast there are Lower and Middle Cretaceous and lower Tertiary sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part there are mainly Precambrian granites and gneisses. The groundwater potentials of these rocks is supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater from these rocks, but some unsuccessful wells should be expected.

In the eastern part of the basin there are Precambrian dolerites, partly occurring as very large dikes, that are supposed to be quite good aquifers. Average yields of 3 l/s may be obtained.

The alluvial sediments along the lower part of Rio Cavqaco could be a good aquifer with a large groundwater potential, and have the possibility to supply larger towns if they contain groundwater in the dry season. Along the lower part of the river, however, the alluvium probably contains saline water or there will at least be a risk of getting salt water after long time pumping of wells.

2.3.8.28 Basins 40-45 Curinge, Uche, Mormolo, Pima, Ndungo and Calumbolo

Along the coast in these six small basins there are Lower and Middle Cretaceous and lower Tertiary sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with greater groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. To the east there are Precambrian granitic gneisses. The groundwater potentials of most of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. However, villages with low water demands in rural districts could be supplied with groundwater, but some unsuccessful wells should be expected.

All these basins are situated in a large delta area, where alluvial deposits are common. In the geological and hydrogeological maps alluvial sediments are shown only along some of the river courses in the delta. In the maps from the FRIEND project the groundwater potential is said to be high in most of the area. Thus the possibilities for good aquifers cannot be ruled out, but probably most of the water from the lower part of the delta has a high saline content and probably both the water in the river and all fresh groundwater vanish in the dry seasons.

According to the hydrogeological map a high mineral content is commonly found in the groundwater in the lower part of the Ndungo and Calumbolo basins.

2.3.8.29 Basin 46 Coporolo

Along the coast of the Coporolo basin there are Lower and Middle Cretaceous sedimentary rocks. At the outlet of Rio Coporolo there are alluvial sediments in a large delta. The potential for groundwater supplies could have been large, but the groundwater in this coastal zone is probably saline. According to the hydrogeological map of Angola the mineral content increases with depth.

In the eastern part of the basin there are mainly Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. However villages with low water demands in rural districts could be supplied with groundwater, but some unsuccessful wells should be expected.

In the middle, southern and eastern parts of the basin there are dolerites partly occurring as very large dikes. In the middle of the basin there is a rather large area of basic metamorphic rocks and most easterly there are also outcrops of metasediments. An average yield of 3 l/s is estimated for all these Precambrian rocks, so water supply for villages and small towns could be obtained.

In both the geological and hydrogeological maps large alluvial deposits are shown along Rio Coporolo and tributary rivers in the upper part of the basin. There are probably also a lot of smaller alluvial deposits that are not shown in the maps. These recent sediments could probably supply large towns with groundwater, if the quality is good and the alluviums contain water in the dry seasons.

2.3.8.30 Basin 47 Nhime

Along the coast of the Nhime basin there are mainly Lower and Middle Cretaceous sedimentary rocks. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places more could be expected. In the southern part of the basin there are mainly Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. In this area groundwater could probably supply only villages in rural districts.

Alluvial sediments are shown along the lower part of Rio Nhime In the maps. Both the river and the alluvium could be dry most of the year. According to the hydrogeological map of Angola all groundwater near to the coast has a high mineral content - probably too high to be used as drinking water. Therefore only villages with low water demands in rural districts could be supplied with groundwater in the southern part of the basin.

2.3.8.31 Basin 48 Lua

Along the coast of the Lua basin there are mainly Lower and Middle Cretaceous and Lower Tertiary sedimentary rocks. The groundwater potential is probably low, and according to the hydrogeological map of Angola, most of the groundwater in this area has a too high mineral content to be used as drinking water.

In the southeastern part of the basin there are mainly Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. In this area groundwater probably could supply only villages in rural districts.

There are alluvial sediments both along the upper and lower part of the Rio Lua. The alluviums along the lower part of the river are probably saline. Those in the upper part of the basins should have potential for supplying several inhabitants, but their water capacity in the dry seasons are unknown and probably low.

2.3.8.32 Basin 49 Equimina

The bedrock in the main part of this basin consists of Precambrian granitic and gneissic rocks. An area of carbonatitic rocks is also found. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. In this area groundwater could probably supply only villages in rural districts.

The alluvial sediments along the lower parts of the river are probably dry or contain saline groundwater, and according to the hydrogeological map of Angola, the groundwater in the Mesozoic rocks near to the coast the have a high mineral content.

2.3.8.33 Basin 50 Chamanga

The bedrock in the main part of this basin consists of Precambrian granitic and gneissic rocks. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. Therefore only villages with low water demands in rural districts could be supplied with groundwater from these rocks.

Along the coast of the Chamanga basin there is a small zone of Cretaceous and Tertiary sedimentary rocks. According to the hydrogeological map of Angola the mineral content of the groundwater in this rocks is so high that its use as drinking water is probably not possible.

2.3.8.34 Basin 51 Calongolo

The rocks in the Calongolo basin are mainly Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. In this area groundwater could probably supply only villages in rural districts.

There are alluvial sediments along some of the upper parts of Rio Calongolo that should have potential as aquifers, but their water capacities in the dry season are unknown and probably low.

Along the coast of the Chamanga basin there is a small zone of Cretaceous and Tertiary sedimentary rocks. In the hydrogeological map of Angola it is indicated that the groundwater both in the largest alluvial deposit and in the Tertiary and Cretaceous rocks could have too high a mineral content to be used as drinking water.

2.3.8.35 Basins 52-55 Lucipo, Catara, Cangala, and Capim

The rocks of these basins are mainly Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. Groundwater from these rocks could probably supply only villages in rural districts. The mineral content in the groundwater along the coast is probably too high to be accepted in drinking water.

There are alluvial sediments in the western part of the area that should have potential for supplying groundwater, but their water capacity in the dry seasons are unknown, and according to the hydrogeological map of Angola their mineral content is probably too high to be suitable for drinking water.

2.3.8.36 Basin 56 Chileva

The rocks of the Chileva basin are mainly Precambrian granites and gneisses. The groundwater potential of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. In this basin groundwater probably could supply only villages in rural districts.

The mineral content in the groundwater along the coast is probably too high to be acceptable as drinking water.

2.3.8.37 Basins 57-58 Carunjamba and Inamagano

The bedrock in the main part of these basins consists of Precambrian granitic and gneissic rocks. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. Groundwater from these rocks could probably only supply villages in rural districts.

A NNW-SSE running fault line and a large doleritic dyke of the age of the Pan-African orogen cross the eastern parts of the basins. There are also some smaller dikes of the same age. Water wells in these structures are supposed to have a possible groundwater yield of 3 l/s on average, and could give water supply to villages and small towns.

Along the coast there are Mesozoic and Cenozoic rocks and Quaternary sediments with different groundwater potentials. In general the groundwater in this southern coastal area has a high mineral content caused by the low annual rainfall. High mineral content can also be found in the western part of the Precambrian rocks. These waters are probably not usable as drinking water.

The groundwater in the alluvial deposits along the lower part of the rivers is probably saline, and there will always be a risk of an unacceptable increase in the saline content when pumping a well for a long time in this area. The alluviums can be without water in the dry seasons.

2.3.8.38 Basin 59 Mapungo

In about 2/3 of this basin close to the coast there are Mesozoic rocks and some Quaternary rocks and sediments. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part of the basin there are Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. Groundwater from these rocks could probably supply only villages in rural districts.

According to the hydrogeological map of Angola both the groundwater in the Mesozoic rocks and in the western part of the Precambrian rocks has a high mineral content, probably too high to be used as drinking water.

2.3.8.39 Basin 60 Sao Nicolau

The bedrock in the main part of this basin consists of Precambrian granitic and gneissic rocks. The groundwater potentials of these rocks is supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. Groundwater from these rocks could probably supply only villages in rural districts.

There are two small areas of fissured rocks with a higher groundwater potential in the basin. In the southwest, along the border to the Mutiambo basin, there are old Precambrian sediments. Wells in these metasediments are supposed to have an average groundwater yield of 3 l/s, and could give water supply to villages and small towns. In the south-eastern end the Sao Nicolau basin touches the northern part of the rocks of the Pan-African orogen that are situated in an large area south and west of Lubango. These rocks are known to have a high water yield, probably as much as 6 l/s on average.

Several doleritic dikes of the age of the Pan-African orogen are found in the eastern part of this basin. Water wells in these rocks are supposed to have a possible groundwater yield of 3 l/s on average, and could give water supply to villages and small towns.

Along the coast there are Mesozoic and Cenozoic rocks and Quaternary sediments with low groundwater potentials, and a small area of volcanic rocks with a better yield. In general the groundwater in this southern coastal area has a high mineral content caused by the low annual rainfall. The mineral content is probably too high to be acceptable as drinking water. High mineral content can be found in the western part of the Precambrian rocks also.

The groundwater in the alluvial deposits along the lower part of the rivers is probably saline, and there will always be a risk of an unacceptable increase in the saline content when pumping a well for a long time in this area.

2.3.8.40 Basin 61 Salgada

There are Mesozoic rocks and some Quaternary rocks and sediments in about two thirds of this basin close to the coast. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. In the eastern part of the basin there are Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

According to the hydrogeological map of Angola the groundwater in this entire basin has a high mineral content, probably too high to be used as drinking water.

2.3.8.41 Basin 62 Chilulo

In the western part of the Chilulo basin close to the coast there are Mesozoic rocks and some Quaternary rocks and sediments. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected. There is also a small area of volcanic rocks with a higher water yield. There are Precambrian granites and gneisses in most of the basin. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

According to the hydrogeological map of Angola the groundwater both in the Mesozoic rocks and in the western part of the Precambrian rocks has a high mineral content, probably too high to be used as drinking water.

2.3.8.42 Basin 63 Caniço

In about three quarters of this basin close to the coast there are Mesozoic rocks and some Quaternary rocks and sediments. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential.

An average water yield of 1 l/s and in places a little more could be expected. In the eastern part of the basin there are Precambrian granites and gneisses. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

According to the hydrogeological map of Angola the groundwater in this entire basin has a high mineral content, probably too high to be used as drinking water.

2.3.8.43 Basin 64 Mutiambo

The bedrock in the main part of this basin consists of Precambrian granitic and gneissic rocks. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

There are also some areas of old Precambrian sedimentary rocks with a higher groundwater potential, mainly along the borders of the basin. Water wells in this metasediments are supposed to have a possible groundwater yield of 3 l/s on average, and could give water supply to villages and small towns.

Along the coast there are Mesozoic and Cenozoic rocks and Quaternary sediments with low groundwater potentials. In general the groundwater in this southern coastal area have a high mineral content caused by the low annual rainfall, probably too high to be accepted in drinking water. High mineral content can be found in the western part of the Precambrian rocks as well. There will always be a risk of an unacceptable increase in the saline content when pumping a well for a long time in this area.

There are alluvial sediments in the western part of the area that should have potential for supplying groundwater, but their water capacity in the dry seasons are unknown, and according to the hydrogeological map of Angola their mineral content is probably too high to be suitable for drinking water.

2.3.8.44 Basin 65 Muchimanda

In most of the Muchimanda basin there are Precambrian granites and gneisses. The groundwater potentials of all of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

In the western part of the basin close to the coast there are Mesozoic rocks and some Quaternary rocks and sediments. None of these rocks are described as good aquifers, but there could be layers of sandstones and limestones with some better groundwater potential. An average water yield of 1 l/s and in places a little more could be expected.

According to the hydrogeological map of Angola the groundwater both in the Mesozoic rocks and in the western part of the Precambrian rocks has a high mineral content, probably too high to be used as drinking water.

2.3.8.45 Basin 66 Giraul

The bedrock in the main part of this basin consists of different groups of Precambrian rocks. Most of the northern and eastern parts of the basin consist of granitic and gneissic rocks. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. Groundwater from these rocks could probably supply only villages in rural districts.

In the southern part of the basin and also in some areas to the east, there are old quartz schists. To the north there are areas of the same younger metasediments. The groundwater yield of both these rock groups is estimated to 3 l/s on average. Most easterly in the basin there are rocks of the Pan-African orogen. These rocks are known to have a high water yield, probably as much as 6 l/s on average. Groundwater supply for towns should be obtained from these rocks.

Several doleritic dikes of the age of the Pan-African orogen are found in the northeastern part of this basin. Water wells in these rocks are supposed to have a possible groundwater yield of 3 l/s on average, and could give water supply to villages and small towns.

Along the coast there are Mesozoic and Cenozoic rocks and Quaternary sediments with low groundwater potentials, and a small area of volcanic rocks with a better yield as well. In general the groundwater in this southern coastal area has a high mineral content, probably caused by the low annual rainfall. The mineral content is probably too high to be acceptable for drinking water. High mineral content can be found in the western part of the Precambrian rocks also. The groundwater in the alluvial deposits along the lower part of the Rio Giraul is probably saline, and there will always be a risk for an unacceptable increase in the saline content when pumping a well for a long time in this area.

2.3.8.46 Basin 67 Bero

The bedrock in the main part of this basin consists of different groups of Precambrian rocks. In most of the basin there are old quartz schists with and groundwater yield estimated to 3 l/s on average.

In parts of the basin, especially to the south and east, there are also outcrops of younger Precambrian granitic and gneissic rocks. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate. To the northeast and southeast there are rocks of the Pan-African orogen. These rocks are known to have a high water yield, probably as much as 6 l/s on average.

Along the coast there are Mesozoic and Cenozoic rocks and Quaternary sediments with different groundwater potentials. In general the groundwater in this southern coastal area has a high mineral content caused by the low annual precipitation. The mineral content is probably too high to be acceptable as drinking water.

High mineral content can be found in the western part of the Precambrian rocks also. There will always be a risk of an unacceptable increase in the saline content when pumping a well for a long time in the western part of this basin.

According to the reported groundwater yield of the rocks, groundwater could supply both villages and towns in this basin. In the western part of the basin, however, the annual precipitation is low and the potential evapotranspiration high. Thus the amount of available water could be less than expected.

2.3.8.47 Basin 68 Changulo

In the Changulo basin there are Quaternary sand and sandstones. According to the hydrogeological map of Angola the water yield is low, 1 l/s on average. In the maps from the FRIEND project an average yield of 3 l/s is indicated, but this is probably a misinterpretation.

In this area with a very low annual precipitation the groundwater has a high mineral content, and is probably not suitable for drinking water.

2.3.8.48 Basin 69 Subida Grande

In the Subida Grande basin most of the rocks are Quaternary sand and sandstones. According to the hydrogeological map of Angola the water yield is low, 1 l/s on average. In the maps from the FRIEND project an average yield of 3 l/s is indicated, but this is probably a misinterpretation.

In the eastern part there are Lower Tertiary rocks with a low groundwater potential. In this area with very low annual precipitation the groundwater has a high mineral content, and is probably not suitable for drinking water.

2.3.8.49 Basin 70 Metere

In the Metere basin there are mainly Lower Tertiary sedimentary rocks with a low groundwater potential. In a small area to the north there are Quaternary sediments, and the south part of the basin is inside the area of the Namibe desert.

In general the groundwater in this area has a high mineral content, and is probably not suitable for drinking water.

2.3.8.50 Basin 71 Flamingos

The eastern two-thirds of the Flamingos basin is situated in an area of Precambrian rocks, and the western part is in the area of the Namibe desert.

The groundwater in most of the basin has a high mineral content. The average yield of the quartz schists in the eastern part of the basin is estimated as 3 l/s in the maps, but due to the low precipitation the real water capacity in this area is unknown.

In general the groundwater in this area has a high mineral content, and is probably not suitable for drinking water.

2.3.8.51 Basin 72 Curoca

In the northwestern and the southern part of the basin there are Precambrian quartz schists. The groundwater yield of these rocks is elsewhere estimated to 3 l/s on average.

Furthest east the basin reaches into an old Precambrian complex that mainly consist of gabbroic rocks. The groundwater potential is considered to be relatively high, and the average yield is estimated to 3 l/s.

In the central part of the basin and in areas in the western parts there are granitic and gneissic rocks. The groundwater potential of these rocks is supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

In central eastern parts of the basin and in small areas to the south and west, there are sedimentary and volcanic rocks of the Pan-African orogen. The average water yield is estimated to 3-6 l/s with the highest yield in the volcanic rocks, and some less in basic intrusives such as norites and dolerites.

Towards the west the Rio Curora runs into the Namibe desert. Several of the fractured rocks in the Curora basin have an apparently high groundwater potential, and the water yield should be enough to supply both villages and smaller towns. However, in most of this basin there is a very low annual precipitation, and the actual groundwater potential here is unknown. In the western half of the basin the groundwater is known to have a high mineral content, and here it is hardly suitable for drinking water purposes.

2.3.8.52 Basin 73 Cunene

Along the northern border of the western part of the basin there are Precambrian quartz schists. The groundwater yield of thse rocks is elsewhere estimated to 3 l/s on average.

In the western part of the basin there is an old Precambrian complex mainly consisting of gabbroic rocks. The groundwater potential is considered to be relatively high, and the average yield is estimated to 3 l/s.

There are granitic and gneissic rocks in the area northeast of Lubango and in several outcrops in the northern and eastern parts. The groundwater potentials of these rocks are supposed to be low, with an average yield of 1 l/s or less, and a low drilling success rate.

In between the granitic rock areas to the north and east, there are also some outcrops of old Precambrian sedimentary rocks with a higher groundwater potential. Water wells in these metasediments are suppsed to have a possible groundwater yield of 3 l/s on average, and could give water supply to villages and small towns.

Along the northern border of the western part of the basin (west of the quartz schists mentioned above), and in an area south and west of Lubango, there are sedimentary and volcanic rocks of the Pan-African orogen. The average water yield is estimated to 3 to 6 l/s with the highest yield in the volcanic rocks, and somewhat less in basic intrusives such as norites and dolerites.

Most of the eastern and northern parts of the basin are covered with Tertiary and Quaternary sediments, called Kalaharian sand in the hydrogeological map. The groundwater potential of these sediments are unknown, but probably low.

Towards the west the Rio Cunene runs into the Namibe desert. Several of the fractured rocks in the Cunene basin have an apparently high groundwater potential, and the water yield should be enough to supply both villages and smaller towns. However there is very low annual precipitation in the southwestern part of the basin, and the actual groundwater potential here is unknown. In the western half of the basin the groundwater is known to have a high mineral content, and here it is hardly suitable for drinking water purposes.

2.3.8.53 Basin 74 Zambeze

Most of the eastern and northern parts of the basin are covered with Tertiary and Quaternary sediments, called Kalaharian sand in the hydrogeological map. The groundwater potential of these sediments is unknown. In the eroded river valleys Jurassic and Cretaceous rocks are exposed. Outcrops of Upper Cretaceous dolerites are also found. The groundwater potentials of these rocks are unknown, but dolerite dikes in the valleys should probably give the highest water yield.

To the northeast there are old Precambrian rocks of different (and partly unknown) origin, and also younger Precambrian rocks of the Pan-African orogen. The latter are known to have a rather high average water yield, ranging from 3 l/s in doleritic and associated rocks to 6 l/s in sandstones and limestones. An average yield of 3 l/s is also estimated for some of the older quartzites and conglomerates. The Precambrian rocks in part of the eastern area could supply groundwater to villages and small towns, but elsewhere in the basin large groundwater potentials should not be expected.

2.3.8.54 Basin 75 Cubango

Almost the entire Cubango basin is covered with Tertiary and Quaternary sediments, called Kalaharian sand in the hydrogeological map. The groundwater potential of these sediments is unknown. In the eroded river valleys Jurassic and Cretaceous rocks are exposed. The groundwater potentials of all these rocks and sediments are unknown, but probably low.

To the northwest there are outcrops of old Precambrian rocks of different origin. There are both granitic and gneissic rocks known to have a rather low average yield, and older metasediments and metavolcanic rocks supposed to have an average water yield of 3 l/s. These Precambrian rocks in parts of the northwestern area could supply groundwater to villages and small towns, but elsewhere in the basin large groundwater potentials should not be expected.

2.3.8.55 Basin 76 Cuando

Almost the entire Cuando basin is covered with Tertiary and Quaternary sediments, called Kalaharian sand in the hydrogeological map. In the eroded river valleys Jurassic and Cretaceous rocks are exposed. The groundwater potentials of these all these rocks and sediments are unknown, but probably low.

2.3.8.56 Basin 77 Cuvelai

Most of the Cuvelai basin is covered with Tertiary and Quaternary sediments, called Kalaharian sand in the hydrogeological map. The groundwater potential of these sediments are unknown. In the eroded river valleys Jurassic and Cretaceous rocks are exposed. The groundwater potentials of these all these rocks and sediments are unknown, but probably low.

To the northwest there are outcrops of old Precambrian rocks of different origin. There are both granitic and gneissic rocks known to have and rather low average yield and older metasediments and metavolcanic rocks supposed to have an average water yield, of 3 l/s. These Precambrian rocks in part of the northwestern area could supply groundwater to villages and small towns, but elsewhere in the basin large groundwater potentials should not be expected.

Table 2.3.2 Division of Hydrological Sub Basins in Angola

1. Division	2. Division	3. Division	Major Basin	Catchment Name
4	40	**1**	S.W.Coast	**Lubinda**
4	40	**2**	S.W.Coast	**Chiloango**
4	40	**3**	S.W.Coast	**Lulondo**
4	40	**4**	S.W.Coast	**Lucula**
4	43	**5**	Zaïre / Congo	**Zaire**
4	60	**6**	S.W.Coast	**Zombo**
4	60	**7**	S.W.Coast	**Luela**
4	60	**8**	S.W.Coast	**Lucolo**
4	60	**9**	S.W.Coast	**Sange**
4	60	**10**	S.W.Coast	**Lucunga**
4	60	**11**	S.W.Coast	**M'Bridge**
4	60	**12**	S.W.Coast	**Sembo**
4	60	**13**	S.W.Coast	**Loge**
4	60	**14**	S.W.Coast	**Uezo**
4	60	**15**	S.W.Coast	**Onzo**
4	60	**16**	S.W.Coast	**Lifune**
4	60	**17**	S.W.Coast	**Dande**
4	60	**18**	S.W.Coast	**Bengo**
4	60	**19**	S.W.Coast	**Cuanza**
4	60	**20**	S.W.Coast	**Perdizes**
4	60	**21**	S.W.Coast	**Sangando**
4	60	**22**	S.W.Coast	**Cabo Ledo**
4	60	**23**	S.W.Coast	**Mengueje**
4	60	**24**	S.W.Coast	**Tanda**
4	60	**25**	S.W.Coast	**Longa**
4	60	**26**	S.W.Coast	**Cutanga**
4	60	**27**	S.W.Coast	**Quiteta**
4	60	**28**	S.W.Coast	**Catata**
4	60	**29**	S.W.Coast	**Tortombo**
4	60	**30**	S.W.Coast	**Queve**
4	60	**31**	S.W.Coast	**N'Gunza**
4	60	**32**	S.W.Coast	**Quicombo**
4	60	**33**	S.W.Coast	**Dui**
4	60	**34**	S.W.Coast	**Evale**
4	60	**35**	S.W.Coast	**Balombo**
4	60	**36**	S.W.Coast	**Cuhula**
4	60	**37**	S.W.Coast	**Cubal Da Hanha**
4	60	**38**	S.W.Coast	**Catumbela**
4	60	**39**	S.W.Coast	**Cavaco**
4	60	**40**	S.W.Coast	**Curinge**
4	60	**41**	S.W.Coast	**Uche**
4	60	**42**	S.W.Coast	**Mormolo**
4	60	**43**	S.W.Coast	**Pima**
4	60	**44**	S.W.Coast	**Ndungo**
4	60	**45**	S.W.Coast	**Calumbolo**
4	60	**46**	S.W.Coast	**Coporolo**
4	60	**47**	S.W.Coast	**Nhime**
4	60	**48**	S.W.Coast	**Lua**
4	60	**49**	S.W.Coast	**Equimina**
4	60	**50**	S.W.Coast	**Chamanga**
4	60	**51**	S.W.Coast	**Calongolo**
4	60	**52**	S.W.Coast	**Lucipo**
4	60	**53**	S.W.Coast	**Catara**
4	60	**54**	S.W.Coast	**Cangala**
4	60	**55**	S.W.Coast	**Capim**
4	60	**56**	S.W.Coast	**Chileva**
4	60	**57**	S.W.Coast	**Carunjamba**
4	60	**58**	S.W.Coast	**Inamagando**
4	60	**59**	S.W.Coast	**Mapungo**
4	60	**60**	S.W.Coast	**Bentiaba**
4	60	**61**	S.W.Coast	**Salgada**
4	60	**62**	S.W.Coast	**Chilulo / Chapéu Armado**
4	60	**63**	S.W.Coast	**Caniço**
4	60	**64**	S.W.Coast	**Mutiambo**
4	60	**65**	S.W.Coast	**Muchimanda**
4	60	**66**	S.W.Coast	**Giraul**
4	60	**67**	S.W.Coast	**Bero**
4	60	**68**	S.W.Coast	**Changulo**
4	60	**69**	S.W.Coast	**Subida Grande**
4	60	**70**	S.W.Coast	**Metere**
4	60	**71**	S.W.Coast	**Flamingos**
4	60	**72**	S.W.Coast	**Curoca**
4	60	**73**	S.W.Coast	**Cunene**
4	62	**74**	Zambezi	**Zambeze**
4	63	**75**	Okavango	**Cubango**
4	63	**76**	Zambezi	**Cuando**
4	63	**77**	Etosha pan	**Cuvelai**

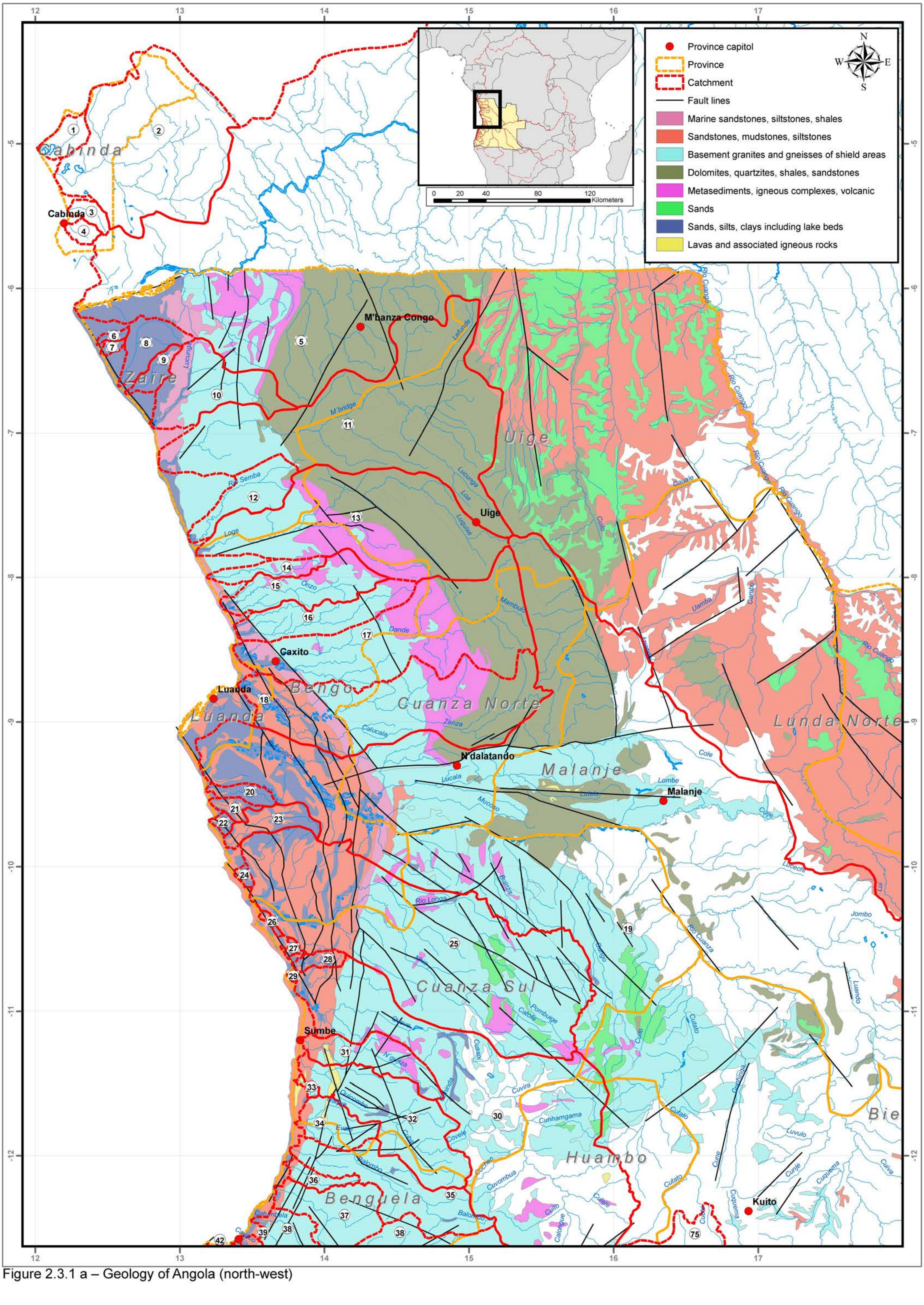


Figure 2.3.1 a – Geology of Angola (north-west)

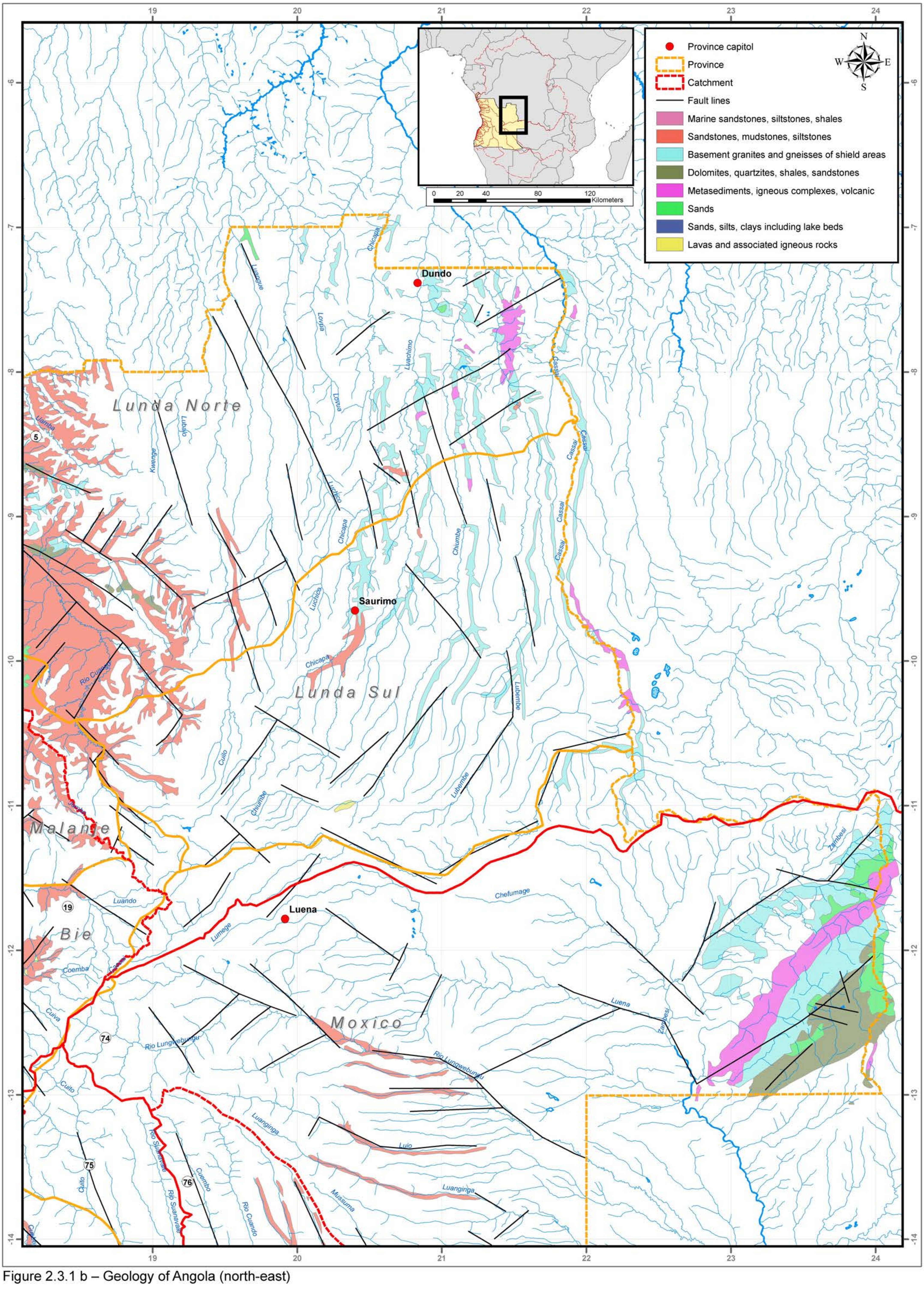


Figure 2.3.1 b – Geology of Angola (north-east)

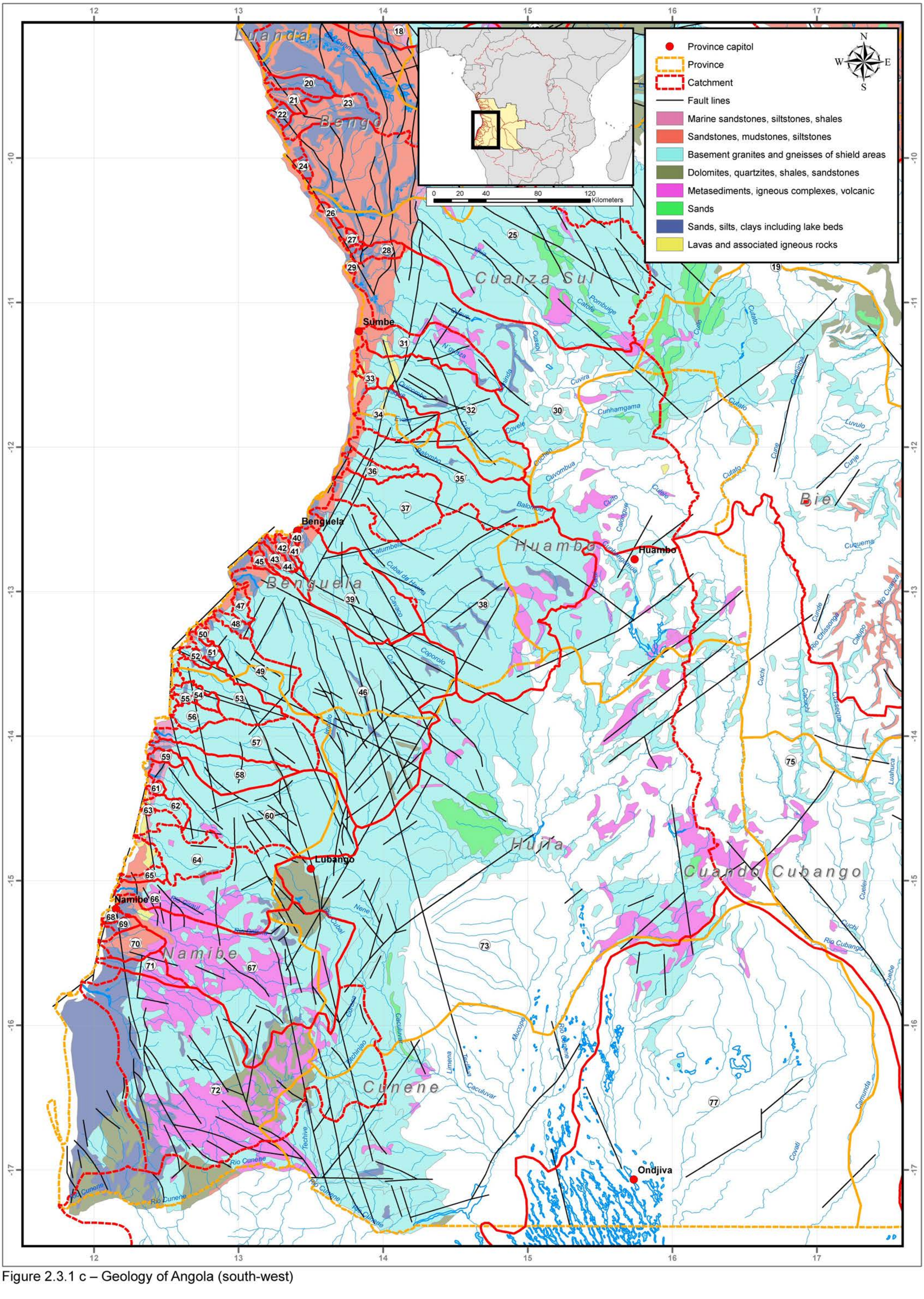


Figure 2.3.1 c – Geology of Angola (south-west)

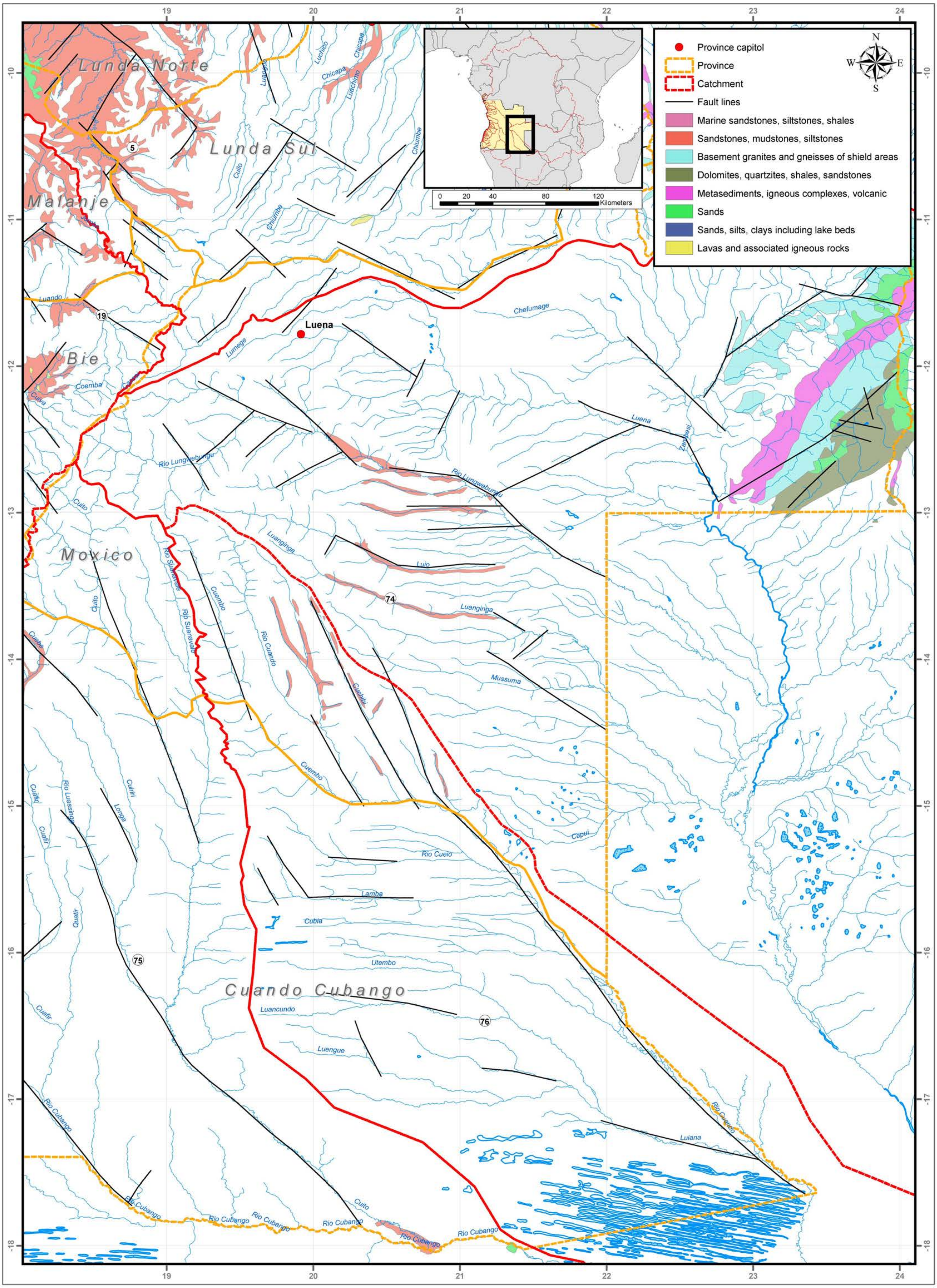


Figure 2.3.1 d – Geology of Angola (south-east)

3. SEDIMENT TRANSPORT & SOIL EROSION

3.1 Introduction

The Terms of Reference calls for a preliminary estimation of sediment transport in the different river basins, and the identification of river basins where soil erosion problems are most severe. Due to the complete lack of sediment transport measurements revealed by this rapid assessment, no such river-by-river estimation has been possible. Efforts have, however, been made to collect and analyze the scant data that has been uncovered. In addition background research has been made to uncover comparative information from regional rivers and basins. The results are included in the following sections.

3.2 Bathymetric Measurements of Cambambe Reservoir

Cambambe Dam in the Middle Cuanza River basin was completed in 1960 is 60 m high and may be heightened by some 20 m as part of the rehabilitation of the power plant. Construction of a second powerhouse is foreseen. This would increase the total installed capacity to 780 MW. Cambambe has large volumes of sediment deposits that reduce the effective storage. The original total storage volume was 50 million m^3. Measurements and calculations from a bathymetric survey[1] carried out in 2001 showed that the siltation is quite excessive, the new measured volumes being then some 24 million m^3 total storage including somewhat under 19 million m^3 of live storage. This implies an average siltation rate of some 26 million m^3 over a period of some 41 years, or a rate of some 0.63 million m^3 per year. The catchment area at the Cambambe Dam is 117,194 km^2. Unfortunately, no measurements are available of the properties of the sediment material in the reservoir, nor of the amounts of sediments that have passed by the dam and turbines. However, the reservoir being relatively large, relatively high trap efficiency would be expected, and the bedload and a major portion of the suspended sediments would be expected to be deposited in the reservoir. Considering a (unconfirmed) density of the sediments laid down in water of 1.5 tonne/m^3, this corresponds to a sediment yield of somewhat less than 8 tonnes/km^2/year.

A search has been made for comparison sediment yield data for African rivers. The FAO[2] have a trial database available on the Internet that gives sediment yield values from rivers in many of the countries of the World. The database quotes a very wide range of values of sediment yield for African Rivers, ranging from 0.9 tonnes/km^2/year to 19520 tonnes/km^2/year. Significantly, Angola has no entries in this database, but there are entries in some of the neighbouring countries including South Africa, Zimbabwe and Zaire. As an example, sediment yield figures of 35 tonnes/km^2/year are quoted for the Zambezi in Mozambique and 11 tonnes/km^2/year for the Zaire River. Consequently, the estimate of some 8 tonnes/km^2/year for the Cuanza River at Cambambe Dam is perhaps not unreasonable. Within the framework of the time and resources available for this rapid assessment, it is not possible to draw conclusions from this single point measurement and apply it to other Angolan rivers. Such an exercise could, however, be the subject of future follow-up of this Rapid Water Resources Assessment.

[1] Study of the sedimentation of the Cambambe Dam reservoir on the Cuanza River (Estudo de Avaliação da Sedimentação da Albufeira da Barragem de Cambambe no Rio Cuanza, PM Consultoria Obras Hidráulicas, Luanda, February 2002).
[2] FAO-AGL - Database of World Rivers Sediment Yields

3.3 Measurements in the Okavango River at Divundu, Caprivi, Namibia

In May 2003 a bathymetric study[3] of the application of side-scan sonar and bathymetric survey techniques was carried out in the Okavango River at Divundu, Caprivi, Namibia in order to determine bedload sediment transport rates in the Okavango River.

The survey measured rates of migration of sedimentary bedforms in the river over a 28-hour period, and came up with values of average bedload sediment transport across the width of the river of 121.91 m^3/day, with densities of sediments of some 1.6 tonnes/m^3.

The results were said in the report to be provisional only and that further field measurements were recommended.

3.4 Soil Problem Areas and Soil Erosion

Meetings with the ministry of Agriculture revealed some information about the distribution and severity of soil erosion problems in Angola. This is backed up by international information and datasets on the issue of human induced soil erosion.

The central plateau is among the most densely populated areas and where, due to a high mean annual rainfall, rainfed agriculture is most developed. These areas are therefore also among those with the most extensive forestry devastation. Water erosion by rainfall in these areas leads to loss of topsoil that reduces the agricultural value of soils and contributes to increased sediment load and reduced water quality in the rivers. This central plateau is the region where many of the rivers have their source and sediment problems cause effects in several of the large rivers.

In areas west of the central highlands, nearer the coast, increased agricultural activity also causes deterioration of the vegetation coverage and increased erosion. During the war, many people fled to these coastal areas and the natural vegetative cover there was reduced through the planting of crops, often by “slash and burn” techniques. Land erosion in these areas also contributes to increased sediment loads in the rivers. In addition, reduction of vegetation cover leads to more susceptibility to flooding.

Two datasets with full coverage of Angola have been found, both from the UNEP/DEWA/GRID-Geneva. One dataset describes human induced soil erosion and soil erosion severity soil and the other soil problem areas.

The GLASOD database contains information on soil degradation as reported by numerous soil experts around the world. It includes the type, degree, extent, cause and rate of soil degradation. The dataset for Angola is shown in *Figure 3.4.1*.

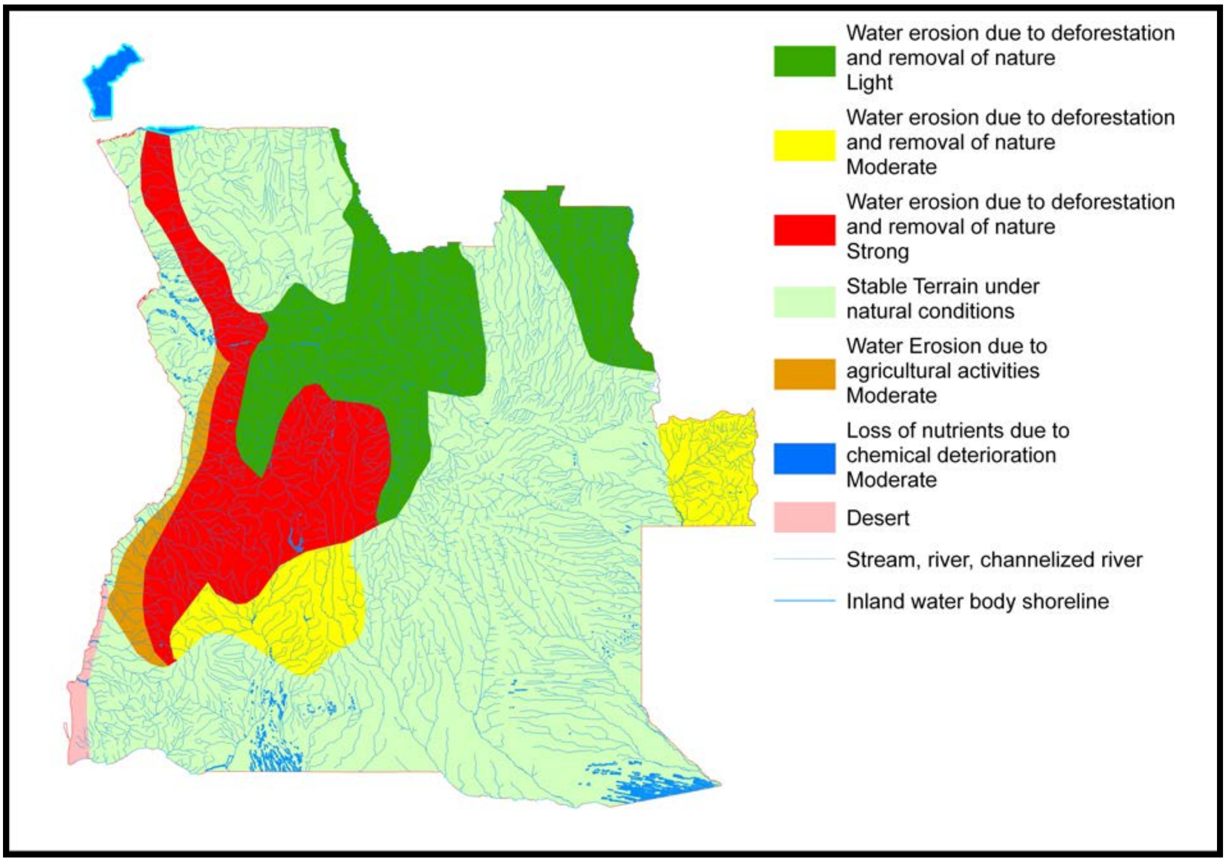
The “cause” variable indicates the kind of human interference that has triggered the degradation process. The five major soil degradation causes are: deforestation, overgrazing, agricultural activities, overexploitation of vegetative cover for domestic use, and (bio)-industrial activities.

Problem soils have been defined as soils with inherent physical or chemical constraints to agricultural production. In these soils degradation hazards are more severe and adequate soil management measures are more difficult or costly to apply. Such soils, if improperly

[3] Application of side-scan sonar and bathymetric survey techniquesto a determination of bedload sediment transport rates in the Okavango River at Divundo, Caprivi, Namibia on behalf of Eco-Plan/Nampower; Council for Geoscience, Marine Geoscience Unit, Cape Town, RSA, May 2003.

used or inadequately managed, will degrade rapidly, sometimes irreversibly. As a result the land itself might go out of productive use.

Figure 3.4.1 Human Induced Soil Erosion in Angola. (GLASOD dataset)



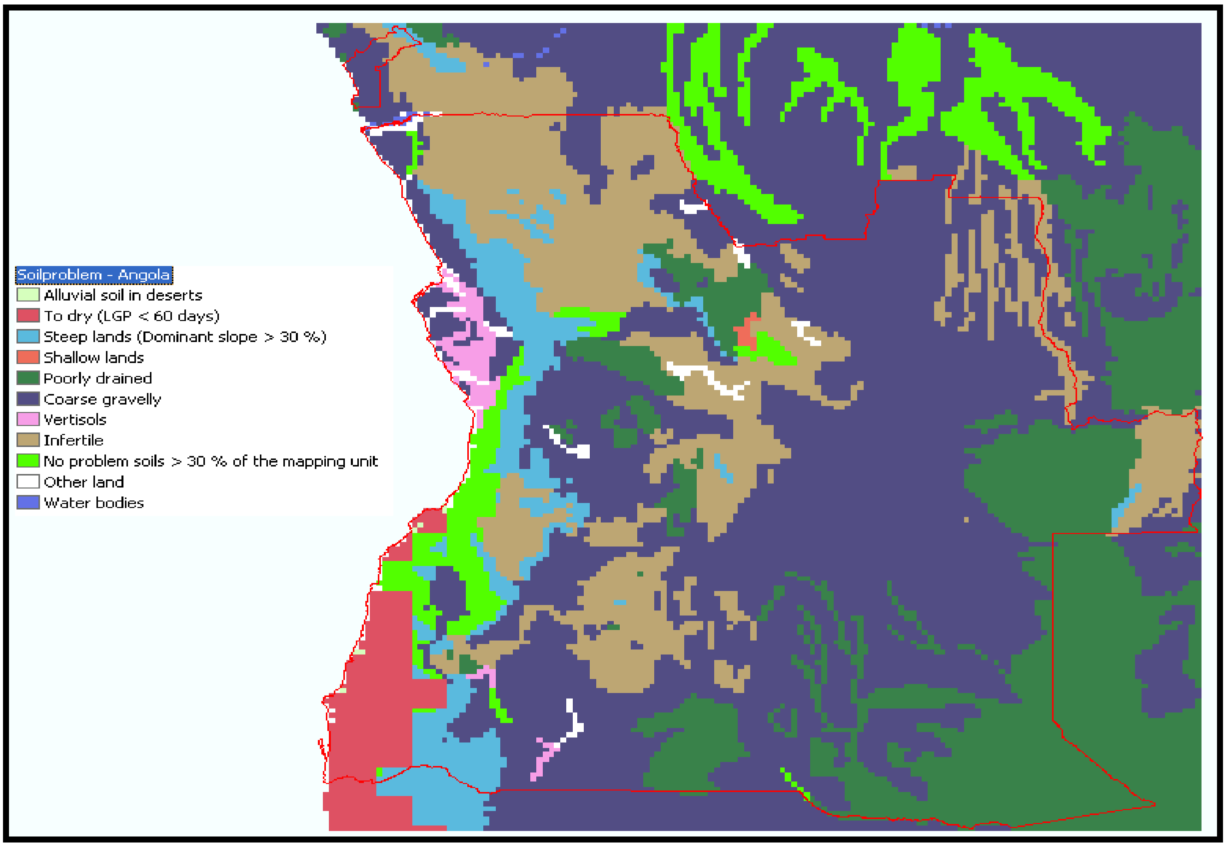
The process of grouping land areas according to constraints to agricultural production is complex because:

In many cases tracts of land will exhibit a combination of a number of soil and agro-climatic constraints.
Environmental requirements of individual crops vary considerably so that what is a severe constraint for one crop may be less severe or no constraint for another crop.
The mapped soil data at 1:5 000 000 scale is presented as an association of a number of different soils, and each mapping unit may contain a variable proportion of no problem soils and soils with different constraints.

The dataset is part of the TERRASTAT I Global GIS Databases and was created as part of the Poverty and Food Insecurity Mapping Project (GCP/INT/761/NOR) funded by the Government of Norway.

The dataset for Angola is shown in Figure 3.4.2. Closer inspection of the figure shows that over 30% of the mapping unit represents soils with no problems with respect to agricultural production. However, it also shows that there are large tracts of “steep lands” (1.e. areas with dominant slopes greater than 30%), which may therefore be subject to increased erosion, especially when subjected to human and animal activity. As Figure 3.4.2 shows, and as confirmed by local knowledge, these steep areas with higher erosion potential occur typically along the edge of the central plateau.

Figure 3.4.2 Problem Soil Areas of Angola
(Data from TERRASTAT 1 Global GIS Database)



3.5 Conclusions

Since no sediment-sampling network is in existence in Angola today, the little data assembled during this assessment is of limited value. In Chapter 13 some recommendations are given for how this situation may be improved.

4. POPULATION ESTIMATES AND FORECASTS

4.1 The Setting for Estimating Present National Population and Growth Rates

Angola is a large and very sparsely populated country, being four times the size of Norway and having less than four times the population of Norway.

Angola appears to have undergone a very rapid change from a predominantly rural economy as recent as 1990 (28% urban and 72% rural population, according to FAO), towards a significant degree of urbanization (34% rural and 66% urban in 2001, according to INE-estimates). Around 30% now appear to live in the Capital Luanda metropolitan area.

Different sources apply very different estimates of Angola's total population; it's provincial as well as urban/rural distribution growth rates, life expectancies, and mortalities. Short of a recent post-war nationwide census, there is very little to indicate which of the data sources are most reliable, and it is not always clear if some sources build more or less on some of the other ones referred to in the sampled population estimates presented in Table 4.1.

Table 4.1 Some Recent Population Estimates for Angola

Indicator / Source	Total population	Urban/sub-urban population	Rural population	Pop. Growth rate
Present assessment by Learned Angolans	14-15 mill (2004)	Na	Na	3.0% (2004)
UN OCHA 2004	15.2 mill (2004)	na	na	na
UNDP Human Devt. Report (2003)	12.8 mill. (2001)	35%	65%	2.9% (2001-15)
Min. Of Energy and Water Strategy	13.8 mill (2003)	66% (2003)	34% (2003)	na
Inst for Sec.Studies	13.1 mill. (2003)	na	na	2.9 % (2003)
SADC/GTZ	13.5 mill. (2002)	55%. (2002)	45%. (2002)	3.0% (2002)
EIA Country analysis	13.9 mill (2002)	na	na	na
FAOSTAT	13.2 mill. (2002)	na	na	3.2% (2001)
INE[1]	13.8 mill (2001)	66% (2001)	34% (2001)	na
World Bank	13.5 mill. (2001)	na	na	3.1 % (1995)
Emb. of Angola, UK	11.2 mill. (1999)	na	na	2.8 % (1999)
SADC-FAO	12.5 mill. (1999)	na	na	4.0% (mid-1990s)
MICS[2]	na	42%(1996)	58% (1996)	na
FAOSTAT	10.9 mill (1995)	31% (1995)	69% (1995)	2.7% (1995)
FAOSTAT	9.3 mill (1990)	28% (1990)	72% (1990)	2.6% (1990)

Disaggregating the population estimates by province and/or by rural/urban delineations makes the estimates much more speculative. This is very much due to the massive dislocation of millions of people, particularly after the resumption of civil war in 1992. As of June 2004, more than 4 million people had been resettled in their original provinces. However, close to 400,000 people remained dislocated to be resettled, and no census is available to provide facts about how many of the dislocated people have actually settled permanently in the provinces they fled to.

[1] National Institute of statistics
[2] MICS = Multiple Indicator Cluster Survey by UNICEF

In addition, no census data are available to map the migration flows (both war-induced and induced by economic discrepancies between urban and rural areas) during the past 12 years, a period of around 3% or more annual natural population growth. FAO estimates the Angola population to have doubled from 1992 to 2004. As an illustration of intra-country population growth variation, Luanda is now (2004) said to have between 4 and 5 million people, whereas it had an estimated 1.74 million in 1992. This suggests almost a tripling of the population of the capital metropolitan area in 12 years. Over this 12-year period, Luanda's share of the national population has increase from an estimated 17.5% to 29%.

Aside from the ongoing adjustments from almost 30 years of wartime to peace and reconciliation, future population development is affected by changes in life expectancy and infant and child mortality. As for the other demographic indicators in Table 4.1, these health-provision related indicators are also highly uncertain, see Table 4.2.

Table 4.2 Health-related Demographic Indicators of Angola

Source	**Life expectancy** (years)	**Infant mortality** (per 1000 births)
UNDP Human Development Report 2003	40.2 (2001)	154 (2001)
Inst for Sec.Studies	41 (2003)	Na
SADC/GTZ	45 (2002)	Na
MICS	na	150 (2001)
World Bank	na	154 (2001)
Emb of Angola, UK	48 (1999)	129 (1999)
SADC-FAO	47 (1992)	Na
MICS	na	166 (1996)
World Bank	na	172 (1995)

Various sources

4.2 The Provincial Population Distribution

The more recent provincial population statistics are rather speculative estimates. The electoral process of September 1992 helped the country to have an idea about how many citizens were living in Angola at that time, based on the registered adult population. No recent census data are available, and the resumption of the civil war between 1992 and 2001 resulted in tremendous dislocation of peoples between provinces and across borders to neighbouring countries.

Table 4.3 presents INE-estimated provincial population totals for 1994, along with the most recent UN OCHA estimates for 2004. In addition, it presents year 2000 estimates of structured urban and peri-urban/transition/periphery/shantytown population numbers (the distinctions between the elements of the latter urban cluster-category own is not at all clear as regards unitary water consumption assumptions) for the provincial capitals and the other main cities from the various Water Master Plans. These latter population estimates tends, however, to be significantly different (sometimes higher, sometimes lower) from those presented as urban totals in the 2003 "Strategy for the Development of the Water Sector" paper prepared by the Ministry of Energy and Water.

Disturbingly, but not at all surprisingly, there are very substantial discrepancies between the estimates from the various sources, even for the same year.

Furthermore, different definitions and criteria for disaggregation of population data into categories that have significantly different access to potable water (urban structured, periurban/peripherical/shantytown, and rural) and therefore different levels of daily per capita water consumption are applied in different studies and databases.

For example, the estimated total 2003 urban population for Benguela city is 400,000 in the "Strategy" paper, while the estimated 2000 urban population in the Water Master Plan is 520,000. For Lobito the comparable numbers are 600,000 and 750,000 respectively.

In the case of Bie, the 2000 Master Plan estimate for the province is 1,230,000, of which 400,000 in Kuito municipality alone. The estimated 1995 provincial population was 600,000. Similar dramatic changes in estimated provincial populations are detected for Huambo (from 1 million in 1995 to 3 million in 2000), Huila (from 680,000 in 1995 to 1.34 million in 1999), and Lunda Sul (from 125,000 in 1995 to 400,000 in 2004).

Luanda metropolitan area is now believed to hold between 4 and 5 million people, or around 1/3 of the nations estimated population of around 15 million. This means that the population is highly concentrated in and around Luanda, but there are also important population concentrations in the main provincial capitals such as Benguela, Lubango, Huambo, Uige and Kuito. At the same time, the population densities are extremely low in extensive provinces such as Cuando-Cubango, Lunda Norte, Lunda Sul, Moxico and Namibe.

The war and the resulting dislocation, followed by relocation in the wake of the war, makes it virtually impossible – short of any recent census data – to prepare provincial population forecasts based on historic population trends. UN OCHA in the report "Angola 2004", estimates that during 2003 alone, more than 3.8 million war-affected persons resettled or returned to their areas of origin, and hundreds of thousands remain temporarily resettled, while 350,000 refugees are still in neighbouring countries. Only an overall national demographically based growth rate can be established with some degree of confidence. Then one can make trend assumptions about the continued rural to urban migration trends, and finally – given what has been assumed for these national trends in the coming two decades – make best guess assumptions about the future population developments in each province as a basis for preparing forecasts for each water catchment area.

From Table 4.3, one sees that the estimated population of the key urban areas in the Water Sector Strategy plan column to the right covers 79% of the estimated 2002 urban population of Angola. It would – considering the data available population and water use data for forecasting purposes – seems reasonable to assume that the Master Plan data presented in columns 2 and 3 in Table 4.3 represent 80% of the urban population of the country, and that default parameters derived from these cities, should be adopted to expand the forecasts to nationwide coverage.

Table 4.3 Provincial Population Estimates for Angola based on Available Studies ('000)

Indicator / Province	INE estimated Provincial 1994 Population Corrected	UN OCHAo Angola 2004 estimated Provincial 2004 Population	Estimated Structured Population in Key Urban Centres In 2000 (Water Master Plans)	Estimated Peri-urban Population in key Urban Centres In 2000 (Water Master plans)	Estimated key urban population from "Water Strategy Paper" 2003
1. Bengo	215	322	na	na	60[a]
2. Benguela	1,302	1,570	451b	1,019[b]	400
3. Bie (2000)[c]	774	1,016	16 (2002)	53	69
4. Cabinda	181	362	-	197 (2004)[d]	20
5. Cunene	348	449	11 (2001)	103 (2001)	63[e]
6. Cuando-Cubango	312	514	na	na	70
7. Cuanza-Norte	323	551	12 (2002)	81 (2002)	105[f]
8. Cuanza-Sul	820	1,130	na	na	210g
9. Huambo (2000)[h]	1,094	1,148	91 (2001)	299 (2001)	400
10. Huila (1999)[i]	1,174	1,347	87 (1999)	361 (1999)	300
11. Lunda-Norte	362	479	14 (2004)	62 (2004)	60[j]
12. Lunda-Sul (2004)[k]	207	277	7 (2004)	143 (2004)	70
13. Luanda	1,995	2,935	266 (2000)	1,628 (2000)	4,000
14. Malanje	754	824	19 (2002)	240 (2002)	275
15. Moxico	285	442	na	na	70
16. Namibe	199	253	-	58 (2004)[d]	150
17. Uige	702	1,321	na	na	140
18. Zaire	178	285	-	51 (2004)[m]	125[l]
Total	11,224	15,225	--	--	7,155
Water Sector Strategy National Plan (2002)	13.8 million	13.8 million	--	--	9,100[n] (all urban)

a Includes Caxito (20'), Dondo (30') and Catete (10')

b The sum of Lobito, Benguela, Catumbela, Baia Farta,. Lobito and Benguela alone added up to 1,470,000 in the Master Plan document for 2000.

c Total population estimate for the Bie municipalities 1,123,000 as estimated in the Master Plan data base, of which 400,000 in Kuito Municipality..

d Assumes all urban in peri-urban category with 40litres/person/day consumption

e Includes only Ondjiva while Master Plan data includes Xangongo etc as well

f Includes 10,000 peri-urban dwellers in Lucala

g Includes Sumbe (140'), Porto Amboin (40') and Gabela (30')

h Total population for Huambo municipalities 3,002,667 (here assumed to be peri-urban from a water use perspective) as estimated in the Master Plan data base.

i Total population for Huila province 1,339,311 as estimated in the Master Plan data base (ONU)

j Dundo and Chitato

k Total population estimate for the Lunda Sul Province municipalities 400,000 as estimated in the Master Plan data base.

l Includes Soyo (45'), Tomboco (10'), N'Zeto (20') and Mbanza Congo (50')

m Assumes 20liters/person/day consumption in 2004; i.e. all is periurban in Mbanza Congo.

n All Urban (2.8 million) plus suburban (6.3 million). Rural is thus 4.7 million.

o OCHA was closed down in June 2004, and replaced with Transition Coordination Unit (TCU)

4.3 Establishing National Population Estimates for Water Use Forecasting

This Rapid Water Use Assessment acknowledges the great uncertainties characterising all demographic and economic data for Angola. Bold assumptions must be adopted, and the assessment takes as its starting point the population numbers and distribution between major water user categories that have been recently prepared for the various Water Master plans for Angola's major urban areas. These population estimates build on all the best available population data at hand, coupled with local knowledge and insight of informed people regarding people movements within and between provinces during and after the war. There is no way that this Rapid Water Assessment could expect to start from scratch and produce more reliable estimates.

The overall national population estimates suggest that 66% of the estimated overall 13.8 million population around the start of peace in 2002 lived in urban areas. Urbanisation has been rapid, in part due to the security situation, but based on worldwide migration experience, it is unreasonable to assume a major move back to their origin rural areas. For the purpose of forecasting future provincial population distribution and water use, it is assumed that the 2000 population was 13 million, of which 8 million (62%) lived in urban areas, and 5 million (38%) in rural areas.

However, one needs to deduct the Luanda population from these statistics because of its unique national role and size. The entire Luanda population should be considered urban/periurban from a future water use perspective. This means deducting three million people from the national urban totals before calculating the urban/rural shares for the rest of the country. The national (exclusive of Luanda) urban/rural split for 2000 then becomes 5 million urban/periurban and 5 million rural/periurban.

In this assessment, it is assumed that during the initial transition from war to peace starting in 2002, population movements within- and back into Angola from abroad have been substantial and in no way reflecting peacetime migration patterns. From an estimated year 2000 population of 13 million, growing to 13.8 million at the end of the war in 2002, it is assumed here an extraordinary growth due to net inflows that brings the overall population to 15.9 million in 2005.

The first step in the forecasting process is to project the total population from 2005 to 2025. An annual average growth rate of 3% is adopted here until 2015, and then 2.9% thereafter. The estimated 2005 population would also result from a 3% increase from 15.225 million in 2004 (the UN OCHA estimate), to 15.865 million in 2005. The forecast would yield a population of 21.070 million in 2015, and 27.801 million in 2025. These estimates and forecasts would seem to be consistent with prevailing and expected fertility and mortality rates, and therefore would form a relatively reliable basis for the subsequent far more speculative distribution of the overall population between provinces, river basins (catchments), rural and urban areas, and distinctly different water user groups.

From these population forecasts, one should first deduct the forecasts for Luanda, starting with 3 million in year 2000, and a projected annual growth rate of 7% reflecting the war-drive of people to Luanda, leading to a projected 4.2 million Luanda population in 2005. From then an annual growth rate of 4% is assumed until 2015, reflecting the stop in war-induced migration, but allowing for continued capital city "magnetism" to override the reduction in fertility among the higher educated in Luanda. This increases Luandas population to 6.2 million by 2015. From 2015 to 2025 this capital city growth rate is assumed to be 3%. This reduction combines a reduced fertility of people in the metropolitan area below 3% and a continued net migration to the capital city. With such a growth rate Luanda would reach 8.33 million by 2025. This means that Luanda's share of the overall population increases steadily from 23% in 2000, via 26% in 2005, to 29% in 2015 and 2025. Such a concentration of population in the nations capital city is not atypical of developing countries with a highly centralized power- and decision-making basis in the capital city.

Having deducted the projected Luanda population from the national totals, the remaining population must be distributed between other cities and rural areas. It is assumed in this Rapid Water Use Assessment that urban areas outside of Luanda also attract rural people in search of non-agriculture jobs (formal- and informal services, construction, etc), so that the urban/periurban share (not including Luanda) of the remaining population will gradually change from the assumed 38% in 2000 to 37% in 2005, to 38% in 2015, and reach 40% in 2025.

These forecast assumptions lead to the future distribution of the national population of Angola as shown in Table 4.4.

Table 4.4. Future Distribution of Angola's Population (millions)

Year	Total population	Luanda	Other major urban/periurban	Rural and rest periurban
2000	13.0	3.0	5.0	5.0
2005	15.9	4.2	5.9	5.8
2015	21.4	6.2	8.2	7.0
2025	28.2	8.3	11.2	8.7

Source: Consultant's own estimates based on available economic and demographic studies

Rural population shares vary from one province to another. Rural in this assessment includes villages and towns where there is no water network to which people can be connected. Some provinces are extremely sparsely populated with around one or two person per km^2. Namibe, Moxico, Lunda Norte, Lunda Sul, and Cuando-Cubango are such predominantly rural provinces. In addition, Cunene, Uige, Cuanza Norte, Bengo and Zaire provinces are also predominantly rural. However, even here one could well imagine concentrations of population especially as a result of the war, so that the urban population shares are close to, or even above the national average outside of Luanda. Since there are no population data available to suggest what these rural provincial shares actually are, this study derives rural population in all provinces outside of Luanda as the residual once the provincial totals and the urban estimates have been completed.

For Bengo, Cuanza Sul, Moxico, and Uige provinces, no Water Master Plan urban population data are available at the time of preparing the Rapid Water Use Assessment. The study adopts national average figures as default numbers for these provinces.

For reasons of a serious lack of reliable population data, and due to the country still being in the process of resettling millions of war-affected people, this assessment has prepared its own "best guess" population forecasts based on available data from various sources and based on informed assessments by Angolan experts with extensive and frequent travels for development advisory work throughout the country.

The results of this estimation and forecasting process are presented in Table 4.5, which is consistent with the aggregate forecasts in Table 4.4. This table, along with the economic growth and consumer water demand forecasts in Table 7.2, as well as supply efficiency assumptions of the water networks, then forms the basis for the water use estimates in Chapter 7 where the provincial totals are disaggregated by urban and rural water use categories.

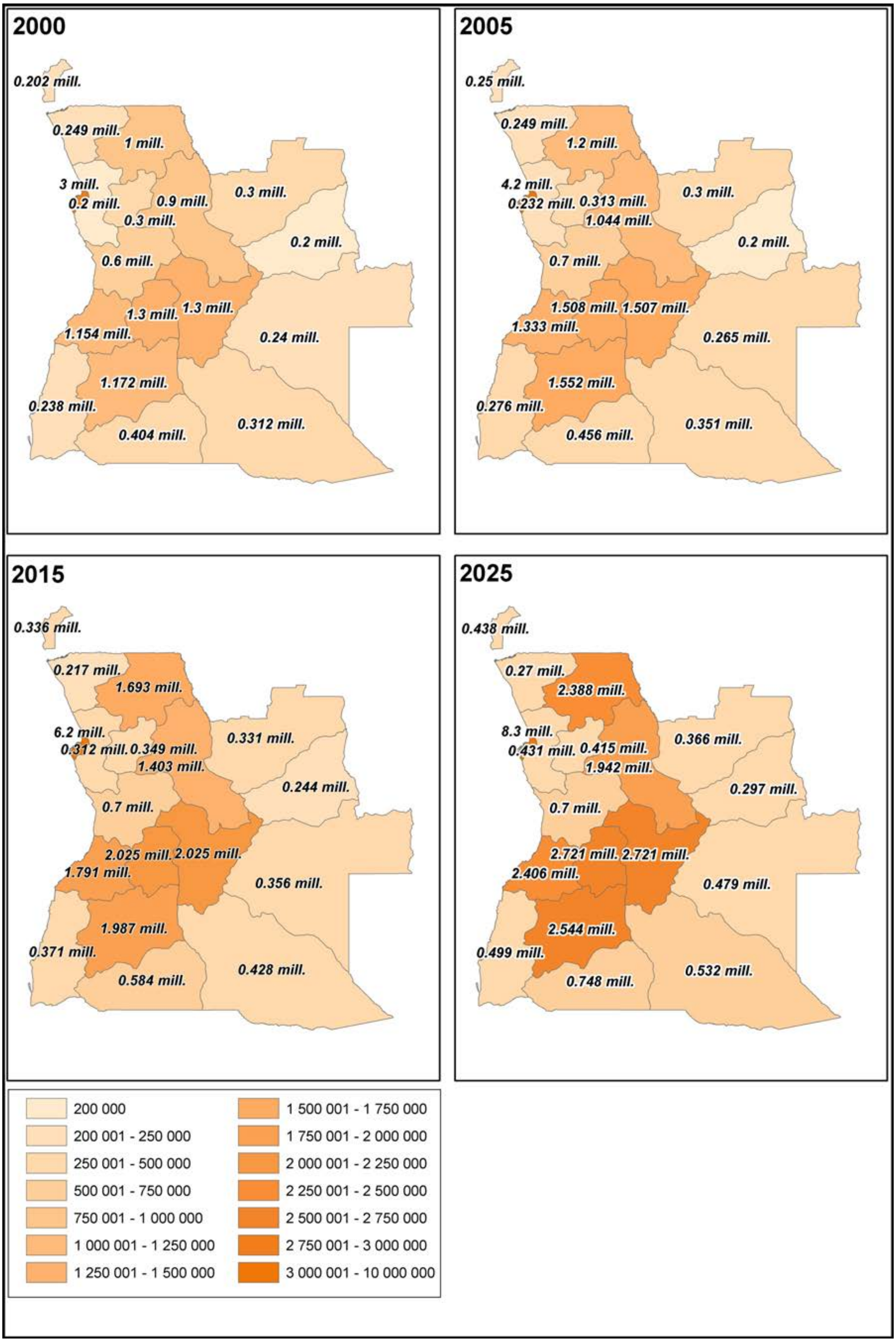
Table 4.5. Provincial Population Forecasts ('000 population) for Angola

Province	2000	2005	2015	2025
Bengo	200	232	312	431
Benguela	1,154	1,333	1,791	2,406
Bie	1,300	1,507	2,025	2,721
Cabinda	202	250	336	438
Cunene	404	456	584	748
Cuando-Cubango	312	351	428	532
Cuanza-Norte	300	313	349	415
Cuanza-Sul	600	700	700	700
Huambo	1,300	1,508	2,025	2,721
Huila	1,172	1,552	1,987	2,544
Lunda-Norte	300	300	331	366
Lunda-Sul	200	200	244	297
Luanda	3,000	4,200	6,200	8,300
Malange	900	1,044	1,403	1,942
Moxico	240	265	356	479
Namibe	238	276	371	499
Uige	1,000	1,200	1,693	2,388
Zaire	249	249	217	270
Angola total	**13,071**	**15,936**	**21,352**	**28,197**

Alternative scenarios for total population and its distribution are not prepared. Even with an unlikely record high 4% annual population growth for the entire forecasting period, it would not come near a level that could tip the water balances into a water deficit situation. Water shortages exists today, and will become more serious in the future, not as a result of a catchment area water deficits, but as a result of the authorities not prioritising investments in- and proper maintenance and operation of adequate water supply and sanitation systems. Alternative population and water use scenarios will not contribute to a better basis for such decision making and resetting of priorities.

The provincial population forecasts are illustrated geographically in Figure 4.1.

Figure 4.1 Provincial Population Forecasts for Angola



5. ECONOMIC DEVELOPMENT ASSUMPTIONS

5.1 GDP: Estimates of Level, Composition and Growth

Indicators of economic development during the last three decades of war form a poor basis for extrapolation into the future, assuming it will be a sustained post-war period of peace, reconciliation and reconstruction. The most recent GDP growth figures – shown in Table 5.1 – suggest that economic growth is resumed. It was estimated at double digits immediately following the termination of the war, and was estimated to sustain a growth level between 4 and 7% in 2003. However, the growth rates of the dominating petroleum and diamond sectors fluctuate a lot from year to year, making it difficult to prepare reliable short term annual revenue- and GDP predictions.

Table 5.1 The Annual Growth Rate of Angola's GDP at 1992 Market Prices

Year / Sector	1999	2000	2001	2002	2003
Agriculture, forestry, fisheries	1.3%	11.3%	17.7%	11.6%	11.7%
Mining	4.6%	2.0%	1.8%	16.9%	0.8%
Oil and gas	1.0%	0.4%	-1.0%	20.6%	-2.2%
Manufacturing	7.1%	8.9%	9.8%	10.1%	12.0%
Construction	5.0%	7.5%	8.5%	10.0%	12.5%
GDP	2.7%	3.9%	5.2%	13.0%	5.2%

Source: Banco National Angola: www.bna.ao

While agriculture is the dominating source of employment (85% in 2003), it contributes only 8% to GDP. However, the primary extractive sectors dominated by agriculture have shown a remarkably high and stable real double-digit growth rate since 2000. The petroleum sector (oil and gas) is the dominating source of revenue with more than 60% of GDP and 90% of all export revenues. However, it only contributes marginally to direct domestic employment generation, and the growth rates have fluctuated wildly. Industry and services – most of which is petroleum sector and linked to this sector in direct and indirect ways (tourism is virtually non-existent) – jointly provides 92% of GDP, but only 15% of employment. Diamonds are the second most important sector with an estimated 9% of GDP and 13% of exports, and have also experienced large annual fluctuations in output. Manufacturing and construction, on the other hand, have demonstrated steady and sustained high growth rates since 1999.

Macro-economic indicators for Angola are at best estimates of the relative role and development of the different sectors of the economy. Table 5.2 shows the latest aggregate estimates from some sources that regularly update and present country indicators.

Table 5.2 GDP: Estimates of Level, Composition and Growth

Indicator / Source	GDP per capita USD	GDP growth rate	GDP composition		
			Agriculture	Industry	Services
CIA Factbook	1,900 PPP (2003)	7.14% (2003)	8% (2001)	67% (2001)	25%(2001)
EIA	720 (2002)	4.40% (2003)	na	na	na
SADC/GTZ (2002)	500 (2002)	na	7-11%	60% (oil/gas) 9%(diamonds)	22% (2002)
World Bank	500 (2001)	0.30% (2001)	8% (2001)	67% (2001)	25% (2001)
UNDP UDR 2003	701 (2001)	-1.1% (1990-2001)			

5.2 Macro-economic Forecasting Assumptions

Angola possesses very substantial natural resources, and based on these, a huge potential for economic and social development. The extraction of oil is set to double from one to two million barrels a day between 2004 and 2009, a rate presently estimated at around 16% a year. The oil and gas revenue presently constitutes roughly 60% of GDP, and this share will increase significantly over the next 5 years.

Diamond production is the second largest contributor to GDP with 9%, and diamond production is also likely to increase rapidly over the next few years. Reliable statistics on diamond production and sales are not available, neither are the statistics on the use of water as an input as well as recipient of wastewater from this mining activity.

The UN Food and Agricultural Organization (FAO) estimates that Angola probably has the richest agricultural land in Africa; land that is not vulnerable to natural disasters. Angola used to be a major producer and exporter of a number of agricultural crops before independence. Clearly, the natural potential is still there, even if the international markets and export potentials have changed over the last three decades.

In sum, natural resources capital is not an obstacle to rapid economic growth and equitable distribution of the huge returns from extraction and use of the natural resource base.

The main development challenge facing Angola is that of effective and efficient governance providing for a balanced reconstruction and development in the wake of the three decades of war.

Mobilizing and utilizing the natural capital resources for the benefit of the people at large so as to bring down population growth, infant and child mortality, illiteracy, and prevalence of deadly and productivity hampering health hazards, hinges entirely on the human and institutional resources of the country; the two resources being – as in every country worldwide – the crucial national wealth component, upon which the mobilization of virtually all of the national growth potential hinges.

Macro-economic growth assumptions for the next two decades cannot build on past history due to the recent change from a war to a peace and reconciliation setting. Instead, the rapid water assessment must make a set of assumptions upon which future water demand forecasts shall be based. Over time, these assumptions may prove invalid, and updating will be needed.

In the following, optimistic assumptions are adopted in the sense that:

- A lasting peace is assumed;
- Governance will gradually develop and foster substantially increased use of oil and diamond revenues for much investment in health, education, public infrastructure and an effective and efficient government at national, provincial and local levels.
- Dislocated people will in part migrate to urban/periurban settlements and seek employment in services- and industry sectors, while the remainder will return to the places of origin and take up farming, but smallholder subsistence farming and employment on commercial farms that will emerge with the gradually improved investment climate following in the wake of improved governance
- Oil revenues will grow 16% annually until 2009. This alone will increase GDP by 8% initially (assuming oil revenues constitute 60% of GDP in 2004), gradually increasing the GDP growth rate so long as oil revenue increases at an above average GDP rate.

- Diamond production – being the second largest GDP contributor with 9%- is assumed to increase significantly in the coming years, also enhancing the overall GDP growth rate.
- The rest of real GDP is assumed to grow in line with natural population growth of 3%.

Since there is no quantitative historical basis for detailed GDP forecasts, it is assumed here that future revenue generation is sufficient without threatening financial and macroeconomic stability, to finance the investments needed for the achievements of the various Water Master Plan goals, and those of the Water Sector Strategy. The challenge is to achieve a high level political commitment to provide such financial development support.

This Rapid Water Sector Assessment takes it for granted that such commitment is achieved and that the necessary funds will be allocated and disbursed.

6. HOUSEHOLD USE OF WATER

6.1 National Coverage of Water Supply and Sanitation

The Angola Water Development Strategy Paper of 2003 (Ministry of Energy and Water) refers to the UNICEF's MICS 11 of 2001 when concluding that 62% of the population had access to drinking water and 59% to adequate sanitation (i.e. access to organised sewerage system or to latrines and septic tanks of various description). These coverage rates are higher in urban areas, with 71% and 74% for drinking water and adequate sanitation respectively, whereas the rural average coverage is 40% and 25%.

In urban areas, 11% are estimated to have piped access to house connections, and 31% have access to a public or neighbours tap or a public fountain. This percentage is 13% in rural areas. 29% rely on safe borehole sources, protected springs and wells, and rainwater, and here the percentage coverage is almost the same for urban and rural dwellers. 21% rely on unprotected lakes, rivers and streams. The share is only 12% in urban areas, but 42% in rural areas. Finally, 17% of the people (both urban and rural) use of unprotected wells, springs and purchase from lorries with water tanks. Of those with sanitation facilities in urban areas, 19% are connected to appropriate technical nets, and the rest use latrines or cesspits.

The above estimated rates of accessible safe drinking water and sanitary equipment could be excessively upward biased due to the many inoperable outlets, and due to restricted operational hours resulting from energy shortages and the lack of timely systems maintenance.

6.2 Present per Capita Use by Household Category

The urban per capita design supply of water from water supply networks in the national and provincial capital cities of Angola was estimated in the Water Sector Strategy Paper of 2003. The nominal capacity was estimated to be 58 litres on the average, varying from a high of 165 litres in Dundo to a low of 8 litres in Mbanza Congo, with Luanda being slightly above the average with 67 litres. These estimates took into account an assumed network system loss of 25%.

Similar calculations were carried out for a sample of other main cities in the provinces, and for these the resulting design capacities were 51 litres per capita per day on the average, ranging from a 97 litres high in Catete to 24 litres as the lowest in Negage.

The Water Strategy Paper also estimated actual per capita daily water availability, assuming a 50% systems loss on the way to the consumer. However, these estimates were erroneously executed and have therefore been recalculated as part of this assessment study. The recalculated average actual water supply from the public network for the provincial capitals is far below the potential supply due to the large system losses. The average actual supply is 34 litres per capita per day, with a range from 110 litres in Dundo down to no more than 5 litres in Mbanza Congo and 9 litres in N'Dalatando, while Luanda is estimated at 37 litres. SADC/GTZ (2003) concludes, however, that this daily consumption level only applies to the households with network connections. The perhaps 3 million majority of Luanda's population is captive to buying water from local vendors operating tankers at 30-60 times the price of piped water from the public supplier EPAL. In the peri-urban areas the estimated daily pr capita consumption is no more than 5-10 litres per person per day.

Several more cities were estimated with less than 20 litres per day per capita, assuming the Water Strategy Study population figures are reliable (i.e. not too low). The average actual supply in the secondary cities covered by the study is only slightly below the provincial capitals average, but the variation around the mean value is much less, with no cities near neither the highest nor the lowest registered among the provincial capitals.

However, these average numbers present only part of the real situation. Equally important from a national health and social development perspective is the distribution of available water within cities. The recent Water Sector Strategy Paper underlines the existence of a chronic and increasing insufficiency, and a highly unequal distribution between the "haves" and the "have-nots" as regards being connected to and served by the water supply system. The former tend to consume in the range of 80-120 litres per day (comparable to urban averages elsewhere in the world), whereas the latter - and much larger group of consumers - residing in poor and venerable areas may have to settle for as little as 5 litres per day, in most cases water of low quality, and when served by private vendors, at many times higher rates per litre than what is paid by those connected to public networks. The Water Sector Strategy Paper states that such residual water represents around 80% of the domestic water consumption.

For further details see Tables 2 and 3 in the "Strategy for the Development of the Water Sector" (2003). Due to the miscalculations of actual urban water systems supply in the original Water Strategy paper tables, the recalculated estimates undertaken as part of this assessment have been adopted and used as part of the background dataset when establishing estimates for present and future urban supply of water from public networks (i.e. the supply to so-called category A and B type inhabitants) in Angolan cities.

6.3 Comparison to International Unit Water Consumption Estimates

Dale Whittington (1998) in "The political economy of increasing block tariffs for water in developing countries", presented at an EEPSEA workshop, concludes: *"Internationally cited standards for basic water needs are usually in the range of 25-30 litres per person per day".*

Similar unit figures are used by various UN organizations Robert Lenton (2003), "Background paper of the Task force on water and sanitation" for the Millennium Project of the UN, concluded: *"Basic water supply requires 25 litres/day of water of acceptable quality within 200 metres from home"*

Stein Hansen, Haakon Vennemo, Hang Yin, Zhang Shiqiu and An Shumin (2002) in "Green taxes and the poor in China – Policy challenges in a changing economy", found from urban and rural household expenditure and consumption data that urban water consumption was 180 litres per person per day in 1993, while the rural average was 73 litres. In the poor western provinces rural per capita daily consumption was 50 litres.

Provided that the per capita estimates of daily water provision are reliable, the Angola city averages are not far from the basic water supply requirements (basic needs volumes) established in international studies. However, as discussed in the Angolan Government's Water Sector Strategy Paper (2003), these urban averages conceal great intra-urban variations between those connected to the supply networks and those not being connected, or being located in a poorly served location. If this situation is not improved, household water supply constraints could emerge as an obstacle to economic and social growth.

6.4 Taxes and Tariffs

In Angola the Water Law defines water as an economic good and establishes the principle of payment for use of water resources. Executive Decree 27/98 gives the Provincial Governments the responsibility to establish, and at regular intervals adjust, water tariffs in accordance with inflation for their area, to be put into practice by whoever is entrusted with the drinking water supply.

However, no regulation presently exists to apply the prevailing legal principles to the formal sector water supply systems. There is no regularity in the administrative approval of the updating of the tariff, which - due to inflation - has reached such low levels, which do not allow operators to cover expenses of operating and maintaining the systems. Service, in the form of reliable and predictable water supply from the systems, deteriorates over time, as does commercial efficiency, and an increasing number of customers refrain from paying their bills, since they refuse to pay for not being serviced as per agreement with the utility supplier.

In sharp contrast to the above described prevailing situation as regards public network supply and tariff recovery, the informal sector water market is very sensitive to supply and demand balances. The large majority of urban citizens - those not being served by the public utility networks - face scarcity driven water prices in the range of USD 2-16 per m^3, sometimes as much as 60 times what the public utility charges the better-offs who are connected to the network. This situation is, however, not unique to Luanda, but rather typical of large and fast growing cities throughout sub-Saharan Africa.

Since it appears unlikely that urban water network systems operational upkeep and expansion will keep pace with urban population growth, a growing share of urban populations in Angolan cities will become what in Chapter 7 is defined as category C consumers of water and sanitary facilities, i.e. consumers relying on more informal water sources (safe as well as unprotected).

Some of these water sources are available at no charge (lakes, streams and rivers) constituting the main source of drinking water for around 21% of the total population in 2001, according to the MICS 2003 study, ranging from 16% in Luanda, 12-19% in the central southern and southern provinces, 17-18% in the west and north, and 43% in the east.

Other category C users rely on unprotected wells and springs, and water trucks in towns and urban areas, and often face scarcity driven water prices in the range of USD 2-16 per m^3, sometimes as much as 60 times what the public utility charges the better offs who are connected to the network. Such users constituted an estimated 17% of the total population in 2001 according the MICS survey, including a high share of 21% in Luanda and the south of the country, and 14-17% shares in the rest of Angolan towns and cities.

Also included in this category of population is the 29% share having access to relatively safe sources such as boreholes, protected wells and springs and rainwater. This share is very low in Luanda (6%) and western provinces (9%), but more than 50% in the north and centre south. In the east it is estimated to be 19% and it is 25% in the south.

In total such water sources constitute 2/3 of all water sources used in Angola in 2001. This share is naturally much higher in rural areas (87%) than in urban areas (58%). Among those 33% having access to piped water, for which the users are supposed to pay, the large majority of whom are found in cities. The share is highest in Luanda and cities in the western provinces (57%), and lowest in the north and centre south with only 13% and 19% respectively. 11% of all urban households have house connections (category A users) and 31% access via public fountains, joint taps or neighbours taps.

The future water use estimates assume that the water tariffs will keep pace with inflation. However, this assessment assumes no relative change in the capture of water tariff revenues so long as the service level does not become significantly more stable and improved, other than improved efficiency in the form of reduced system losses of distributed water.

Chapter 7.3 to 7.19 provide detailed estimates and forecasts for the distribution of water users in the provinces by water use categories A, B and C (which defines water users by source of supply and use per person per day for the present and the forecast period). These estimates and forecasts are presented in such a way that they can be regrouped by catchment areas that the population belong to.

6.5 Water Demand Sensitivity to Price and Income Changes

With water being a vital basic need, the demand is rather insensitive to price changes for subsistence level water consumption. Those connected a functioning public supply network are privileged by extremely low water tariffs, and being in the upper income brackets of the population, they hardly notice water costs in their expenditure accounts.

For the vast majority of the population - including those among the better offs who also need additional supplies from private water tankers - the situation is different. As an example, take a typical poor peri-urban family of 5, consuming 20 litres per capita per day, and paying USD 2 per m^3. This means that they spend USD 2 per ten days, or USD 6 per month, equal to USD 72 per year for water. With the majority of the population being below the internationally defined poverty line of USD 1/person/day, this means that these people - with a household income of USD 5/day spend USD 0.20/day on water, which is 4% of their income. However, for those in the most critical areas as regards water supply, who also are likely to be the poorest and most vulnerable households, the water price paid to vendors may be as high as USD 16/m^3. This means USD 1.60 for water per household per day, which is equal to 1/3 of their household budget, a most alarming situation.

Unfortunately, no household expenditure survey is available for Angola to provide reliable demand information for the components of a typical household basket of goods and services at different household income levels. Such a survey would have provided information that would inform decision-makers of who is affected adversely and in a benign way when the tariffs and prices paid for various goods and services are changed. As such survey results would provide information of value to the utilities concerned with designing water tariff scales that combine the need to establish commercial viability for the utility with social equity and basic needs satisfaction.

Short of any such information on households and income distribution in Angola, one has to resort to comparable experience from other developing countries where such studies has generated insight and knowledge of the demand behaviour regarding basic necessities of poor consumers. A survey of such information is presented in the discussion and tables below. The price and income elasticity scales established from the below survey can serve as default parameter values in estimating demand responses of Angolan households to water tariff adjustments in the future, until a reliable set of Angolan household expenditure survey data becomes available.

Stein Hansen et al (2002), op. cit. found from Chinese household consumption and expenditure data that rural Chinese below the poverty line of Yuan 1,000/person/year (equal to around USD 140/person/year) who consume 50 litres per day (equal to 18 m^3 per year) and pay less than USD 0.30/m^3 (which is around the estimated marginal cost of potable water supply in China), spend less than 4% of the annual income on water.

Furthermore, they found that the price elasticity of demand for water is low at a low water tariff, and increases with the tariff level. In other words, water demand becomes more elastic - or price sensitive - as the unit price of water goes up. However, water demand remains price inelastic over the entire range of observed and estimated water charges observed in China; (the marginal cost of domestic water supply is estimated to be around USD 0.28/m^3):

Table 6.1 The Elasticity of Water Demand with respect to Water Tariff

Price elasticity of demand	Price level per m^3 of water
-0.20	USD 0.11/m^3
-0.40	USD 0.22/m^3
-0.50	USD 0.28/m^3
-0.57	USD 0.42/m^3
-0.64	USD 0.56/m^3

Source: Stein Hansen et al (2002), op.cit.

At the same time the estimated income elasticity of demand for water in China declines with income level and is:

Table 6.2 The Elasticity of Water Demand with Respect to Household Income

Income elasticity of demand	Income level (USD per capita/year)
0.78	USD 280
0.75	USD 560
0.69	USD 1120
0.53	USD 2800

Source: Stein Hansen et al (2002), op.cit.

Short of demand elasticity observations from Angola, it is of interest to compare the above Chinese estimates to other developing country estimates, in order to have a better basis for choosing default elasticity estimates for planning and forecasting uses in Angola. For the Philippines, Cristina David and Arlene B Inocente (1998), “Understanding Household Demand for Water: The Metro Manila Case”, EEPSEA Research Report Series, Singapore, used household consumption data and found that the average price elasticity of demand for household water was -0.5 (covering also the most costly water from private vendors where the partial price elasticity was -2.1, when the price per m^3 of water by the litre tends to be 20-30 times that of tap water). This price elasticity of demand is compatible with the findings from China, as well as estimated price elasticities of demand other developing country cities they examined.

At the same time, they found that once annual household income exceeded P30,000 (income below the poverty line), per capita water consumption increased very moderately with income, and the budget share of income spent on water consumption dropped rapidly with income, showing water to be a basic necessity, with an income elasticity of demand significantly below one.

Price elasticities of demand for water in urban Mexico and Brazil in the 1980s were found to be -0.38 and -0.6 respectively (Christian Gomez (1987), “Experiences in predicting willingness-to-pay on water projects in Latin America.” Proceedings of “Resource mobilization for drinking water and sanitation in developing nations," San Juan, Puerto Rico, May 26-29, 1987).

A sample of estimated price and income elasticities of demand for domestic water use is presented below (taken from Ramesh Bhatia, Rita Cestti and James Winpenny (1995), "Water conservation and reallocation: Best practice cases in improving economic efficiency and environmental quality", A World Bank-ODI joint study under the UNDP-World Bank Water and Sanitation Program, further underlines the robustness of our conclusion that the demand for domestic water is price inelastic as well as income inelastic, but at the same time that there is a considerable - albeit inelastic - price effect on domestic water demand.

Table 6.3 An International Overview of Price and Income Elasticities for Water

Source/comment	Price elasticity	Income elasticity
1. Average water prices, for 138 households in northern Jakarta, 1988	-0.37	0.15
2. Sales of metered domestic consumers in Bogor, Indonesia, 1989	-0.29 to -0.33	0.4 to 0.5
3. Average water price, 100 households in Jakarta, 1992	-0.68	0.37
4. 480 urban households in Mexico, 1985	-0.37	0.32
5. 4452 urban and rural households in Costa Rica, 1984	-0.37 to -0.44	0.58
6. 408 urban households in Brazil, 1983	-0.60	0.78
7. Average water price, 326 households in Denver, USA, 1984	-0.34	0.46

6.6 Intended Service Levels of Household Water Supply

The Water Sector Development Strategy presents intended quality of service as follows:

- In urban areas - to assure a minimum actual consumption of water of 70 litres/person/day (equal to 100 litres/person/day design capacity) and reduction in the network system to values close to 25%.

- In periurban and rural areas - to assure that in the short term, minimum consumption of 15 litres/person/day, and in the long term (by 2016) increase to 30 litres/person/day

While these may appear as modest targets to outsiders, the reality is that it is an ambitious task to achieve the targeted 25% reduction in systems losses, and to increase water supply coverage and outreach so that such average consumption rates can be achieved.

The above targets must be seen in the context of the estimated 2002 population drinking water coverage which is estimated in the strategy document to be 39% for rural areas (1.8 million out of 4.7 million rural dwellers), and 34% coverage in urban areas (3.1 million out of a 9.1 million total urban population (composed of 2.8 million urban and 6.3 million suburban).

The Strategy long term drinking water coverage targets for 2016 is 67% for urban and 70% for rural areas. This means that an additional 5.8 million urban/suburban and an additional 2.3 million rural people will have to be served, since the population forecasts for 2016 in the Strategy Document are 14.7 million urban (7.3 million genuinely urban and 7.4 million suburban), and 6.3 million rural population.

6.7 Sanitation Coverage

The 2003 MICS (UNICEF) found that 41% of Angola's population in 2001 does not use sanitary means of excreta disposal. The coverage varies between regions. The coverage is poorest in the West and Central South where two thirds of the population does not have access to sanitary means of excreta disposal. The South region - in contrast - has 82% coverage, where 62% use traditional pit latrines.

39% of the national population is found to dispose of excreta in open air, ranging from 74% in rural areas to 26% in urban areas. 30% use traditional pit latrines, and 14% have access to sewage systems. The sewage system coverage varies from 28% in Luanda to 6% in the sparsely populated East Region. In fact only five cities have partial sewage system coverage. These are: Luanda, Huambo, Namibe, Lobito, and Benguela.

The sanitation coverage ambitions are no less demanding. The actual coverage is estimated in the National Water Strategy Paper of 2003 to be 57% (1.6 million out of 2.8 million connected to the sewage net) for urban dwellers, 61% suburban coverage (3.9 million out of 6.3 million), and 26% rural coverage (1.2 million out of 4.7 million).

As of now, there is little to suggest that investments and operating expenses will increase beyond what is needed to maintain the present coverage and level of service. This assessment therefore assumes that sanitation systems in use are distributed among water use category A, B and C users so that category A users have a sewage network connection. Some category B users are also connected to the sewage network or they have septic tank connection. Category C users are assumed to be divided between pit latrines and open-air excreta disposal in the same proportions as found in the MICS.

Such sanitary system distribution assumptions for the present and the forecast period can then be applied to the category A, B and C population distributions prepared and presented in Chapters 7.3 to 7.19.

The strategy target, however, is to have a sanitation system coverage (urban network, septic tanks, septic pits, and latrines) up from 57% for urban areas in 2003 to 85% in 2016, from 61% to 85% for suburban areas, and from 26% to 65% for rural areas. This means adding another 9.9 million people to this composite sanitation system (4.6 million urban, 2.4 million suburban, and 2.9 million rural dwellers).

6.8 Disaggregation of Population into Water Use Categories

As can be seen from Table 4.3, the available Master Plan documents have prepared detailed population estimates and forecasts for the major urban areas disaggregated by characteristics that separate households in terms of per capita water use. The population is divided into three different housing categories (A, B and C) each representing significantly different levels of expected daily water use per person as a result of: a) their water supply situation, and b) their income level, which again is strongly correlated with (although no such correlation is quantified) to the housing category (A, B and C).

Furthermore, each urban population is divided into urban proper areas (sometimes called only urban, other times urban structured), and peri-urban areas, except for Luanda, where the population is disaggregated into "modern", "transition", "periphery" and "green belt" areas. For the large majority of available Water Master Plans, both the urban areas and peri-urban areas are divided into three household types (A, B and C) as a basis for estimating household water use.

Not all the available Master Plans have strictly followed this procedure of categorizing population estimates, and those that have not, and for those where Master Plan data are missing, this Rapid Water Use assessment makes its own judgement and estimates, starting with the available "Water Strategy Paper" population estimates, applying the population growth rates of the other urban areas from the Water Master plans, and taking advantage of the fact that the available Master Plans cover 80% of the urban population of Angola.

7. PROVINCIAL DOMESTIC WATER USE FORECASTS

7.1 The National Forecast Framework

The national population forecasts of Chapter 4 constitute the starting point for preparing an internally consistent set of forecasts for future population and water use by provinces, divided into urban and rural areas, and such that the findings can be transferred to catchment areas as a basis for establishing water balances.

Table 7.1 Future Distribution of Angola's Population (million)

Year	Total population	Luanda	Other major urban/periurban	Rural and rest periurban
2000	13.0	3.0	5.0	5.0
2005	15.9	4.2	5.9	5.8
2015	21.4	6.2	8.2	7.0
2025	28.2	8.3	11.2	8.7

Source: Consultant's own estimates based on available economic and demographic studies (see discussion in relation to Table 4.4).

7.2 Some Necessary Simplifying Forecasting Assumptions

As a basis for forecasting future population distribution and water use per catchment, it is assumed that communities not covered in the Water Master Plans for cities, are rural/periurban constituencies not connected to any public water supply network, and consuming water volumes as projected under Category C in Table 7.2.

Rural population shares are likely to vary from one province to another. Some are extremely sparsely populated with around one or two person per km^2. Namibe, Moxico, Lunda Norte, Lunda Sul, and Cuando-Cubanzo are such predominantly rural provinces. However, even here one could well imagine concentrations of population so that the urban population shares are close to, or even above the national average outside of Luanda. Since there are no population data available to suggest what these rural provincial shares actually are, this study derives the rural/periurban population to all provinces outside of Luanda as a residual, once the provincial totals and the urban/periurban populations have been estimated by using a combination of indigenous knowledge of the urban development along with forecasts from the Water Master Plans.

Within each province, the rural/periurban population outside the urban areas is distributed between catchments based on the density of settlements (towns/villages) on the most detailed maps available. While this is no substitute for population census data, it would seem to be as good an estimation approach as any available alternative given the prevailing disequilibrium situation.

For Bengo, Cuanza Sul, and Moxico provinces no Water Master Plan urban population data are available at the time of preparing the Rapid Water Use Assessment. For the urban areas in these provinces, the approach adopted is to compare the estimated urban populations for year 2000 from the "Water Strategy Paper" of 2003 with best available knowledge, such as estimates from the recent Water Master Plans (where available) and select the estimates judged to be most realistic. In order to prepare for estimating actual water use forecasts, this assessment adopts the average A, B, C- water use categories of housing-types used in the various Water Master Plans. Such data that should be used with care and only preliminary are available for the main cities of Cabinda, Namibe, Uige, and Zaire. Again, this assessment applies local updated knowledge. It is neither based on census data nor sample surveys.

Water consumption per capita per day for the three housing categories (A, B and C) have been established for use as forecasting parameters in those provincial Water Master Plans, where a disaggregation by such housing categories has been made, see Table 7.2. These default values are then applied to both urban and periurban areas for the cities in question. It is assumed that daily water consumption per capita is constant throughout the year.

For each city, forecasts are made as regards the distribution of the population between A, B and C. Where such A, B, and C disaggregation is not available (as e.g. for Benguela cities Water Master Plan, see 7.3 below), unit daily per capita consumption rates have to be assumed for structured urban and periurban areas respectively, e.g with category A and C per person per day respectively representing average urban and periurban housing conditions. The growth in per capita water consumption seen in Table 7.2 is consistent with the observed macroeconomic growth of Angola and the international experience as regards consumer water demand responses to price and income changes discussed above.

For category A inhabitants one must also take into account water distribution system losses when estimating the total water supplies required to meet the assumed per capita demands.

Table 7.2 Daily Water Supply (litres) per Capita for each Housing Category

Year	Category A consumption	Water network losses to supply category A's consumption	Category B consumption	Category C consumption
2000	60 litres	50% (60 litres)	30 litres	15 litres
2005	70 litres	50% (70 litres)	40 litres	15 litres
2015	90 litres	40% (60 litres)	70 litres	30 litres
2025	150 litres	30% (64 litres)	80 litres	30 litres

7.3 Benguela Province

Benguela Province experienced both in and out-migration as a result of the long periods of war. INE estimated its 1994 population to be 1.302 million. OCHA has estimated that 431,000 people have returned home (mainly from coastal Benguela to inland Benguela) since the end of the war. In addition, 65,530 demobilized soldiers and their family members are reintegrating into communities. The OCHA estimate for the 2004 provincial population is 1,570,000.

The Water Master Plan (2001) for Benguela's four main cities, however, estimated the Benguela urban population to have grown very rapidly to 1,470,000 in 2000, implying a total Benguela population that year of perhaps more than 2 million. This extremely high population was presumably a result of large flows of refugees coming from Huambo, Bie and other war-torne provinces. These people have for the most part returned since the war, thus bringing the provincial population back closer to a "without war equilibrium". For Benguela Province the Water Master Plan Study (2001) includes the four main cities Lobito, Benguela, Catumbela and Baia Farta. The Plan foresees a much higher population growth rate in the poor periurban areas (musseques, where water is supplied more at random). The analysis of the Master Plan for these four Benguela cities compares two alternative population growth projections and decides on the higher one with an average annual 4.5% population growth from 2000 to 2025. This average annual growth rate is higher than 4.5% in the 2000 - 2009 period, and below 4.5% in the 2010 - 2025 period.

This assessment, however, has carefully reconsidered the Water Master plan assumptions and estimates. It has concluded that the 2000 population estimate should be reduced to 1,154,000, with an annual growth rate of 3% thereafter to 1,333,000 in 2005. The UN OCHA 1,570,000 estimate for 2004 is also considered to be too high. This assessment applies the

3% growth rate uniformly to the four cities and the rest of the province for the 2005-2025 period. This yields a provincial population forecast for 2005, which is 1.3 million less than that of the Water Master Plan. The population share of the four large urban communities covered by the Water Master Plan is assumed to cover 80% of the provincial population.

The estimated population for 2000 and 2005, for the four cities is presented for their structured urban areas and musseques separately, since the per capita water consumption is assumed to be very different for the two population categories. The resulting populations in the four cities, distributed between urban and periurban areas is presented below in Table 7.3 for base year 2000, and forecast years 2005.

Table 7.3 Population ('000) for the Four Main Cities in Benguela Province

City:	Lobito		Catumbela		Benguela		Baia Farta	
Year	Urban	Periurban	Urban	Periurban	Urban	Periurban	Urban	Periurban
2000	141	327	28	66	98	228	16	16
2005	148	222	89	148	222	222	8	7

As for the rest of Benguela's population (rural and periurban), this assessment assumes it to be 267,000 in 2005.

After grouping the population from their water use characteristics, this adds up to an aggregate provincial population profile as follows, grouping Lobito and Catumbela in one group and Benguela and Baia Farta in another since they use two different catchments as given in Table 7.4.

Table 7.4 Population Forecasts ('000) for Benguela Province

Year	Total province population	Lobito and Catumbela urban	Lobito and Catumbela periurban	Benguela and Baia Farta urban	Benguela and Baia Farta periurban	Rural and rest of periurban
2000	1,154	169	393	114	244	234
2005	1,333	237	370	229	229	268
2015	1,791	318	497	309	309	358
2025	2,406	428	668	414	414	482

Multiplying the urban populations (assumed to be connected to a public water network) with daily per capita consumption of 60 litres per day for year 2000, and the periurban and rural populations with 15 litres per day, the estimated year 2000 water consumption figures emerge and are shown together with the forecasts in Table 7.5

This forms the basis for redistributing water use from cities and rural areas to catchments for Benguela Province.

However, the losses in the water system are substantial at 50% from the outset, but will gradually be reduced so that system efficiency reaches 60% in 2015 and 70% in 2025.

This means that water extracted from the system to produce the per capita consumption rates is that much higher than the consumption rates. Table 7.5 shows the supply of water to meet the actual demand in 2000 and in the forecasting period.

Table 7.5 Domestic Water Supply Forecasts for Benguela Province (m^3 per day) (actual consumption plus network losses)

Area	**2000**	**2005**	**2015**	**2025**
Lobito and Catumbela	$26{,}175_a$	$38{,}730_b$	$62{,}610_c$	$111{,}632_d$
Benguela and Baia Farta	$17{,}340_a$	$35{,}495_b$	$55{,}620_c$	$101{,}016_d$
Rest periurban/rural	$3{,}510_e$	$4{,}020_e$	$10{,}740_e$	$14{,}460_e$
Total province	**47,025**	**78,245**	**128,970**	**227,108**

The assumed daily per capita volumes (consumption plus network losses) are adapted from Table 7.2 as follows:

- *a: Have assumed 120 litres/person/day in urban areas and 15 litres/person/day in periurban and rural areas*
- *b: Have assumed 140 litres/person/day in urban areas and 15 litres/person/day in periurban and rural areas*
- *c: Have assumed 150 litres/person/day in urban areas and 30 litres/person/day in periurban and rural areas*
- *d: Have assumed 214 litres/person/day in urban areas and 30 litres/person/day in periurban and rural areas*
- *e: Assumes all as periurban consumption levels*

7.4 Namibe Province

Namibe Province has been very little affected by the war, other than the effects of being part of a war-ridden country. It is a sparsely populated province with development potentials. The estimated 1994 population was 199,000. Assuming a 3% average annual population growth rate since then, it would have reached 238,000 by year 2000. OCHA has estimated the 2004 population to be 253,000.

The Water Master Plan data for Namibe are incomplete and imprecise and short of forecasts and unit estimates for water use. The urban areas of the province are largely concentrated in Namibe city. Namibe city was estimated in the Water master Plan data to have 58,000 living in the urban area, and 67,000 in the periurban area (presumably in year 2000). This amounts to 53% of the estimated provincial population.

It is assumed that the structured urban area population will grow at 2.5% annually in the future, while the periurban areas will grow at 3.5%.

Building on these assumptions and various data sources and on discussion with people who have followed the development for the last three decades, this assessment has reached the prognosis as given in Table 7.6.

Table 7.6 Population Forecasts for Namibe Province ('000)

Year	Total Province	Namibe urban	Periurban	Rural
2000	238	58	67	119
2005	276	66	80	130
2015	371	84	112	175
2025	499	108	158	233

Short of any per capita water consumption data and forecasts, this assessment has adopted the same forecast assumptions as for neighbouring Benguela Province.

However, the losses in the water system are substantial. They are assumed to be the same as in other Angolan water supply networks, at 50% from the outset in 2005, but will gradually be reduced so that system efficiency reaches 60% in 2015 and 70% in 2025. This means that water extracted from the system to produce the per capita consumption rates is that much higher than the consumption rates.

This leads to the household water use supply forecasts given in Table 7.7.

Table 7.7 Domestic Water Supply Forecasts for Namibe Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Namibe Urban	6,960	9,240	12,600	23,143
Namibe periurban	1,005	1,200	3,360	4,740
Rural	1,785	1,950	5,250	6,990
Total province	**9,750**	**12,390**	**21,210**	**34,874**

Unit figures adopted from Table 7.2.

7.5 Cunene Province

Cunene province is another sparsely populated and predominantly rural province. Cunene is one of the Angolan provinces most affected by the war. The South African army occupied it for more than one year. After withdrawal of the South African army, Cunene province was permanently bombarded by South African aircrafts. Many of the inhabitants move between this southern Angolan province and Namibia to the south. The urban/periurban population is concentrated first of all in the provincial capital Ondjiva and to a lesser degree in Xangongo. In addition, Cuvelai and Cahama municipalities have significant urban settlements, but no Water Master Plan population data have been made available for them. In Cahama there, is amongst other things, a large slaughtering house killing more than 100 heads of cattle per day.

This assessment assumes an annual provincial population growth of 2.5% since its estimated 1994 level of 348,000, and maintains this growth rate for the forecast period. This has led to an estimated 2000 population of 404,000 and 456,000 for 2005. This fits closely with the OCHA 2004 estimate of 449,000.

The growth of the population of Ondjiva's and Xangongo's urban areas (housing category A) and periurban areas (categories B and C) is adopted from the Water Master Plan, and interpolations are made consistent with the implied growth rates of the Water Master Plan forecasts. However, the actual population of Ondjiva has been adjusted to 95,000 for 2004, and therefore 98,000 for 2005, based on a recent joint Angolan/Namibian river basin study there. For other urban areas, this assessment assumes they are all periurban and in category C, and that they constitute 20% of total provincial urban population.

The growth of household water use in Ondjiva's and Xangongo's urban areas (housing category A) and periurban areas (categories B and C) is adopted from the Water Master Plan. The assumed present and future per capita consumption per housing category is as presented in Table 7.2.

However, the losses in the water system are substantial at 50% from the outset, but will gradually be reduced so that system efficiency reaches 60% in 2015 and 70% in 2025. This means that water extracted from the system to produce the per capita consumption rates is that much higher than the consumption rates.

Table 7.8 Population Forecasts for Cunene Province ('000)

Area	2000	2005	2015	2025
Ondjiva category A	11	16	38	80
Ondjiva category B	00	23	29	42
Ondjiva category C	47	58	47	40
Ondjiva Urban/periurban total	**58**	**97**	**114**	**162**
Xangongo Category A	1	6	19	35
Xangongo Category B	5	10	24	45
Xangongo Category C	43	48	52	45
Xangongo urban/periurban total	**49**	**64**	**95**	**125**
Other periurban (category C)	27	35	52	72
Rural	270	260	323	389
Provincial Total	**404**	**456**	**584**	**748**

This leads to the following household water supply forecasts:

Table 7.9 Domestic Water Supply Forecasts for Cunene Province, (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Ondjiva category A	1,320	2,240	5,700	17,143
Ondjiva category B	000	920	2,030	3.360
Ondjiva category C	705	870	1,410	1,200
Ondjiva Urban/periurban total	**2,025**	**4,030**	**9,140**	**21,703**
Xangongo Category A	120	640	2,850	7,500
Xangongo Category B	150	400	1,680	3,600
Xangongo Category C	645	720	1,560	1,350
Xangongo urban/periurban total	**915**	**1,760**	**6,090**	**12,450**
Other periurban (category C)	405	525	1,560	2,160
Rural	4,050	3,900	9,690	11,670
Provincial total	**7.395**	**10,215**	**26,480**	**47,983**

7.6 Huila Province

Huila Province in the south has also been relatively little affected by the war, but the northeast of the province has experienced some changes because it has good development potentials. Table 4.3 shows Huila's 1994 population as 1.174 million. According to footnote i under Table 4.3, the total population of Huila province it was estimated to be 1.339 million for 1999 in the Water Master Plan. Assuming 2.5% growth as for the neighbouring Cunene province, this would mean a 2000 population of 1.372 million. The OCHA estimate for 2004 is 1,347,000.

The provincial capital Lubango was estimated to have 87,320 people in the urban network connected area in 1999, and 360,381 in periurban areas. With promising development prospects one could assume this population to grow at 4.5% annually in the future. There are several other towns in the province, but short of population statistics, it is assumed that these add up to 400,000 for year 2000,with 75% of them in housing category C, and will grow at an annual rate of 3% thereafter. The remaining population is classified as rural.

Table 7.10 Population Forecasts for Huila Province ('000)

Area	2000	2005	2015	2025
Lubango urban (category A)	50	62	97	150
Lubango urban (category B)	40	50	77	120
Lubango periurban (category B)	75	93	145	225
Lubango periurban (category C)	300	374	581	902
Lubango Total	**465**	**579**	**900**	**1,397**
Other periurban (category B)	100	116	156	209
Other periurban (category C)	300	348	468	627
Urban/periurban total	**865**	**1,043**	**1,524**	**2,233**
Rural (category C)	307	509	463	311
Provincial Total	**1,172**	**1,552**	**1,987**	**2,544**

The growth of household water use in Lubango and other urban areas in Huila Province and periurban areas is adopted from the Water Master Plan default tables for housing categories A, B and C. A constant consumption rate throughout the year is assumed at those low levels of consumption. The assumed present and future per capita consumption per housing category is as presented in Table 7.2.

However, the losses in the water system are substantial at 50% from the outset, but will gradually be reduced so that system efficiency reaches 60% in 2015 and 70% in 2025. This means that water extracted from the system to produce the per capita consumption rates is that much higher than the consumption rates.

This leads to the following household water supply forecasts for household uses:

Table 7.11 Domestic Water Supply Forecasts for Huila Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Lubango urban (category A)	6,000	8,680	14,550	32,143
Lubango urban + periurban (category B)	3,450	5,720	15,540	27,600
Lubango urban + periurban (category C)	4,500	5,610	17,430	27,060
Lubango total	**13,950**	**20,010**	**47,520**	**86,803**
Other periurban (category B)	3,000	4,640	10,920	16,720
Other periurban (category C)	4,500	5,220	14,040	18,810
Other Urban/periurban total	**7,500**	**9,860**	**24,960**	**35,530**
Rural (category C)	4,605	7,635	13,890	9,330
Provincial Total	**26,055**	**37,505**	**86,370**	**131,663**

7.7 Cabinda Province

Cabinda is isolated from the rest of the country. It is an enclave between the Republic of Congo Brazzaville and the Democratic Republic of Congo (DRC). It is one of the smallest provinces in terms of both area and population, but strategically of vital importance to Angola due to its wealth of petroleum resources.

INE estimated 181,000 people in Cabinda in 1995. Assuming a 3% growth rate, this would give 202,000 by year 2000 and 250,000 by 2005. OCHA, on the other hand, estimates the 2004 population to be 362,000. The assessment team has adopted the INE-prolonged data for its estimates of water use.

The provincial capital is the dominating city of the province. Assuming (as in the Water Master Plan database) a 3.5% annual population growth rate of the city, it would have had 172,000 people in year 2000, which was 85% of the provincial population. In the following water use assessment, the city population is assumed to grow at 3.5% annually, and thus takes on a growing share of the provincial population, which is assumed to grow at 3%.

As in the Water Master Plan database, it is assumed that an increasing share of the city population will be covered by the water supply network; growing from 60% in 2000, to 63% in 2005, 70% in 2015 and reaching 80% by 2025.

Table 7.12 Population Forecasts for Cabinda Province (‘000)

Area	2000	2005	2015	2025
Cabinda urban covered by water network	103	128	201	325
Cabinda City Periurban	69	76	87	81
Remaining Periurban and Rural	30	46	48	32
Province Total	**202**	**250**	**336**	**438**

At the same time the daily per capita water consumption for this network-covered population is assumed to increase from 30 litres in 2000, to 40 litres in 2005, 55 litres in 2015, and 70 litres in 2025, as assumed in the Master Plan database. Those not covered by the network, both inside and outside the city, are assumed to follow the category C consumption forecast of 15 litres in 2000 and 2005, and 30 litres in 2015 and 2025.

However, the losses in the water system are substantial at 50% from the outset, but will gradually be reduced so that system efficiency reaches 60% in 2015 and 70% in 2025. This means that water extracted from the system to produce the per capita consumption rates is that much higher than the consumption rates.

Table 7.13 Domestic Water Supply Forecasts for Cabinda Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Cabinda urban covered by water network	6,180	10,240	18,425	32,250
Cabinda City Periurban	1,035	1,140	2,610	2,430
Remaining Periurban and rural	450	690	1,440	960
Province Total	**7,665**	**12,070**	**22,475**	**35,640**

7.8 Lunda Sul Province

Lunda Sul is a sparsely populated province bordering on Zaire with many war-affected returnees (170,000). It is predominantly a subsistence agriculture economy for the rural people, but has important diamond mining activities and power production.

The population estimates from INE for 1994 was 207,000, whereas other estimates for the early- to mid-1990s range from 125,000 to 158,000. Due to the war situation, it is assumed that the 2000 population was 200,000 and for the most part seeking safety in and around Saurimo. It is assumed that it will grow relatively slowly at 2% from 2000 to 2025 due to some out-migration to other provinces. OCHA’s 2004 estimate is 277,000 people.

The Water Master Plan assumes the provincial capital Saurimo to have lost population between 1995 and 2004. It assumes a 2004 population of 150,000. In this assessment the 2000 population is assumed to be the same. The forecasts for the city are those adopted in the Water Master Plan, and show a relatively rapidly growing population connected to a water system. The periurban population in category B also grows rapidly, while the remaining category C population and the rural population of the province stagnate.

Table 7.14 Population Forecasts for Lunda Sul Province ('000)

Area	2000	2005	2015	2025
Saurimo urban/periurban covered by water network (category A)	7	8	16	50
Saurimo Periurban (category B)	0	0	25	64
Saurimo Periurban (category C)	143	145	160	148
Remaining Provincial Periurban and rural (category C)	50	47	43	35
Province Total	**200**	**200**	**244**	**297**

Water consumption per capita per day during the forecast period is assumed to be as in Table 7.2, and the losses are assumed to develop as described for the other provinces. This leads to the following water supply forecasts to meet regional domestic demand for water.

Table 7.15 Domestic Water Supply Forecasts for Lunda Sul Province (m^3 per day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
Saurimo urban/periurban covered by water network (category A)	840	1,120	2,400	10,700
Saurimo Periurban (category B)	0	0	1,750	5,120
Saurimo Periurban (category C)	2,145	2,175	4,800	4,440
Saurimo total	2,985	3,295	8,950	20,260
Remaining Provincial Periurban and rural (categoryC)	750	705	1,290	1,050
Province total	**3,735**	**4,000**	**10,240**	**21,310**

7.9 Lunda Norte Province

Lunda Norte also borders on Zaire. Like Lunda Sul it is also sparsely populated, estimated at 362,000 in the corrected INE database for 1994. It was predominately subsistence agriculture-based in rural areas. At the same time, during the war large segments of the population moved away or to Dundo/Chitato for safe refuge, but the net effect was a drain on population also in Dundo, which was estimated to have had 109,000 people in 1999 and only 76,000 in 2004 (The Water Master Plan). Like in Lunda Sul, hydropower and diamonds form important resources that are being developed.

The 1994 corrected INE population estimate was 362,000. However, due to the war, this provincial population declined and is estimated to have dropped to 300,000 by 2000, and even further until peace occurred in 2002. This assessment assumes the provincial population to have recovered somewhat to 300,000 by 2005. Some 80,000 war-affected people have returned to their places of origin since the war ended.

The Water Strategy Document estimated the 2003 population of Dundo at 50,000 (down from 109,000 in 1999) and Chitato at 10,000. These cities are near each other and in the same catchment. In the following they will be treated as one "metropolitan" area called Dundo/Chitato.

This assessment assumes the Dundo/Chitato population of 2000 to have been 110,000, with 30,000 in category A urban area, and the remaining 80,000 in category C areas (including

Chitato's 10,000 population). Then, as a result of the war, the Dundo/Chitato population is assumed to have declined significantly, but since the war ended it has started to grow as people return from refuge. The Water Master Plan assumes a 3% per year growing Dundo population from 2004 and into the future, and one could add Chitato to this with 10,000 in category C housing as the 2005 estimate. The provincial total population is assumed to grow at 1% in the future up to 2025.

Using the Water Master Plan and the above Chitato assumptions in this way yields the following population forecast:

Table 7.16 Population Forecasts for Lunda Norte Province ('000)

Area	2000	2005	2015	2025
Dundo/Chitato urban/periurban covered by water network (category A)	30	14	24	42
Dundo/Chitato Periurban (category B)	0	0	9	30
Dundo/Chitato Periurban (category C)	80	73	80	80
Remaining Provincial Periurban and rural (category C)	190	213	218	214
Province Total	**300**	**300**	**331**	**366**

Domestic consumption and loss forecasts assumptions are the same as for Lunda Sul province.

Table 7.17 Domestic Water Supply Forecasts for Lunda Norte Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Dundo/Chitato urban/periurban covered by water network (category A)	3,600	1,960	3,600	8,988
Dundo/Chitato Periurban (category B)	0	0	630	2,400
Dundo/Chitato Periurban (category C)	1,200	1,095	2,400	2,400
Dundo/Chitato total	**4,800**	**3,055**	**11,300**	**13,788**
Remaining Provincial Periurban and rural (category C)	2,850	3,195	6,540	6,420
Province Total	**7,650**	**6,250**	**17,840**	**20,208**

7.10 Cuando Cubango Province

Cuando Cubango bordering on and with a subsistence farming population interacting with Namibia, is the second largest province in Angola with around 200,00 km^2, but has only somewhat more than 300,000 inhabitants. The Water Master Plan data available for this province were finalized in June 2004. The corrected INE 1994 statistics estimates suggested 312,000 people for the province in total. The province was a UNITAS' stronghold and a lot of people were affected. OCHA has recorded more than 550,000 war-returnees, and estimated the provincial population to be as high as 514,000 in 2004. This assessment considers that to be much too high, considering the number of war-affected people expected to move back to their places of origin. This assessment therefore adopts 351,000 as its 2005 forecast.

The 1994 INE statistics estimate 105,000 people for the provincial capital Menongue. A later estimate for 1999 suggested 109,000. As a result of the war, the Menongue population dropped significantly, estimated to 100,000 in 2000, and further to 76,000 in 2004, according to Water Master Plan estimates. A 3% annual growth is assumed for the future, assuming a sustained peace, and this gives 78,000 for 2005. The total provincial population is assumed to grow at 2% annually.

Table 7.18 Population Forecasts for Cuando Cubango Province ('000)

Area	2000	2005	2015	2025
Menongue urban (category A)	20	15	26	42
Menongue Periurban (category B)	0	0	10	28
Menongue Periurban (category C)	80	63	68	65
Menongue total	**100**	**78**	**104**	**135**
Remaining Provincial Periurban and rural (category C)	212	273	324	397
Province Total	**312**	**351**	**428**	**532**

Table 7.19 Domestic Water Supply Forecasts - Cuando Cubango Province (m^3/day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
Menongue urban (category A)	2,400	2,100	3,900	9,000
Menongue Periurban (category B)	0	0	700	2,240
Menongue Periurban (category C)	1,200	945	2,040	1,950
Menongue total	**3,600**	**3,045**	**6,640**	**13,190**
Remaining Provincial Periurban and rural (categoryC)	3,180	4,095	9,720	11,910
Province Total	**6,780**	**7,140**	**16,360**	**25,100**

7.11 Moxico Province

Moxico province borders on DRC and the Republic of Zambia, and is located between two largely rural and sparsely populated provinces (Lunda Sul and Cuando Cubango). Moxico is also very sparsely populated, with an estimated total population of 285,000 in 1994, according to the corrected INE estimates. It was affected by almost 250,000 war-affected returnees.

The provincial capital, Luena, was estimated to have 70,000 people in 2003, according to the Water Plan Strategy Paper. However, discussions and observations by the Assessment Team suggest that this is a serious underestimation. Due to the war, people moved to Luena and out of the province. Instead, it is assumed that 66% of the provincial population lives and will continue to live in Luena. No Water Master Plan data exist for this remote province. In this assessment it is assumed a 2000 provincial population of 240,000, growing from then at 2% per year, and a Luena population for year 2000 of 160,000, growing at 3% a year, with 10% in category A, 20% in category B, and 70% in category C as regards water use.

Table 7.20 Population Forecasts for Moxico Province ('000)

Area	2000	2005	2015	2025
Luena urban (category A)	16	18	24	32
Luena Periurban (category B)	32	35	48	64
Luena Periurban (category C)	112	122	163	220
Luena total	**160**	**175**	**235**	**316**
Remaining Provincial Periurban and rural (category C)	80	90	121	163
Province Total	**240**	**265**	**356**	**479**

The same default values for consumption and losses are assumed as in neighbouring provinces.

Table 7.21 Domestic Water Supply Forecasts for Moxico Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Luena urban (category A)	1,920	2,520	3,600	6,848
Luena Periurban (category B)	960	1,400	3,360	5,120
Luena Periurban (category C)	1,680	1,830	4,890	6,600
Luena total	**4,560**	**5,750**	**11,850**	**18,568**
Remaining Provincial Periurban and rural (categoryC)	1,200	1,350	3,630	4,890
Province Total	**5,760**	**7,100**	**15,480**	**23,458**

7.12 Zaire Province

Available population data for Zaire province should be used cautiously. The province has experienced substantial refuge flows into the Congo Republic during the war, and it is as yet not clear what will be future population flows and growth.

The provincial population was estimated in the U.K. Angola Embassy web-page for 1992 at 600,000. Later an initial INE estimate said 234,000, which was subsequently revised to 178,000. This latter population estimate is retained as the estimated 2000 and 2005 population of this war-ridden province, and 2% net population growth is projected, even if the OCHA estimate for 2004 is 285,000. This growth is assumed for Soyo as well. The disaggregation of this estimate concluded with 63,000 in M'banza Congo, 40,000 in Soyo, and 26,000 in N'Zeto.

The Water Strategy Paper of 2003 estimated a reduced 2003 urban population of the province at 125,000 (see Table 4.3, footnote l). The provincial capital M'banza Congo was estimated to have 50,000, while the other urban population was located in Soyo (45,000), Tomboco (10,000) and N'Zeto (20,000).

The preliminary Water Master Plan data for M'banza Congo suggest a 2004 population of 51,000 and an average water use per person per day of 40 litre, growing to 55 litres in 2015 and 70 litres in 2025. The population of M'banza Congo and N'Zeto is assumed to grow by 3.5% annually. These are average covering the entire urban population of M'banza Congo, and no disaggregation into housing categories A, B and C has been provided so far.

For forecasting purposes in this assessment it is assumed that 10% of this population is in category A, 20% in B and the rest in C, along with the rural population and the urban population of the other three listed cities. The earlier listed default consumption figures for these categories are then applied in the forecasts. The efficiency of the system in M'banza Congo is estimated to be 50% in 2004 (2005), 60% in 2015, and 70% in 2025.

For forecasting present and future water use, M'banza and N'Zeto are grouped as belonging to the same catchment, whereas Soyo is located in the Congo Basin. Both Soyo and N'Zeto are assumed to have only category C housing types.

Table 7.22 Population Forecasts for Zaire Province ('000)

Area	2000	2005	2015	2025
M'banza Congo urban (category A)	5	5	10	14
M'banza Congo Periurban (category B)	10	10	20	28
M'banza Congo and N'Zeto Periurban (category C)	56	56	70	99
M'banza Congo and N'Zeto total	**71**	**71**	**100**	**141**
Soyo periurban (Category C)	45	45	55	67
Remaining Provincial Periurban and rural (category C)	133	133	62	62
Province Total	**249**	**249**	**217**	**270**

The same default values for consumption and losses are assumed as in other provinces.

Table 7.23 Domestic Water Supply Forecasts for Zaire Province (m^3 per day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
M'banza Congo urban (category A)	600	700	1,500	2,996
M'banza Congo Periurban (category B)	300	400	1,400	2,240
M'banza Congo and N'Zeto Periurban (category C)	840	840	2,100	2,970
M'banza Congo and N'Zeto total	**1,740**	**1,940**	**5,000**	**8,206**
Soyo periurban (Category C)	675	675	1,650	2,010
Remaining Provincial Periurban and rural (category C)	1,995	1,995	1,860	1,860
Province Total	**4,410**	**4,610**	**8,510**	**12,076**

7.13 Cuanza Norte Province

Cuanza Norte is one of the more densely populated provinces, with an INE-estimated 323,000 population in 1994 on its 24,110 km^2 of land area. The earlier estimated population was around 400,000 but the war resulted in people moving towards Luanda.

OCHA estimated a 551,000 population, but this includes a large number of war-affected people to return to their places of origin. For this assessment it is estimated that the 2000 provincial population is 300,000 of which 90,000 in the provincial capital N'Dalatando, and 10,000 in the town of Lucala to its east but in the same catchment. Another 100,000 inhabitants are assumed to live in other towns, so that the rural population is 100,000 as well.

The Water Master Plan estimated the N'Dalatando population in 2002 at 94,270. The Water Strategy Paper estimated the 2003 population of N'Dalatando at 95,000. Based on these estimates, it is assumed here that the year 2000 population was distributed with 12,000 living in category A housing conditions, and 78,000 in category C conditions. All other province dwellers were assumed to live in category C conditions.

The population of N'Dalatando is projected to grow by 3% annually from 2002. The remaining urban population is assumed here to remain constant, and the rural population likewise. This gives a future population profile as shown in Table 7.23.

Table 7.24 Population Forecasts for Cuanza Norte Province ('000)

Area	2000	2005	2015	2025
N'Dalatando urban (category A)	12	13	30	62
N'Dalatando Periurban (category B)	0	0	24	53
N'Dalatando and Lucala Periurban (category C)	88	100	95	100
N'Dalatando/Lucala total	**100**	**113**	**149**	**215**
Remaining Provincial Periurban and rural (category C)	200	200	200	200
Province Total	**300**	**313**	**349**	**415**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.25 Domestic Water Supply Forecasts for Cuanza Norte Province (m^3/day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
N'Dalatando urban (category A)	1,440	1,820	4,500	13,268
N'Dalatando Periurban (category B)	0	0	1,680	4,240
N'Dalatando and Lucala Periurban (category C)	1,320	1,500	2,850	3,000
N'Dalatando and Lucala total	2,760	3,320	9,030	20,508
Remaining Provincial Periurban and rural (category C)	3,000	3,000	6,000	6,000
Province Total	**5,760**	**6,320**	**15,030**	**26,508**

7.14 Cuanza Sul Province

No Water Master Plan data are available for this war-ridden province estimated by INE to have had 820,000 people in 1994. People had come from Huambo during the war, but some also moved towards Luanda. The net inflow of war-affected people made OCHA estimate a provincial population of 1.1 million. However, after the war a lot of people have moved back to Huambo. Short of any new census data or estimates, it is assumed that the 2000 provincial population was reduced to 700,000, and is projected to remain constant at that level in the future.

The urban population was estimated in the Water Strategy Paper for 2003 to be 140,000 in the provincial capital Sumbe, 40,000 in Porto Amboin and 30,000 in Gabela. Short of other data, it is assumed that these population figures were valid for 2000 as well. However, after the war ended, people have moved significantly both within and out of the province. In this assessment, it is assumed that the capital city Sumbe will have 150,000 inhabitants in 2005, and then increase by 3% annually. Porto Amboin on the other hand is assumed to remain at 40,000 for 2005 and in the future, while Gabela is believed to have increased to 60,000 in 2005, and will remain at that level. In addition, due to rapid movement of people to the south eastern agricultural part of the province, Waco Kungo has grown rapidly recently, and is assumed to have grown from 10,000 to 40,000 between 2000 and 2005, and is projected to grow at 3% thereafter.

Short of data regarding types of housing, it is assumed that 10% of the Sumbe population will be and remain in category A, housing, 20% in category B, and the rest in category C. For the other cities, category C is assumed throughout.

Table 7.26 Population Forecasts for Cuanza Sul Province ('000)

Area	2000	2005	2015	2025
Sumbe urban (category A)	14	15	20	27
Sumbe Periurban (category B)	28	30	40	54
Sumbe Periurban (category C)	98	105	142	190
Sumbe total	**140**	**150**	**202**	**271**
Porto Amboim, Gabela, Waco Kungo periurban category C	80	140	154	172
Remaining Provincial Periurban and rural (category C)	380	410	344	257
Province Total	**600**	**700**	**700**	**700**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.27 Domestic Water Supply Forecasts for Cuanza Sul Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Sumbe urban (category A)	1,680	2,100	3,000	5,778
Sumbe Periurban (category B)	840	1,200	2,800	4,320
Sumbe Periurban (category C)	1,470	1,575	4,260	5,700
Sumbe total	**3,990**	**4,875**	**10,060**	**15,798**
Porto Amboim, Gabela, Waco Kungo periurban category C	1,200	2,100	4,620	5,160
Remaining Provincial Periurban and rural (category C)	5,700	6,150	10,320	7,710
Province Total	**10,890**	**13,125**	**25,000**	**28,668**

7.15 Malange Province

Malange province has experienced significant people movements internally as well as between provinces during and since the war. Due to its development potentials in agriculture and mining, it is assumed to be an attractive province which will experience 3% overall population growth, a number which is adopted for the entire period since the corrected 1994 INE estimate of 754,000 population. This exceeds the OCHA estimate of 824,000 for 2004.

It would appear that the large majority of the provincial population (perhaps 80%) live in the Cuanza basin, i.e. the western part of the province, whereas only a small portion (perhaps 20%) of the people live in the Congo basin to the east.

Malange city is the provincial capital. It is estimated by the provincial authorities to have grown rapidly and doubled its population from 150,000 in 2000 to 291,000 in 2005 (Water Master Plan estimate). The future population growth, and housing type distribution of the city is projected to be in line with the Water Master Plan forecasts.

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.28 Population Forecasts for Malange Province ('000)

Area	2000	2005	2015	2025
Malange urban (category A)	10	21	71	150
Malange Periurban (category B)	0	0	80	163
Malange Periurban (category C)	140	270	279	271
Malange urban/periurban total (Cuanza basin)	150	291	430	584
Remaining Provincial Periurban and rural (category C) in the Cuanza basin	600	602	778	1,086
Remaining Provincial Periurban and rural (category C) in the Congo basin	150	151	195	272
Province Total	**900**	**1,044**	**1,403**	**1,942**

Table 7.29 Domestic Water Supply Forecasts for Malange Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Malange urban (category A)	1,200	2,940	10,650	32,100
Malange Periurban (category B)	0	0	5,600	13,040
Malange Periurban (category C)	2,100	4,050	8,370	8,130
Malange urban/periurban total (Cuanza Basin)	3,300	6,990	24,620	61,640
Remaining Provincial Periurban and rural (category C) in the Cuanza basin	9,000	9,030	23,340	32,580
Remaining Provincial Periurban and rural (category C) in the Congo basin	2,250	2,265	5,850	8,160
Province Total	**14,550**	**18,285**	**53,810**	**102,380**

7.16 Bie Province

Before independence, Bie was one of the most populated provinces of Angola, and Kuito one of the largest cities. Bie Province suffered a lot during the war and large number of people fled to Luanda, Huila and Huambo.

INE estimated the provincial population to have dropped to 774,00 in 1994. After the war, a lot of people have moved back, but no reliable statistics exist. OCHA estimated the 2004 population to be 1,016,000. It is the best judgement of the assessment team that the province population has surpassed 1 million by far; in fact, Bie has more people that Benguela province. It is therefore assumed that it had 1.3 million in 2000 and is growing.

This assessment assumes that half a million of that year 2000 population is located in Kuito. Due to data uncertainty, and the fact that INE and other estimates are considerably smaller, this assessment assumes both the provincial and the Kuito population to increase throughout the 2000-2025 period by 3% annually.

From the perspective of this water balance assessment, the entire Bie population belongs to the Cuanza catchment.

Table 7.30 Population Forecasts for Bie Province ('000)

Area	2000	2005	2015	2025
Kuito urban (category A)	15	30	60	150
Kuito Periurban (category B)	0	0	30	60
Kuito Periurban (category C)	485	550	690	837
Kuito urban/periurban total (Cuanza basin)	500	580	780	1,047
Remaining Provincial Periurban and rural (category C) in the Cuanza basin of Bie	800	927	1,245	1,674
Province Total (all in Cuanza catchment)	**1,300**	**1,507**	**2,025**	**2,721**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.31 Domestic Water Supply Forecasts for Bie Province (m^3 per day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
Kuito urban (category A)	1,800	4,200	9,000	32,100
Kuito Periurban (category B)	0	0	2,100	4,800
Kuito Periurban (category C)	7,275	8,250	20,700	25,110
Kuito urban/periurban total (Cuanza basin)	9,075	12,450	31,800	62,010
Remaining Provincial Periurban and rural (category C) in the Cuanza basin of Bie	12,000	13,905	23,400	31,410
Province Total (all in Cuanza catchment)	**21,075**	**26,355**	**55,200**	**93,420**

7.17 Huambo Province

Huambo is traditionally one of the most populated provinces but it was much disrupted during the war. Population estimates vary widely. The original INE estimate for 1994 was 1.64 million. This was revised downwards by INE to 1,094,000. Data produced for the Water Master Plans estimated the Huambo provincial population to be 1,948,000 in 1999 and 3 million in 2000.

In view of the many people who left the province during the war, this 2000 estimate is considered much too high by the assessment team. At the same time, the OCHA estimate for 2004 of 1,148,00 is considered far too low, since it is generally accepted that Huambo and Bie in the post-war period will have approximately the same population size and internal distributions (urban/rural), and be somewhat larger than Benguela.

An estimate of 1.3 million for 2000 and an annual growth rate of 3% is the basis for the water use forecasts of this assessment. This should allow for the number of returnees after the war.

As for the urban population and its growth, Huambo city is assumed to grow at a rate from 2005 that results in the same urban/periurban population forecasts as for Kuito.

Table 7.32 Population Forecasts for Huambo Province ('000)

Area	2000	2005	2015	2025
Huambo urban (category A)	15	30	60	150
Huambo Periurban (category B)	0	0	30	60
Huambo Periurban (category C)	485	550	690	837
Huambo urban/periurban total (Cunene basin)	**500**	**580**	**780**	**1,047**
Remaining Provincial Periurban and rural (category C) in the Cunene basin	800	928	1,245	1,674
Province Total (all in Cunene catchment)	**1,300**	**1,508**	**2,025**	**2,721**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.33 Domestic Water Supply Forecasts for Huambo Province (m^3 per day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
Huambo urban (category A)	1,800	4,200	9,000	32,100
Huambo Periurban (category B)	0	0	2,100	4,800
Huambo Periurban (category C)	7,275	8,250	20,700	25,110
Huambo urban/periurban total (Cunene basin)	**9,075**	**12,450**	**31,800**	**62,010**
Remaining Provincial Periurban and rural (category C) in the Cunene basin of Bie	12,000	13,905	23,400	31,410
Province Total (all in Cunene catchment)	**21,075**	**26,355**	**55,200**	**93,420**

7.18 Uige Province

Uige Province, bordering on DRC, suffered considerably during the war and many people fled the province. There is no available Water Master plan for Uige, and available population estimates for the mid-1990s range from 7 to 900,000 with the corrected INE estimate of 1994 of 702,000 as the most recently adjusted one. However, with the ending of the war, lots of people having fled the country are now returning, and a better 2005 estimate would be 1.2 million, and a growth rate of 3%. This estimate corresponds with the OCHA 2004 estimate of 1,321,000.

As regards urban population, the province capital Uige is estimated to have 152,000 people in 1994, and 140,000 in the Water Strategy documents estimate for 2003. However, neither estimate appears in line with what appears to be the city population. It is assumed for this study to be 200,000 for 2005, up from 168,000 in 2000. There is no data to suggest growth rates neither for the province nor for the city, but informed guesstimates would suggest 3.5% due to the return of refugees and the potential for absorbing people.

It is further assumed that 10% of the city population enjoys housing category A, 20% live in housing category B, and the rest in category C. So do the rest of the periurban and rural population of the province.

Table 7.34 Population Forecasts for Uige Province ('000)

Area	2000	2005	2015	2025
Uige urban (category A)	17	20	28	40
Uige Periurban (category B)	34	40	56	80
Uige Periurban (category C)	117	140	198	278
Uige urban/periurban total	**168**	**200**	**282**	**398**
Remaining Provincial Periurban and rural (category C)	832	1,000	1,411	1,990
Province Total	**1,000**	**1,200**	**1,693**	**2,388**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.35 Domestic Water Supply Forecasts for Uige Province (m^3 per day)
(actual consumption plus network losses)

Area	2000	2005	2015	2025
Uige urban (category A)	2,040	2,800	4,200	8,560
Uige Periurban (category B)	1,020	1,600	3,920	6,400
Uige Periurban (category C)	1,755	2,100	5,940	8,340
Uige urban/periurban total	**4,815**	**6,500**	**14,060**	**23,300**
Remaining Provincial Periurban and rural (category C)	12,480	15,000	42,330	59,700
Province Total	**17,295**	**21,500**	**56,390**	**83,000**

7.19 Bengo Province

No report or Water Master Plan was available for Bengo province and its capital city Caxito. The INE estimated population for 1994 was 215,000. There is no information as to population development during the war, but the war resulted in significant redistribution of people from the inner areas towards the areas near Luanda. Close to 100,000 such people are now returning to their origins. OCHA estimates the 2004 population to be 322,000, but this assessment applies a lesser population of 200,000 for 2000, growing to 220,000 by 2005. There are three main cities in the province, whose population was estimated in the Water Strategy Paper for 2002: Caxito (20,000), Dondo (30,000) and Catete (10,000), and these populations are assumed to grow at the same 3% annual rate as the province as a whole.

Table 7.36 Population Forecasts for Bengo Province ('000)

Area	2000	2005	2015	2025
Caxito urban (Category A)	5	6	9	13
Caxito Periurban (Category C)	15	17	22	30
Caxito urban/periurban total (Dande basin)	**20**	**23**	**31**	**43**
Dondo/Catete urban (Category A) (Cuanza Basin)	5	6	9	13
Dondo/Catete urban (Category C) (Cuanza Basin)	35	40	53	73
Dondo/Catete urban/periurban (Cuanza Basin)	**40**	**46**	**62**	**86**
Remaining Provincial Periurban and rural (Category C)	140	163	219	302
Province total	**200**	**232**	**312**	**431**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.37 Domestic Water Supply Forecasts for Bengo Province (m^3 per day) (actual consumption plus network losses)

Area	2000	2005	2015	2025
Caxito urban (category A)	600	840	1,350	2,782
Caxito Periurban (category C)	225	255	660	900
Caxito urban/periurban total (Dande Basin)	**825**	**1,095**	**2,010**	**3,682**
Dondo and Catete urban/periurban (Category A)	600	840	1,350	2,782
Dondo and Catete urban/periurban (Category C)	525	600	1,860	2,190
Dondo/Catete urban/periurban (Cuanza Basin)	**1,125**	**1,440**	**3,210**	**4,972**
Remaining Provincial Periurban and rural (Category C)	2,100	2,445	6,750	9,060
Province Total	**4,050**	**4,980**	**11,970**	**17,714**

7.20 Luanda

Estimates of Luanda's population and growth rate vary substantially. The INE-corrected estimate for 1994 concluded with 1.995 million people, The Water Master Plan estimated the 2000 population to be 2.894 million.

OCHA estimated a 2004 population of 2.935 million, while the Water Strategy Paper concluded with 4 million for 2003. There now seems to be wide agreement that the 2005 Luanda population will be between 4 and 5 million. Based on this set of estimates, this assessment concludes with 3 million for year 2000, and 4.2 million for 2005, growing to 6.2 million in 2015 and 8.3 million by 2025.

The latest Water Master Plan data available to the assessment team provides a forecast of the distribution between "modern", "transition" and "periphery/greenbelt" housing categories of Luanda's population for 2000, 2005 and 2010. These three categories are assumed to correspond to categories A, B and C used for all other provinces in this assessment.

The Master Plan forecasts for Luanda assume the relative share of people living in "modern" (category A) dwellings to decline from 9.2% in 2000, to 6.6% in 2005 and 4.9% in 2010. This assessment assumes that future oil and diamond revenues of Angola - along with municipal user charges and taxes - will provide the basis for increased urban infrastructure investments so as to stop this deteriorating trend and stabilize the shares at the 2010 level for the remaining 2010-2025 forecast period.

The transition population (Category B) declines from 17.2% in 2000, via 13.4% in 2005, to 10.7% in 2010, and is assumed to remain at that level. The category C population is assumed to increase its share from 73.6% in 2000, via 80% in 2005, to 84.4% in 2010 and remain there.

This leads to the following future distribution of the forecasted Luanda population as regards water use categories:

Table 7.38 Population Forecasts for Luanda ('000)

Area	2000	2005	2015	2025
Luanda urban (category A)	288	277	304	407
Luanda Periurban (category B)	516	563	663	888
Luanda Periurban (category C)	2,196	3,360	5,233	7,005
Luanda urban/periurban Total	**3,000**	**4,200**	**6,200**	**8,300**

The same default values for consumption and losses and their respective change over time are assumed as in other provinces.

Table 7.39 Domestic Water Supply Forecasts for Luanda (m^3 per day)

(actual consumption plus network losses)

Area	2000	2005	2015	2025
Luanda urban (category A)	34,560	38,780	45,600	87,098
Luanda Periurban (category B)	15,480	22,520	46,410	71,040
Luanda Periurban (category C)	32,940	50,400	156,990	219,150
Luanda urban/periurban Total	**82,980**	**111,700**	**249,000**	**368,288**

7.21 Catchment-wise Representation of Household Water Use Forecasts

The domestic water supply forecasts as presented in the foregoing tables have been designed for easy disaggregation into catchments. They were entered into the GIS water resources database on a catchment basis by first splitting each province up into its various catchments and, using the satellite maps of the locations of the towns, villages and settlements in each catchment, allocating first the urban and periurban figures to the correct catchment in the province.

Next the remaining rural population figures were distributed to the various catchments proportionately to the intensity of settlements in each catchment as indicated by the satellite imagery. The result is a catchment distribution of the forecasts within each province.

Catchments which straddle province boundaries were dealt with as sub catchments within each province, the total of the various provincial sub catchments then being summed by the GIS system to arrive at total catchment figures for further processing and presentation. The catchment-wise population and domestic water consumption forecast breakdowns are given in Table 7.40 and in Figure 7.1.

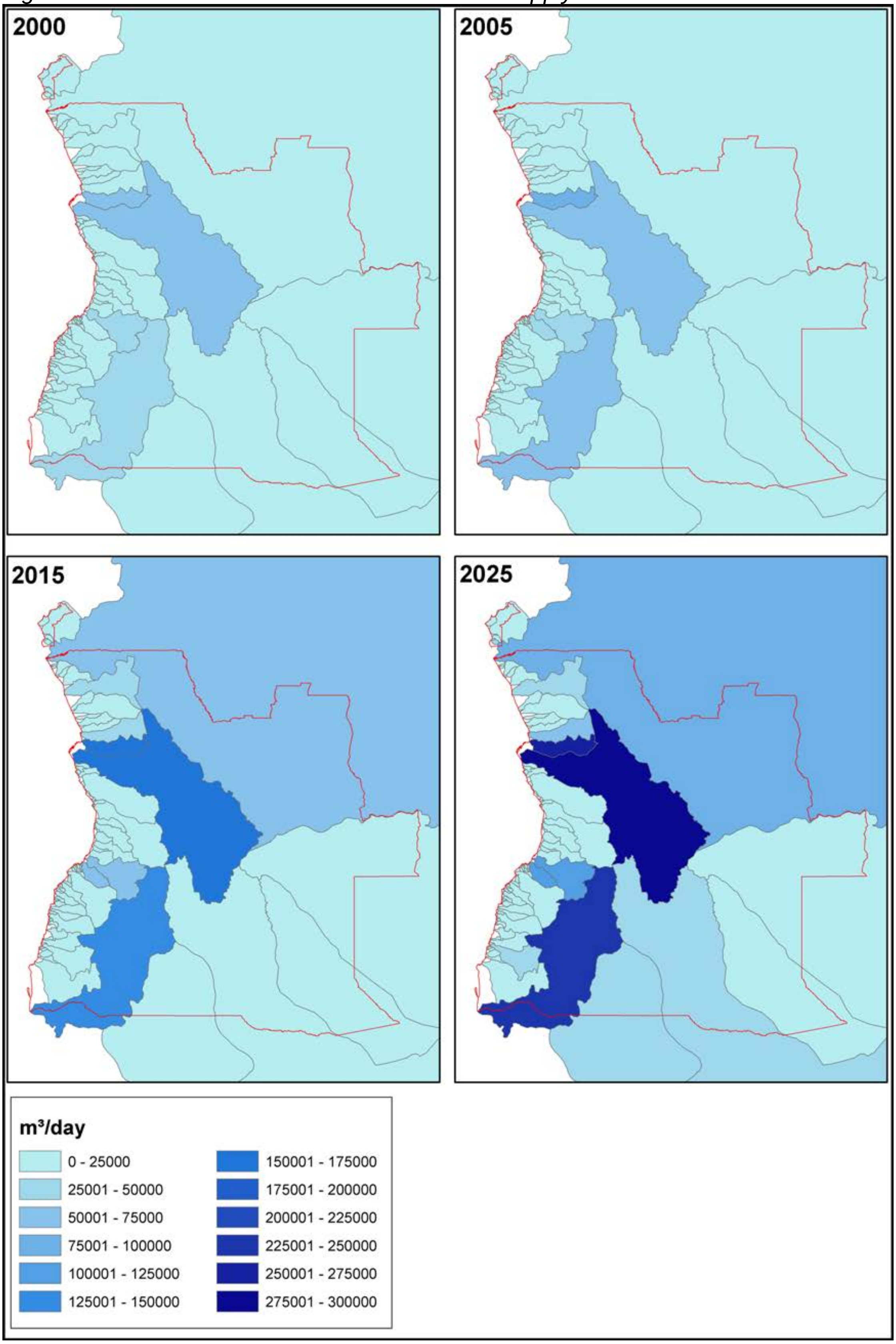
Close inspection of the figures in Table 7.40 shows that, in certain catchment areas, the population their has growth to 2005 and declines thereafter towards 2025. There are good reasons for such assumptions, namely that a substantial population location imbalance caused by the civil war is in the process of being gradually rectified. This implies that a lot of people will move within and between provinces (and hence catchments), and this results in more than average population growth in some catchments and a decline in some others. The individual population development numbers up towards 2025 for each catchment are meant to reflect the gradual correction of such historic imbalances, but obviously, with the poor population data at hand, such forecasts are highly uncertain. We do not, however, know of any better or more reliable population forecasts at this level of geographic disaggregation.

Table 7.40 Catchment-wise Population and Domestic Water Supply Forecasts

	NAME	Population				Domestic Water Use (m³/day)			
		2000	2005	2015	2025	2000	2005	2015	2025
1	Lubinda	3,200	4,907	5,120	3,413	48	74	154	102
2	Chiloanga	24,000	36,800	38,400	25,600	360	552	1152	768
3	Lulondo	2,000	3,067	3,200	2,133	30	46	96	64
4	Lucula	172,000	204,000	288,000	406,000	7,215	11,380	21,035	34,680
5	Zaire	1,177,731	1,270,671	1,643,190	2,164,831	22,226	22,685	62,126	90,549
6	Zombo	2,472	2,472	1,625	1,792	37	37	49	54
7	Luela	2,472	2,472	1,625	1,792	37	37	49	54
8	Lucolo	17,306	17,306	11,375	12,542	260	260	341	376
9	Sange	4,944	4,944	3,250	3,583	74	74	98	108
10	Lucunga	19,778	19,778	13,000	14,333	297	297	390	430
11	M'Bridge	505,076	580,180	725,269	998,155	9,871	12,203	27,358	41,305
12	Sembo	7,417	7,417	4,875	5,375	111	111	146	161
13	Loge	86,938	104,222	146,491	206,249	1,304	1,563	4,404	6,187
14	Uezo	601	700	940	1,296	9	10	29	39
15	Onzo	9,614	11,193	15,039	20,738	144	168	464	622
16	Lifune	19,828	23,086	31,017	42,773	297	346	956	1283
17	Dande	632,509	839,857	1,203,740	1,607,959	15,856	20,840	46,939	68,983
18	Bengo	2,151,693	2,985,128	4,376,232	5,839,697	58,569	78,492	174,923	257,775
19	Cuanza	2,844,186	3,411,304	4,622,503	6,221,152	52,916	67,412	160,486	277,347
21	Sangando	601	700	940	1,296	9	10	29	39
22	Cabo Ledo	601	700	940	1,296	9	10	29	39
23	Mengueje	601	700	940	1,296	9	10	29	39
25	Longa	67,900	74,286	69,387	63,717	1,018	1,114	2,097	1,912
27	Quiteta	657	709	595	445	10	11	18	13
30	Oueve	230,241	302,212	291,044	275,906	3,454	4,533	8,731	8,277
31	N'Gunza	184,706	198,235	242,471	301,235	4,661	5,599	11,274	16,705
32	Quicombo	83,871	90,823	79,036	63,612	1,258	1,362	2,371	1,908
34	Evale	12,868	14,214	14,759	15,591	193	213	443	468
35	Balombo	73,647	84,086	110,209	146,242	1,105	1,261	3,306	4,387
36	Cuhula	3,319	3,801	5,078	6,837	50	57	152	205
37	Cubal Da Hanha	43,149	49,418	66,014	88,879	647	741	1,980	2,666
38	Catumbela	657,503	721,955	961,294	1,282,159	27,659	40,553	67,212	117,574
39	Cavaco	377,915	480,809	648,468	869,021	17,639	35,837	56,534	102,247
40	Curinge	830	950	1,270	1,709	12	14	38	51
42	Mormolo	1,660	1,901	2,539	3,418	25	29	76	103
43	Pima	830	950	1,270	1,709	12	14	38	51
46	Coporolo	32,439	42,728	49,812	56,258	538	740	1,707	2,045
48	Lua	830	950	1,270	1,709	12	14	38	51
49	Equimina	1,660	1,901	2,539	3,418	25	29	76	103
51	Calongolo	830	950	1,270	1,709	12	14	38	51
53	Catara	4,760	5,200	7,000	9,320	71	78	210	280
57	Carunjamba	7,140	7,800	10,500	13,980	107	117	315	419
58	Inamagando	4,760	5,200	7,000	9,320	71	78	210	280
60	Bentiaba	21,420	23,400	31,500	41,940	321	351	945	1,258
62	Chilulo / Chapéu Armado	2,380	2,600	3,500	4,660	36	39	105	140
64	Mutiambo	9,520	10,400	14,000	18,640	143	156	420	559
66	Giraul	28,318	32,893	42,105	53,130	439	522	1,324	1,696

	NAME	Population				Domestic Water Use (m³/day)			
		2000	2005	2015	2025	2000	2005	2015	2025
67	Bero	164,319	204,317	264,722	344,316	8,711	11,442	18,296	30,692
69	Subida Grande	2,380	2,600	3,500	4,660	36	39	105	140
72	Curoca	55,239	65,388	80,878	97,817	872	1,066	2,609	3,240
73	Cunene	2,501,644	3,020,716	4,022,883	5,346,401	47,286	63,165	143,188	232,963
74	Zambeze	220,412	242,963	326,373	439,089	5,466	6,769	14,591	22,261
75	Cubango	391,886	461,034	548,868	650,883	8,220	9,257	20,991	30,349
76	Cuando	53,640	67,496	81,825	102,049	805	1012	2,455	3,061
77	Cuvelai	142,760	181,513	221,313	293,916	3,296	5,298	12,359	25,660

Figure 7.1 Catchment-wise Domestic Water Supply Forecasts



(For catchment names/numbers see Figures 12.1 a, b, c and d. Catchments shown in white are areas with no available population distribution data.)

8. INDUSTRY & MINING ACTIVITIES

8.1 The Challenge of Accessing Reliable Data for Industry and Mining

Updated information on water intensive industrial and mining activities is very difficult to obtain in Angola. There is some information on the government website Angola.org, this is, however, dated from 1995. In order to secure more detailed and up-to-date information and data, meetings were planned with three main institutions:

- Ministry of Industry
- Ministry of Geology and Mines
- Endiama, the national diamond mining company

At the time of writing this report, the meetings with the Ministry of Industry and Endiama were still pending. A meeting was held with the Ministry of Geology and Mines but no information could be given. This was due to the Ministry's request for payment for supplying such information for which there is no facility under the Consultant's contract. This has been brought to the attention of DNA and it is hoped that this matter can be resolved in the future development of the assessment by DNA.

As a result of the lack of available data on this issue, it has not been possible to develop firm scenarios of the growth of industrial and mining industries, let alone forecasts for the use of water resources for production and as a recipient for wastes and effluents. This is a bottleneck that should be prioritized in the further development of the assessment. One line of action for achieving this could be ministerial collaboration between the Ministry of Energy and Water and the Ministry of Geology and Mines. Mutual exchange of information and data could be beneficial to both parties in this respect.

8.2 Location of Industries and Mines

Besides the dominating petroleum sector activities, Angola's main industrial activity is mining of diamonds, for the most part in the sparsely populated provinces of Lunda Norte and Lunda Sul. The activity is apparently concentrated along the Tchicapa river where two diamond mining companies, Catoca and Alrosa, are active in building hydropower dams (24 MW and 16 MW respectively) to supply their mining operations, and for selling surplus power to the province.

However, the country is rich in minerals and extraction takes place for iron ore, phosphates, feldspar, bauxite, uranium, and gold at various locations.

Industrial production includes refining and downstream petroleum-related production, cement, metal products, fish processing, brewing, tobacco products, sugar and textile. However, as a result of the war, almost all industrial activity was closed down. Those that still operate are found in the large cities, such as Luanda, or they are rather self-sufficient mining operators with their own water supply systems, e.g. along the Tchicapa river in Luanda Sul.

The Fina Petroleos de Angola refinery in Luanda processes crude oil, and shall have the capacity to process 60,000 bbl/d as of the end of 2004, and it produces virtually all of Angola's domestic requirements for gasoline, kerosene and jet fuel, as well as a small amount of products for exports, according to the EIA web-page.

Another refinery, this one planned for 200,000bbl/d capacity is to be built near Lobito in Benguela Province, and is scheduled for operation by 2007 at the earliest.

The one specific water use estimate related to industrial production is from the Water Master plan document for Huambo city. For this city there are four industrial sectors listed, with each enterprise identified. For each enterprise, the daily production capacity is presented along with the water consumption per m^3 of output, such as 20 m^3 per m^3 of daily output of beers and fresh drink output, totalling 5,000 m^3 of water use per day for this industry. For the conserves industry in Huambo, the water use per tonne of output is also 20 m^3, totalling 160 m^3 per day. For the casting industry water consumption is 85 m^3 per tonne, totalling 127.5 m^3 per day, and finally for production of soaps and detergents, where 2 m^3 per tonne is required, the daily water use is 61.2 m^3. Ink is also produced in Huambo, but the quantity is so small (1.1 tonne per day) that with a water need of 1.6 m^3 per tonne, the daily use is 1.7 m^3.

8.3 Industrial Water Use

The specific industrial water use estimates from the Water Master Plan data for Huambo city could be interesting and useful for use as default parameters for other cities if their relative order of magnitude to category A urban water users could be assumed to be transferable from the Huambo setting to other Angolan cities. In that case, similar estimates and data could be prepared for all major cities, but so far data is available for Huambo only, and furthermore, it is not quite clear for what year these industrial water use data apply (although it says 2025) in the Huambo document by COBA et al). Regardless of year, what is clear is that compared to overall domestic water consumption, industrial use in Huambo is a relatively minor public network water user. It has not therefore been possible/practicable to include industrial water use in the Rapid Water Use Assessment Database.

On the other hand, there is no reason – given the very modest role of processing industry and manufacturing in Angola at present – to assume the industry use of the capacity of water networks in other cities to be much different from that observed in the Water Master Plan preparations for Huambo. If that can be assumed to hold as a valid hypothesis, industry water use is not a constraining demand factor that will lead to water deficits during the forecasting period.

8.4 Water Quality

According to Neto and Mendes[1], during the war periods, there was no substantial pollution of land water because industrial production was insignificant. A certain amount of pollution does, however, exist in the rivers of Lunda-Norte Province because of diamond mining, the recipient rivers being tributaries of the Casai River in Zaire. An increase in manufacturing and mining after the war could, however, create higher levels of water pollution.

In Luanda, the EPAL water analysis laboratory, located at Marçal, monitors the water quality. Raw water for drinking water production is taken either from the Rio Bengo (at Marçal and Kifangondo plants) or from Rio Kwanza (at the Kikuxi plant). Both rivers have regulating dams upstream and for this reason the water quality is relatively stable over the year. Apparently only the Bengo River intake water is analysed, testing for turbidity, O_2, colour, mineral salts, hardness, alkalinity and conductivity. Although heavy metal content is not monitored, these rivers, lacking any heavy industry, are not expected to bear such pollutants. Consequently, the Rio Bengo water is said to be satisfactory for human consumption after normal coagulation-sedimentation-filtration, giving water of low salt content.

1 Water Resources Management in Angola; Water Resources Management in Sub-Saharan Africa, Nairobi, 12-15 February 1996, Felix M. Neto and Paulo Emilio Mendes.

9. NON-CONSUMPTIVE USE OF WATER RESOURCES

9.1 Hydropower

9.1.1 Introduction

Hydropower is a major activity in Angola but it is a non-consumptive water user. By building dams it may provide for leisure activities, which are also non-consumptive, and such projects may also contribute to river flow controls, including flood control, which in the next phase could provide more stable flows of water for agriculture.

9.1.2 Overview of Existing Hydropower plants

Northern Supply System:

Cambambe Dam (Middle Cuanza River)
Basin Area: 115500 km^2
Mean Flow: 728 m^3/s
Low Flow: 122 m^3/s (i.e. without Capanda which is located u/s Cambambe; Capanda is a gravity dam for hydropower generation and irrigation use.)
Dam crest length: 107 m
Run-of-river concrete gravity dam.
4 x 60 MW turbines (each turbine produces only 45 MW because of lower head than designed (Projected dam height was 110 m but only height of 86 m was achieved.)
Constructed in 1958, First two turbines installed in 1963; 3rd turbine in 1972; 4th turbine in 1973.

Mabubas Dam (Dande River)
Basin Area: 7.5 km^2
Mean Flow: 62 m^3/s
Low Flow: 12 m^3/s
17.8 MW installed capacity
Average Production 60 GWh/annum
Dry Season production 40 GWh/annum
Out of operation since 1992

Capanda Dam (Cuanza River) is managed by GAMEK[1]
1:10,000 year design flood is 11000 m^3/s
Reservoir Capacity 4.7x109 m^3
First Phase 2x130 MW
Turbine 1 installed Dec.2003, turbine 2 installed May 2004
Second Phase (not yet decided)
Minimum regulated flow downstream of Capanda is 500 m^3/s
GAMEK will own/operate this plant for 2 years. After that the Government will decide how or by whom it shall be run/owned.

1 GAMEK was created to deal with the construction of Capanda hydropower scheme. When the construction is over GAMEK may either be disbanded or converted into a joint venture that will be in charge of power generation. The transport of energy (high tension) is the responsibility of ENE while the distribution of lower tension energy is the responsibility of EDEL, in the case of Luanda Province, or the responsibility of other private companies in the case of other provinces.

Central System (2 hydropower schemes)
Lomaum Hydropower plant on Catumbela River
Installed Capacity 35 MW
(1964 – 20 MW; 1973 – 15 MW)
Average Energy Production 107 GWh/annum
Basin Area: 8296 km^2
Mean Flow: 86.3 m^3/s
Out of order since 1983/84

Biopio Hydropower Plant
Installed Capacity 4x3.6 MW
All installed in 1957, and still in operation
Average Energy Production 35 GWh/annum
Basin Area: 15550 km^2
Mean Flow: 117.3 m^3/s

Southern System

Matala Hydropower Plant
Installed Capacity 3x13.6 MW
All installed in 1959, and still in operation
Average Energy Production 100 GWh/annum
Basin Area: 28037 km^2
Mean Flow: 147.2 m^3/s
Also feeds an irrigation channel of 5.0 m^3/s, which was recently rehabilitated.

Gove Dam
Mainly for downstream flow regulation, built in 1975, Turbines not yet installed.
There is a project to install 3x20 MW
According to the 1969 agreement between Portugal and South Africa, and endorsed by Angola and Namibia after their independence, the minimum flow across the border should be 40 m^3/s. The minimum regulated flow by Gove dam is 80 m^3/s. At the border Angola should release 40 m^3/s to Namibia.

Small scale hydro:

Uige Province – Rio Luquixi
1 MW Constructed in 1957 will be expanded to 3 MW. Rehabilitated in 2003
Owned by ENE

Bie Province – Kunje Mini Hydro Project on Rio Kunje
Commissioned in 1971, out of order, although there are plans to rehabilitate it.
Installed capacity 1.5 MW

Bie Province – Kuito Ceramica Mini Hydro Project
1x100 MW turbine
Rehabilitated in 2003 and now in operation again. The project was approved because of the difficulty of extending the transmission system to this area.

Huambo Province – Cuando Mini Hydro Project on Cuando River (Cuando is a tributary of the Cunene river). 4 x 250 kW turbines (2 turbines were out of order during the time of the consultant's field visit). The plant is owned by CFB - Caminho de Ferro de Benguela (the Benguela Railway Company). Cuando Mini Hydro Project is partially operational. It provides energy for the CFB compound and CFB workshop, both located in the outskirts of Huambo City.

In addition there are many other minihydro schemes waiting to be implemented. The main hydro schemes are government financed and government owned projects. The new energy law does, however, allow for private investment in production and distribution. But the major projects are still government owned – but smaller projects are open to private participation. For example Hydrochicapa Consortium that is a Joint Venture between ENE and Alrosa on Rio Chicapa in Lunda Sul Province. It is now under construction and is due to be completed by the end of 2005. With an installed capacity of 18 MW, it will mostly provide energy to the diamond mining industry and the local population. There are also a number of development projects in the northeast of Angola. Other examples are the Luapasso Project, a Joint Venture between ENE and another enterprise and the Luachimo project. Further details of hydropower potentials in Angola are given in the appendix (Bacias Hidrograficas) which was kindly provided by ENE.

9.1.3 GAMEK – The Office for Development of Middle Cuanza River

GAMEK under the Ministry of Energy and Water (MINEA) has its mandate to develop the hydropower resources of the middle Cuanza River Basin. The Cuanza River has its source in the Bie Province and its mouth is at Barra de Cuanza in Luanda province. The Upper Cuanza River basin starts in Bie and finishes near Salto do Cavalo in Malanje province. The middle Cuanza Basin is the responsibility of GAMEK from Salto do Cavalo in Malanje province to Dondo municipality, nearby the section of Cambambe dam in Kuanza Norte province. So the downstream limit is actually the Cambambe dam. Thus the Cuanza Basin (lower) stretches from Capanda dam to the river mouth. As regards hydropower, the Middle Cuanza Basin is most relevant.

The head drop through the middle Cuanza Basin is some 800 m over a reach of 134 km. The main existing dam is CAPANDA at the upstream end. In addition is the Cambambe Dam/Hydro station (180 MW) at the downstream reach of the Middle Cuanza Basin. There are also 7 other potential hydropower sites in between these two dams along the entire reach of the Middle Cuanza Basin.

CAMBAMBE Dam was built in 1958-59, is 60 m high and due to its heavy siltation it may be heightened by some 20 m as part of the rehabilitation of the power plant. Construction of a second powerhouse is foreseen. This would increase the total installed capacity to 780 MW. At the moment Cambambe is functioning as a run-of-river plant since its reservoir is almost full of sediments. It was built in 1960. The original total storage volume was 50 million m^3 with a live storage of 50 million $m^{3.}$ Measurements and calculations from a bathymetric survey carried out in 2001 showed that the siltation is quite excessive, the new measured volumes being then some 24 million m^3 total storage including somewhat under 19 million m^3 of live storage.

CAPANDA hydropower project and dam was planned as a 520 MW station. The head is 110 m, the length of the dam crest is 1470 m, the fetch is 50 km (from Capanda section up to Salto do Cavalo Section), and the reservoir area is 160 km^2. The reservoir storage volume is 4700 million m^3. The fetch of the reservoir is 50 km, the live storage volume is 3500 million m^3. The reservoir was filled in 2002, and therefore there is no data or measurements of sedimentation available. They have planned a bathymetric survey of the Capanda reservoir. Capanda plant does have regulation rules, but they are still trying to find the optimum operation policies. It has a surface spillway, four gates, and a bottom outlet discharge. The design flood was initially 9,700 m^3/s and was later adjusted to 11,000 m^3/s, which corresponds to a 1 in 10,000 year flood. Now, however, as a recommendation from the World Commission on High Dams, they are to use the PMF flood in Angola, which for

Capanda is 14,000 m3/s, and they are currently studying possibilities to handle the excess water by constructing a supplemental spillway.

The Malanje Province has a large agricultural potential and therefore the dam also has a water intake for irrigation supply. This is a low intake in the dam, which can supply water through an (unfinished) tunnel, back up the valley. The flow capacity of this irrigation tunnel will be 20 m^3/s. The irrigation project is as yet not complete because of lack of financing. Only the underwater intake structure and the first 15 m of the tunnel are in place. It is not known when this will be completed. The irrigation project is planned to supply three irrigated areas of a total of 15,700 hectares in the same catchment, upstream of the reservoir.

Capanda hydropower station has 4 turbines of 190 m^3/s design flow each. In the current first phase, however, only two of these are installed. The remaining two turbines will be installed in the second phase of the project. At the moment they have 260 MW available from the combination of the two installed turbines, but the power transmission line to Luanda is only designed to take 200 MW. In addition, due to instability in the net, they can in fact only produce a maximum of 160 MW from Capanda Plant. The other units on the net are Cambambe and the thermal units in Luanda. Before Capanda hydropower plant came on line, energy was rationed, but now they have sufficient - except for the constraints caused by the net capacity/instability. Capanda turbine flow for a production of 160 MW is 190 m^3/s. The Capanda spillway capacity is 7,700 m^3/s, bottom discharge capacity 640 m^3/s, turbine design flow 2 x 190 m^3/s and mean annual flow 380 m^3/s.

Between Capanda and Cambambe there are 7 possible future hydropower schemes. Some of them are run-of-river plants others have regulation reservoirs. The total hydropower potential of the middle Cuanza River Basin is 6180 MW.

9.1.4 Planning Scenarios for Rehabilitation & Construction of Hydropower Schemes

Presently the existing hydropower schemes in Angola generate only a small percentage of the real potential of the country, which was estimated to be 75,600 GWh/year. Based on the available information it can be assumed that only 4% of the theoretical hydropower potential in Angola is being used.

The river with the majority of Angola's hydropower resources is the Cuanza, containing some 45% of the country's hydropower potential. In all 11 hydropower schemes are planned for construction along the entire reach of the Cuanza River, which would produce 30,000 GWh/annum of hydroelectric energy. Two schemes, namely Cambambe and Capanda are already built as detailed earlier in this Chapter. As far as Capanda hydropower scheme is concerned, its first phase is concluded. The second phase will start when the Government of Angola makes funds available.

In the Central Plateau area (the upstream of the Cuanza, Cunene and Cubango rivers) only dams for agriculture purposes are likely to be constructed. However, the installation of turbines for energy generation is planned at least for Gove and Calueque dams. Most hydropower production will occur in the central-eastern region of the country, where rivers fall rapidly before reaching the Atlantic Ocean. The region between the Cuanza and Catumbela rivers contains 80% of the inventoried hydropower potential of the country. According to an inventory provided by ENE (see appendices), most of the Angolan hydropower schemes are located in the following river basins: Cuanza (Upper Cuanza and Middle Cuanza), Lucala, Catumbela,Cunene (Angola), Cunene (international), Cubango, Queve, Longa, Ngunza, Quicombo, Evale and Balombo. This inventory was carried out during the colonial period and obviously needs to be updated by the Angolan authorities.

A description of the disaggregation of planned hydropower schemes by river basins is given below.

Bengo
As far as the Consultant was informed, Quiminha is the only dam built on the Bengo River. Although it was built primarily for downstream flow regulation, the second phase of Quiminha Dam foresees the installation of turbines. The dam has structural problems that require rehabilitation. It is assumed that turbines will be installed by the year 2015.

Upper Cuanza
There are eighteen hydropower schemes planned for the Upper Cuanza, namely: Tassongue (3 MW), Quipeio (15 MW), Banza–Tombe (40 MW), Muanga–Tumbo (20 MW), Lunga (10 MW), Embala Andulo (15 MW), Salamanca (5 MW), Cambungo (60 MW), Cunhinga (unknown), Chivava (15 MW), Cundende (1 MW), Chibemba (1 MW), Coemba (15 MW), Salamba (20 MW), Quissol (3 MW), Cativa (15 MW), Dando (70 MW) and Quissande (120 MW).

None of these hydropower schemes are expected to be constructed in the near future.

Middle Cuanza:
There are nine hydropower schemes planned or constructed in the Middle Cuanza, namely: Capanda (450 MW), N'Hangue (450 MW), Lihaúca (2,120 MW), Caculo-Cabaça (1,560 MW), Zenza-I (450 MW), Zenza-II (120 MW), Túmulo do Caçador (450 MW), Luime (330 MW) and Cambambe (580 MW).

The first phase of Capanda hydropower scheme is complete, however, the construction of the second phase is dependent on the availability of funds, probably by the year 2015. Due to heavy siltation of its reservoir, the dam of Cambambe hydropower scheme is planned heightened. This may be achieved by the year 2015.

Conzo / Zaire:
There are three hydropower schemes planned or constructed in the Congo/Zaire River basin, namely: Luachimo (unknown), Lucapa (unknown) and Chicapa (16 MW). The implementation of the Chicapa hydropower scheme is planned for the end of 2005.

Catumbela:
There are four hydropower schemes planned or constructed in the Catumbela river basin, namely: Chicuma (53 MW), Cuvera (25 MW), Lomaún (25 MW) and Biópio (34 MW). Chicuma and Cuvera hydropower schemes are still in the planning stage. Biópio and Lomaún hydropower schemes were constructed during colonial time. The equipment installed in Biópio hydropower scheme became obsolete and the Brazilian contractor ODEBRECHT carried out the rehabilitation work. The rehabilitation of Biópio hydropower scheme was concluded in December 2004. Lomaún hydropower scheme was destroyed during the war and its rehabilitation is expected to take place by the year 2015.

Cunene (Angolan side):
There are fifteen hydropower schemes planned or constructed on the Angolan side of the Cunene river basin, namely: Gove (25 MW), Jamba-Ia-Oma (50 MW), Chivôndua (15 MW), Jamba-Ia-Mina (130 MW), Matala (45.5 MW), Matunto (10 MW), Chissola (6.5 MW), Caringo (5 MW), Gunge (4 MW), Lucunde (6.5 MW), Cambundi (14.5 MW), Catembulo (unknown), Rega (5 MW), Calueque (20 MW) and Cuando (1 MW). Matala is the only existing hydropower scheme constructed on the river. The Government of Angola has plans to install turbines at Gove Dam. After damage during the war, the structure of Gove Dam was rehabilitated in December 2003. The installation of turbines may be achieved by the year 2015.

The Matala hydropower scheme is in need of rehabilitation and an attempt to rehabilitate the scheme by the Brazilian contractor ODEBRECHT in 2003 was unsuccessful. The rehabilitation of Matala hydropower scheme may be expected at any time within.

Cuando mini hydropower scheme is working half installed capacity. The rehabilitation of CFB, the Benguela Railway Company, may advance the rehabilitation of the Cuando scheme.

Cunene (international reach):
Thre are twelve hydropower schemes planned or constructed on the international reach of Cunene river basin, namely: Jacavale (60 MW), Luandege (195 MW), Ruacana (300 MW), Ondurusu (70MW), Zebra (60 MW), Epupa I (120 MW), Epupa II (325 MW), Baynes (260 MW), Marienflus (300 MW), Hartman (140 MW), Hombolo (195 MW) and Mcha (90 MW). With the exception of Ruacana hydropower scheme which is located in Namibian territory and provides energy for that country, the remaining hydropower schemes are only in the planning stage.

A Feasibility Study and an Environmental Impact Assessment Study were carried out at Epupa for construction of a hydropower scheme. According to the studies the most suitable places for construction of a hydropower scheme in the Lower Cunene should be either Baynes or Marienflus. A decision on this is still pending by both the Government of Angola and the Government of Namibia.

Cubango:
There are ten planned hydropower schemes in the Cubango river basin, namely: Cavango (7 MW), Chazenga (15 MW), Mangonga (26 MW), Mumba (40 MW), Muculungungo (54 MW), Mucundi (74 MW), Mbambi (unknown), Calemba (13 MW), Cutato (80 MW) and Malobras (58 MW).

According to ENE one mini hydropower scheme will be constructed on the Cúebé River, in Menongue.

Lucala:
There are ten planned hydropower schemes in Lucala river basin, namely: Duque (30 MW), Carianga (240 MW), Bembeze (250 MW), Cangala Gala (105 MW), Cambondo (60 MW), Mungongo (60 MW), Cababanga (45 MW), Tabanga (45 MW), Caango (160 MW) and Quituto (16 MW).

Longa:
There are eight planned hydropower schemes in the Lucala river basin, namely: Quissuca (110 MW), Cuteca (185 MW), Cacula (170 MW), Lundo (17 MW), Cassongo (110 MW), Lungo (50 MW), Murimbo (170 MW) and Quissonhe (395 MW).

Mbridge:
According to ENE one mini hydropower scheme will be constructed on the Mbridge River. The installed capacity of Luquixi mini hydropower scheme on the Luquixi River in Uíge province will be expanded from the existing 1 MW to 3 MW.

Ngunza, Quicombo, Evale and Balombo:

There are eight planned hydropower schemes in these river basins, namely: Chiongo (15 MW), Ganja (20 MW), Calixa (90 MW), Cumbe (295 MW), Gangaue (49 MW), Cavonde (25 MW), Sungo (352 MW) and Camama (240 MW).

Queve:
There are eight planned hydropower schemes in Queve river basin, namely: Caiovole (70 MW), Cafula (540 MW), Ntiundumbo (235 MW), Dala (50 MW), Benga (815 MW), Capunda (380 MW), Balalunga (275 MW) and Cachoeiras da Binga (195 MW).

The Cachoeiras da Binga hydropower scheme may be constructed by the year 2025.

Zambezi:
There is one hydropower plant under construction in the Zambezi basin - the Luapasso scheme that will provide energy for a mining project in Luanda Sul province.

Table 9.1 summarises the scenarios for planning and development scenarios of hydropower projects known to the study team.

Table 9.1 Planning Scenarios for Construction or Rehabilitation of Hydropower Plant

Scheme	**River**	**Basin**	**2005**	**2015**	**2025**	**Remarks**
Mabubas	Dande	Dande	R			
Lomaúm	Catumbela	Catumbela		R		
Capanda(fase II)	Cuanza	Cuanza		C		Installation of 2 additional turbines
Matala	Cunene	Cunene	R			
Chicapa	Chicapa	Congo	C			The conclusion of this hydropower scheme is planned for 2006
Luapasso	Luapasso	Zambezi	C			
Gove	Cunene	Cunene	R			Installation of turbines
Mbridge	Mbridge	Mbridge		C		Mini hydropower scheme
Luquixi	Luquixi		C			Mini hydropower scheme with one existing turbine. To be expanded with two more turbines
Menongue	Cuébé	Cubango	C			Mini hydropower scheme
Quiminha	Bengo	Bengo		R		Rehabilitation and installation of turbines
Cambambe	Cuanza	Cuanza	R			Heightening of dam wall
Cachoeiras de Binga	Queve	Queve			C	

C = Construction *R = Rehabilitation*

9.2 Other Non-consumptive Uses

According to the "Country Situation Report" on water resources by Africonsult (1998), there is no tradition of fluvial navigation as regular transport on Angola's extensive hydrographic network. Tourism and tourist use of rivers, lakes etc. are very limited in Angola. However, one can foresee some use of small boats for inland river sports and tourism in the future, but no foreign tourism will develop so long as the present cumbersome and costly visa regulations, the lack of good road infrastructures, the lack of good tourism infrastructures like hotels etc. and the prohibitive costs practised by tourism agents are maintained which hamper the development of the tourism sector in Angola. This situation will hopefully be improved in the future since Angola has a vast untapped potential in this respect.

There is no tradition of inland fisheries for commercial purposes, but aquaculture could become an inland industry on some rivers and lakes in the future.

10 AGRICULTURAL WATER USE

10.1 Areas of Key Irrigated Cultivation Activities by Crop Type and Province

Due to insufficient annual rainfall most irrigation in Angola is developed in the coastal area and in the southern provinces. In these two zones of the country, the alluvial “spots” of important rivers like Dande, Bengo, Cuanza, Longa, Queve, Cunene and Cubango can be found. Due to the high fertility of the soils in these areas, they will eventually be planned for development of irrigated agriculture. Irrigated agriculture will also be planned in zones located in the eastern side of Malanje province and in the area of Baixa de Cassanje, also in Malanje province, were local agro-ecological conditions favour such a development. In some areas of the Plateau (Huambo, Malanje, Uíge and Kuanza Norte), where the mean annual rainfall is sufficient, supplementary irrigation is practised.

Irrigation is the largest agricultural user of water, as livestock water developments is limited in importance and in area (mainly concentrated in southern provinces like Huila, Namibe and Cunene). Despite the dominance of rainfed agriculture in Angola, irrigation is important to maintain year-round production of food and vegetables. The sharp and rapid transition between the coastal plain and the Plateau provides a great number of potential sites to establish reservoirs and major diversion structures to regulate flows and to irrigate the extensive floodplains. The morphology of the Planalto and eastern zone present a high potential for small river diversion structures and small storages tanks.

Three main types of irrigation prevail in the country, namely: a) large to medium scale irrigation schemes fully or partly equipped with water control works; b) small scale gravity or pumped schemes and; c) Low lands and depressions utilising water conservation farming practices. More recently private farmers are introducing sprinkler, micro-sprinkler and trickle irrigation techniques into the country.

In 1989, M. Quintino referred to previous studies which have identified about 420,000 hectares of potentially irrigable land distributed as follows: 174,000 hectares in Dande, Bengo, Cuanza, Longa and Queve river basins; 186,000 hectares in Cunene and Cubango river basins and 60,000 hectares in Malanje province (cf. SADC Regional Irrigation Development Strategy). H. Loze, in his draft report dated May 2004, mentioned that: “of the approximately 425,000 hectares that were partially or completely during colonial time, some 64,750 hectares seems to be irrigated at the present. However, there is no detailed survey of existing schemes exists and there is no accurate information on the effective level of these schemes and on the efficiency of the irrigation being conducted” (cf. ANGOLA – Irrigation and Water Management Study).

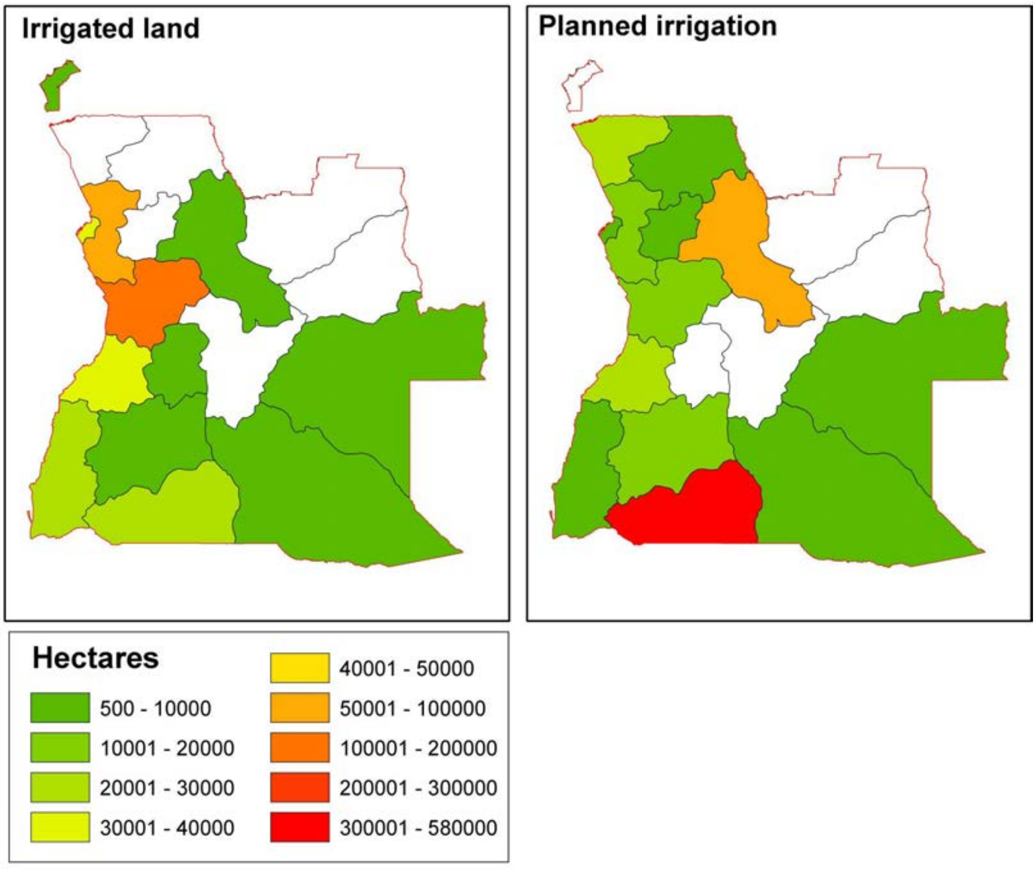
Within the framework of the Rapid Water Resources and Water Use Assessment for Angola, our findings tell us that presently there are 340,478 hectares under irrigated agriculture or partially under irrigated agriculture and 783,338 hectares under rehabilitation or planned for irrigation in Angola. This gives a total of 1,123,816 hectares under irrigated agriculture or to be under irrigated agriculture in the entire country. Most of the crops grown under irrigation are bananas, vegetables, fruits, olives, rice and sugarcane. Irrigation of cereals and other staple crops has not received much attention by farmers in general, as they are usually grown under rainfed conditions.

Table 10.1.1 summarises the irrigated areas in Angola sorted by province. Areas actually under irrigation and areas planned for irrigation/rehabilitation are shown separately. The overview is shown graphically in Figure 10.1.1.

Table 10.1.1 Areas under irrigation (or partially under irrigation) and areas under rehabilitation (or planned for irrigation)

Province	Area under irrigation/ partially under irrigation, (hectares)	Area under rehabilitation/ planned for irrigation (hectares)
Benguela	38,521	25,300
Bengo	70,614	19,000
Cunene	28,500	572,400
Huambo	6,618	-
Huíla	6,832	12,023
Kuando Kubango	4,000	5,000
Kuanza Norte		9,620
Kuanza Sul	109,700	11,900
Luanda	35,830	7,120
Lunda Norte	n.a.	n.a.
Lunda Sul	n.a.	n.a.
Malanje	3,700	86,500
Moxico	500	500
Uíge	-	3,000
Zaire	-	21,000
Namibe	26,801	9,975
Bié	n.a.	n.a.
Cabinda	8,862	-
Angola's total:	**340,478**	**783,338**

Figure 10.1.1 Areas under irrigation (or partially under irrigation) and areas planned for irrigation (or under rehabilitation)



10.1.1 Benguela Province

In Benguela there are 38,521 hectares under irrigated agriculture or partially under irrigated agriculture and 25,300 hectares under rehabilitation or planned for irrigated agriculture. The disaggregation of these areas by irrigation schemes is as follows: Cavaco (6,000 ha), Catumbela (3,000 ha), Dombe Grande (3,000 ha), Hanha do Norte (6,000 ha), Canjala (2,000 ha), Equimina (1,821 ha), Hanja (6,000 ha), Impulo (1,800 ha), Alto Coporolo (14,900 ha), Baixo Coporolo (11,200 ha) and Foz do Coporolo (5,300 ha). The main irrigated crops cultivated in this province are banana, vegetables, fruits and sugarcane.

10.1.2 Bengo Province

In Bengo there are 70,614 hectares under irrigated agriculture or partially under irrigated agriculture and 19,000 hectares under rehabilitation or planned for irrigated agriculture. The disaggregation of these areas by irrigation schemes is as follows: Bom Jesus (1,300 ha), Caquila (1,250 ha), Quiminha Valley (35,000 ha), Caxito (4,000 ha), Kala-Kala (800 ha), Lifune (3,900 ha), Musserra/Onzo (4,350 ha), Loge (2,450 ha), Uezo (3,800 ha), Onzo (5,750 ha), Alto Dande (13,500 ha), Cunga-Quiria (10,450 ha), Muzondo (3,000 ha) and AGRINVEST (14 ha). The main irrigated crops cultivated in Bengo are banana, vegetables, maize and fruits.

10.1.3 Bié Province

The development of irrigated agriculture in Bié province is not significant. This province benefits from an annual volume of rainfall (1,252 mm/year) that enables the development of rainfed agriculture.

10.1.4 Cabinda Province

There are in Cabinda 8,862 hectares under irrigated agriculture. 8,809 hectares exist in Yabi Valley, while in Chiadede there are 53 hectares. The main crops are fruits and vegetables.

10.1.5 Cunene Province

Due to low annual precipitation (200-700 mm) Cunene is one of the Angolan provinces with a high irrigation potential. There are presently 28,500 hectares under irrigated agriculture or partially under irrigated agriculture in Cunene and 572,400 hectares planned for irrigation. The disaggregation of the areas by irrigation schemes is as follows: Matunto (92,800 ha), Quiteve-Humbe (Mânquete) (120,000 ha), Cafu (40,200 ha), Catembulo (187,000 ha), Cova do Leão (104,900 ha), Ndonguena (20,000 ha), Calueque (16,000 ha) and Upper Cuvelai (20,000 ha). The main crops are fruits and vegetables. There are possibilities for the introduction of sugarcane plantations in Cunene province.

10.1.6 Huambo Province

Despite significant annual rainfall (over 1,200 mm), irrigation is also developed in Huambo province as a supplementary activity. Most irrigation is carried out during the dry season (May–October). There are 6,618 hectares of land under irrigated agriculture or partially under irrigated agriculture in Huambo. The disaggregation of the areas by irrigation schemes is: Chissola IV (618 ha) and Kalima (6,000 hectares). The main crops under irrigation are fruits and vegetables. In the Chissola IV irrigation scheme there is introduction of grapevines.

10.1.7 Huila Province

In Huila province there are 6,832 hectares under irrigated agriculture or partially under irrigated agriculture and 12,023 hectares under rehabilitation or planned for irrigation. The disaggregation of the areas by irrigation schemes is as follows: Gandjelas (1,000 ha), Chimúcua I (50 ha), Chimúcua II (60 ha), Bata-Bata (45 ha), Neves (1,300 ha), Mapunda/Tundavala (830 ha), Matala (10,000 ha), Chicungo (400 ha), Quipungo (200 ha), Sendi (1,500 ha) and Pira-Babaera (3,900 ha). The main crops under irrigation are fruits and vegetables.

10.1.8 Kuanza Norte Province

In Kuanza Norte province there are 9,620 hectares either under rehabilitation or planned for irrigated agriculture. The disaggregation of the areas by irrigation schemes is as follows: Luinga (5,000 ha), Camaloa (54 ha), Calemba (156 ha), Uambaca do Luando (59 ha), Luachi (205 ha), Tombo (1,290 ha), Caquelosso (226 ha), Quindúa (149 ha), Quissomona (151 ha), Sesse Pequeno (273 ha), Cambaba (55 ha), Cabaça (95 ha), Catende (169 ha), Quibezo (51 ha), Gola (82 ha), Zanda (311 ha), Lufuco (115 ha), Alá (96 ha), Camaia (20 ha), Luando (20 ha), Mutanda (186 ha), Luquelo (13 ha), Cequete (43 ha), Maloa (21 ha), Mazozo (500 ha) and Lucala (280 ha). The main crops are fruits and vegetables.

10.1.9 Kuanza Sul Province

There are 109,700 hectares of land under irrigated agriculture or partially under irrigated agriculture and 11,900 hectares of land under rehabilitation or planned for irrigated agriculture in Kuanza Sul province. The disaggregation of the areas by irrigation schemes is as follows: Cela (6,000 ha), Quicombo (6,900 ha), Sumbe/Ngunza (4,000 ha), Porto Amboím (5,000 ha), Lower Longa (57,200 ha), Lower Queve (33,000 ha) and Evale Guerra (9,500 ha). The main crops under irrigation are fruits and vegetables.

10.1.10 Cuando Cubango Province

In Cuando Cubango there are 4,000 hectares of land under irrigated agriculture or partially under irrigated agriculture and 5,000 hectares under rehabilitation. The disaggregation of these areas by irrigation schemes is: Menongue I (3,000 ha), Menongue II (1,000 ha) and Cuchi (5,000 ha). The main crops under irrigation are fruits, vegetables and rice.

10.1.11 Luanda Province

In Luanda province 35,830 hectares of land exists under irrigated agriculture or partially under irrigated agriculture and 7,120 hectares of land is planned for irrigation. The disaggregation of the areas by irrigation schemes is as follows: Funda (200 ha), Kikuxi (6,000 ha), Fazenda Experimental (300 ha), Calumbo (700 ha), Banda (1,180 ha), Cabiri (540 ha), Mabuia (500 ha), Bita (1,000 ha), Sequel (300 ha), COPINOL (30 ha), Sapú (2,000 ha) and Tombo (30,000 ha). The main crops are fruits, vegetables and maize.

10.1.12 Lunda Norte Province

As far as irrigated agriculture is concerned, figures are not available for Lunda Norte province.

10.1.13 Lunda Sul Province

As far as irrigated agriculture is concerned figures are not available for Lunda Sul province.

10.1.14 Malanje province

There are presently in Malanje province 3,700 hectares of land under irrigated agriculture or partially under irrigated agriculture and 86,500 hectares of land planned for irrigation. The disaggregation of the areas by irrigation schemes is as follows: Capanda (13,500 ha), Kissol (700 ha), Kamatende (2,000 ha), Vânvala (1,000 ha), Ngangassol (1,000 ha), Lutau (22,000 ha), Cole I (15,000 ha), Cole II (15,000 ha) and Cole III (20,000 ha). The main crops are vegetables and fruits.

10.1.15 Moxico Province

In Moxico province there are 500 hectares of land under irrigation and 500 hectares of land under rehabilitation. The main crops are fruits and vegetables.

10.1.16 Namibe Province

In Namibe province there are 26,801 hectares of land under irrigated agriculture or partially under irrigated agriculture and 9,975 hectares of land under rehabilitation or planned for irrigation. These areas are disaggregated by irrigation schemes as follows: Bero (1,000 ha), Betiaba /São Nicolau (5,000 ha), Curoca (3,000 ha), Carunjamba (2,625 ha), Giraúl (2,650 ha), Inamangando (1,000 ha), Bibala (19,231 ha), Chibiba (100 ha), Tampa (1,500 ha), Lola (300 ha) and Capangombe (370 ha). The main crops are banana, vegetables and olive trees.

10.1.17 Uíge Province

In Lusselúa irrigation scheme there are 3,000 hectares of land awaiting rehabilitation. Rice is the main crop used in that area.

10.1.18 Zaire Province

There are 21,000 hectares planned for future irrigation activity in Pedra do Feitiço in Zaire province. The crops to be used under irrigation will be fruits and vegetables.

10.2 Rainfed Cultivated Areas by Crop Type and Province

Rainfed agriculture is practised in those Angolans provinces where the mean annual rainfall is at least 1,000 mm. According to estimates produced in 1986/1987 by the former Coordination Group (cf. Avaliação dos Recursos de Investigação Agrária nos Países da SADC, Volume II – Relatório de Angola) the small farming sector cultivated a total of 2,330,000 hectares of land. The disaggregation of cultivated lands by crops and by area is as follows: wheat (500 ha), rice (2,000 ha), millet (125,000 ha), sorghum (100,000 ha), maize (1,250,000 ha), beans (100,000 ha), potato (10,000 ha), cotton (2,500 ha), cassava (600,000 ha), groundnuts (40,000 ha) and coffee (100,000 ha). Maize, the staple crop in the central area of the country, occupied approximately 54% of cultivated land, while cassava, the staple crop in the northern and eastern zones of Angola, occupied approximately 26% of cultivated land. Millet and sorghum, the staple crops in southern provinces of the country occupied approximately 5% and 4% respectively.

According to the IFAD working document on Angola, in its chapter II-B-O Sector Rural, Angola has a rich potential in agriculture of about 5 to 8 million hectares of available arable land, from which 2,5 million hectares were cultivated during 2002-2003, meaning an increase of approximately 14% in relation to 2001. Around 40% of cultivated land is located in the central provinces, where the agro-climatic conditions allow the development of rainfed agriculture. In the highlands of the central provinces there are vast areas with good rainfall regime and moderate temperatures, although soils are acid and non-productive.

MINADER, the Ministry of Agriculture and Rural Development, estimates that around 1,8 million rural families do small-scale agriculture. Most of these families conduct rainfed agriculture. The average size of a family plot that uses hand-tools for land preparation under rainfed condition normally varies between 2 and 3 hectares. In the rainfed agriculture sub-sector, land can lie fallow for about 8 to 10 years, although this period can be reduced in places where land resources are not abundant.

10.2.1 Benguela Province

Benguela is a province where, in the coastal strip, it its necessary to irrigate crops for successful agriculture. Moving from the coast to the interior, and also in the south-eastern part of the province, it is possible to practise rainfed agriculture due to an increase of the mean annual precipitation, mainly in the Balombo, Bocoio, Chongorói, Cubal and Ganda municipalities. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias) the main crops under rainfed agriculture are maize, beans, cowpea, sorghum, sweet potato, groundnuts, cotton, tobacco and coffee. There is no data about the available area under rainfed agriculture.

10.2.2 Bengo Province

Bengo province is also located in the coastal area. As such, crops must be irrigated. Moving from the coast to the interior of the province it is possible to practise rainfed agriculture due to an increase of the mean annual rainfall. This is mainly in the municipalities of Pango-Aluquém and Nambuagongo. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops under rainfed agriculture are cassava, beans, palm oil and sweet potato. There is no data about the available area under rainfed agriculture.

10.2.3 Bié Province

In this province the mean annual rainfall is 1,252 mm. This amount of water allows the development of rainfed agriculture in the province. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias) the main crops under rainfed agriculture are maize, beans, coffee, groundnuts, rice, sweet potato and wheat. There is no data about the available area under rainfed agriculture.

10.2.4 Cabinda Province

The mean annual rainfall (1,084 mm) in the province allows the development of rainfed agriculture. Most of the rainfed agriculture activities are carried out in the interior of the province, mainly in the municipalities of Belize, Buco Zau and Lândana. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops under rainfed agriculture are cassava, beans, groundnuts, palm tree and sweet potato. There are no data about the available area under rainfed agriculture.

10.2.5 Cunene Province

This is a province with a low mean annual rainfall (200-700 mm). For the success of agriculture, irrigation is highly recommended. Even though it is possible to practise rainfed agriculture by resorting to drought-tolerant varieties of crops. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops under rainfed agriculture are millet and sorghum. There are no data about the available area under rainfed agriculture.

10.2.6 Huambo Province

This province has a mean annual rainfall of over 1,299 mm, allowing the development of rainfed agriculture. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops under rainfed conditions are maize, beans, Soya, potato, sweet potato, coffee and wheat. There are no data about the available area under rainfed agriculture.

10.2.7 Huila Province

The mean annual rainfall in Huíla province is some 600 – 1,100 mm. When moving to the interior and to the northern zone of the province, the increased rainfall makes it is possible to practise rainfed agriculture in the municipalities of Caconda, Caluquembe, Chipindo, Chicomba, Cuvango, Cacula, Chiange, Hoque, Lubango, Matala and Quipungo. According to A. Castanheira Diniz (cf. Angola - O Meio Físico e Potencialidades Agrárias), the main crops grown under rainfed conditions are maize, beans, cowpea, millet, sorghum, soybeans, sweet potato and wheat. There are no data about the available area under rainfed agriculture.

10.2.8 Kuanza Norte Province

The mean annual rainfall in Kuanza Norte province is just under 1,000 mm. This places the province in a kind of transition zone, requiring supplementary irrigation, although there are some crops grown under rainfed conditions. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main rainfed crops are cassava, coffee, beans, groundnuts, pineapple, palm tree, sweet potato and avocado. There are no data about the available area under rainfed agriculture.

10.2.9 Kuanza Sul Province

This is a coastal province. Its annual rainfall is just over 1,000 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main rainfed crops are maize, beans, cassava, coffee, cotton, cowpea, groundnuts, palm tree, pineapple, potato, rice, soybeans, sunflower and sweet potato. There are no data about the available area under rainfed agriculture.

10.2.10 Cuando Cubango Province

The mean annual rainfall of Cuando Cubango province is some 750 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main rainfed crops are maize, beans, millet, sorghum, soybeans, tobacco and wheat. There are no data about the available area under rainfed agriculture.

10.2.11 Luanda Province

The mean annual rainfall of Luanda province is some 500 mm. Here most of the crops must be irrigated. Even though crops like cassava, beans, maize and sweet potato are grown under rainfed conditions. There are no data about the available area under rainfed agriculture.

10.2.12 Lunda Norte Province

The mean annual rainfall in Lunda Norte province is some 1,450 mm. The natural conditions of the province enable the development of rainfed agriculture. The main rainfed crops in the province are cassava, groundnuts, sweet potato and rice. According to Henri Loze (cf. ANGOLA – Irrigation and Water Management Study), during the year 2003 the government of Angola has been promoting 2,859 hectares of rice production.

10.2.13 Lunda Sul Province

The mean annual rainfall of Lunda Sul province is 1,377 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main rainfed crops are cassava, avocado, groundnuts, sweet potato and rice. There are no data about the available area under rainfed agriculture.

10.2.14 Malanje Province

Malanje province has good natural conditions for development of rainfed agriculture. Despite this fact, in some zones of the province crops must be supplementary irrigated. The mean annual rainfall of Malanje province is some 1,200 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main rainfed crops are cassava, beans, cotton, avocado, groundnuts, maize, pineapple, potato, soybeans, sunflower, sweet potato, tobacco and rice. There are no data about the available area under rainfed agriculture.

10.2.15 Moxico Province

This province has a mean annual rainfall of 1,168 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops grown under rainfed conditions are cassava, beans, cowpea, groundnuts, maize, sweet potato, tobacco and rice. Henri Loze in his report (cf. ANGOLA – Irrigation and Water Management Study) quoting MINADER says that during the year 2003 the government of Angola has been promoting 4,836 hectares of rice production.

10.2.16 Namibe Province

This is a very dry province and is located on the coast. Its mean annual rainfall is 287 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops grown under rainfed conditions are cowpea, millet and sorghum. There is no data about the available area under rainfed agriculture.

10.2.17 Uíge Province

The mean annual rainfall in Uíge province is 1,214 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops grown under rainfed conditions are cassava, coffee, beans groundnuts, avocado, cashew, maize, palm tree, pineapple, sweet potato and rice. There are no data about the available area under rainfed agriculture.

10.2.18 Zaire Province

The mean annual rainfall in Zaire province is 900 mm. According to A. Castanheira Diniz (cf. Angola – O Meio Físico e Potencialidades Agrárias), the main crops grown under rainfed conditions are cassava, beans, groundnuts, coffee, avocado, cashew, cotton, palm tree, pineapple and sweet potato. There are no data about the available area under rainfed agriculture.

10.3 Livestock Volumes and their Water use by Province

Estimates on livestock and poultry were received from the Ministry of Agriculture and Rural Development (MINADER). These estimates are referred to 2001 and are related mostly to three provinces on southern zone of Angola, namely Cunene, Huíla and Namibe provinces. The figures are shown in the table 10.3.1.

Table 10.3.1 Estimation of Livestock and Poultry in the Country During 2001

Type of animal	Estimated Numbers
Cattle	3,500,000
Pigs	800,000
Small ruminants	1,500,00
Poultry	10,000,000

Source: Department of Animal Production of the National Directorate of Livestock (MINADER)

Based on the estimates provided by MINADER, projections were made for the entire country, bearing in mind those provinces (catchment areas) with potential for livestock and poultry production. The catchment areas considered to have a potential for livestock and poultry development are Cunene, Cuanza, Cubango, Cavaco, Catumbela, Queve, Longa, Bengo, Bero, Giraúl, Curoca, Coporolo, Sumbe/Ngunza, Quicombo, Equimina, Cuvelai and Congo/Zaire. For the future projections it was assumed that cattle would grow in numbers by 3% per annum, whereas pigs, sheep, goats and poultry will have an increase of 4% per annum. In some provinces (catchment areas) the number of animals was neglected as the amount was assumed to be insignificant. The projections made are shown in table 10.3.2.

Table 10.3.2 Animal Projections

Catchment	Type of Animal	Year 2000	Year 2005	Year 2015	Year 2025
Cunene	Cattle	1,150,000	1,333,165	1,791,662	2,407,844
Cunene	Sheep	50,000	60,833	90,048	133,293
Cunene	Goats	50,000	60,833	90,048	133,293
Cunene	Pigs	50,000	60,833	90,048	133,293
Cunene	Poultry	-	-	-	-
Cuanza	Cattle	150,000	173,891	233,695	314,067
Cuanza	Sheep	30,000	36,500	54,029	79,976
Cuanza	Goats	30,000	36,500	54,029	79,976
Cuanza	Pigs	150,000	182,498	270,142	399,876
Cuanza	Poultry	2,500,000	2,898,186	3,894,920	5,234,447
Cubango	Cattle	80,000	92,742	124,638	184,495
Cubango	Sheep	20,000	24,333	36,019	53,317
Cubango	Goats	20,000	24,333	36,019	53,317
Cubango	Pigs	20,000	24,333	36,019	53,317
Cubango	Poultry	-	-	-	-

Catchment	Type of Animal	Year 2000	Year 2005	Year 2015	Year 2025
Cavaco	Cattle	70,000	81,149	109,058	146,565
Cavaco	Sheep	100,000	115,927	155,796	209,377
Cavaco	Goats	70,000	85,166	126,067	186,610
Cavaco	Pigs	70,000	85,166	126,067	186,610
Cavaco	Poultry	2,000,000	2,318,549	3,115,936	4,187,558
Catumbela	Cattle	-	-	-	-
Catumbela	Sheep	20,000	24,333	36,019	53,317
Catumbela	Goats	20,000	24,333	36,019	53,317
Catumbela	Pigs	100,000	115,927	155,796	209,377
Catumbela	Poultry	500,000	579,637	778,984	1,046,890
Queve	Cattle	30,000	34,778	46,739	62,813
Queve	Sheep	150,000	182,498	270,142	399,876
Queve	Goats	150,000	182,498	270,142	399,876
Queve	Pigs	100,000	115,927	155,796	209,377
Queve	Poultry	2,000,000	2,318,549	3,115,936	4,187,558
Longa	Cattle	3,000	3,478	4,674	6,282
Longa	Sheep	75,000	91,249	135,071	199,938
Longa	Goats	75,000	91,249	135,071	199,938
Longa	Pigs	60,000	73,000	108,058	159,952
Longa	Poultry	1,000,000	1,159,274	1,557,968	2,093,779
Bengo	Cattle	1,600	1,855	2,493	3,351
Bengo	Sheep	15,000	18,250	27,015	39,989
Bengo	Goats	15,000	18,250	27,015	39,989
Bengo	Pigs	50,000	60,833	90,048	133,293
Bengo	Poultry	1,000,000	1,159,274	1,557,968	2,093,779
Bero	Cattle	300,000	348,782	467,390	628,133
Bero	Sheep	25,000	30,417	45,025	66,648
Bero	Goats	25,000	30,417	45,025	66,648
Bero	Pigs	50,000	60,833	90,048	133,293
Bero	Poultry	-	-	-	-
Giraúl	Cattle	450,000	521,673	701,085	942,200
Giraúl	Sheep	50,000	60,833	90,048	133,293
Giraúl	Goats	50,000	60,833	90,048	133,293
Giraúl	Pigs	20,000	24,333	36,019	53,317
Giraúl	Poultry	-	-	-	-
Curoca	Cattle	550,000	637,601	856,883	1,147,548
Curoca	Sheep	50,000	60,833	90,048	133,293
Curoca	Goats	50,000	60,833	90,048	133,293
Curoca	Pigs	-	-	-	-
Curoca	Poultry	-	-	-	-
Coporolo	Cattle	200,000	231,855	311,594	418,757
Coporolo	Sheep	30,000	36,500	54,029	79,976
Coporolo	Goats	30,000	36,500	54,029	79,976
Coporolo	Pigs	80,000	97,333	144,077	213,270
Coporolo	Poultry	-	-	-	-
Ngunza	Cattle	-	-	-	-
Ngunza	Sheep	25,000	30,417	45,025	66,648
Ngunza	Goats	25,000	30,417	45,025	66,648
Ngunza	Pigs	20,000	24,333	36,019	53,317
Sumbe /Ngunza	Poultry	500,000	579,637	778,984	1,046,890
Quicombo	Cattle	-	-	-	-
Quicombo	Sheep	-	-	-	-
Quicombo	Goats	-	-	-	-
Quicombo	Pigs	20,000	24,333	36,019	53,317

Catchment	Type of Animal	Year 2000	Year 2005	Year 2015	Year 2025
Quicombo	Poultry	-	-	-	-
Equimina	Cattle	200,000	231,855	311,594	418,757
Equimina	Sheep	30,000	36,500	54,029	79,976
Equimina	Goats	30,000	36,500	54,029	79,976
Equimina	Pigs	-	-	-	-
Equimina	Poultry	-	-	-	-
Cuvelai	Cattle	400,000	463,710	537,657	722,446
Cuvelai	Sheep	50,000	60,833	90,048	133,293
Cuvelai	Goats	50,000	60,833	90,048	133,293
Cuvelai	Pigs	-	-	-	-
Cuvelai	Poultry	-	-	-	-
Congo / Zaire	Cattle	30,000	34,778	46,739	62,813
Congo / Zaire	Sheep	30,000	36,500	54,029	79,976
Congo / Zaire	Goats	30,000	36,500	54,029	79,976
Congo / Zaire	Pigs	10,000	12,167	18,010	26,660
Congo / Zaire	Poultry	500,000	579,637	778,984	1,046,890

For the calculation of animal water needs, daily water consumption values recommended by MINADER and by AGRODOK series No. 27 " Criação e Maneio de Pontos de Água para o Gado da Aldeia", MINADER recommends that each bird consumes 0.25 litres per day, while AGRODOK recommends a daily consumption unit of 60 litres per day for cattle and 12 litres per day for sheep, goats and pigs. Table 10.3.3 shows water needs for cattle in the catchments.

Table 10.3.3 Water use by Livestock and Poultry

Catchment	Amount of water in 2000, m³/day	Amount of water in 2005, m³/day	Amount of water in 2015, m³/day	Amount of water in 2025, m³/day
Cunene	70,800	82,180	110,742	149,269
Cuanza	12,145	14,225	19,535	26,871
Cubango	5,520	6,441	8,776	12,990
Cavaco	7,580	8,884	12,218	16,833
Catumbela	1,805	2,120	2,929	4,054
Queve	7,100	8,438	11,397	16,926
Longa	2,950	3,565	5,210	7,619
Bengo	1,306	1,570	2,229	3,284
Bero	19,200	22,327	30,205	40,887
Giraúl	28,440	33,053	44,659	60,371
Curoca	34,200	39,716	53,574	72,052
Coporolo	13,680	15,956	21,722	29,604
Sumbe/ Ngunza	965	1,161	1,708	2,501
Quicombo	240	292	433	640
Equimina	12,720	14,788	19,993	27,045
Cuvelai	25,200	29,283	34,145	46,546
Congo/Zaire	2,765	3,254	4,512	6,270
Total:	**246,616**	**287,253**	**383,987**	**523,762**

10.4 Present Agriculture Water Use Estimates (As Input and Water Discharges)

Angola has a huge potential for intensification of agriculture activities. This intensification will necessarily pass through the use and development of irrigation. According to both past and recent studies, irrigation is either planned or is being developed in the coastal areas and in the southern provinces of the country.

The SADC Regional Irrigation Development Strategy estimates 15,000 m^3 per hectare as net annual water requirements for irrigation. According to the same SADC report, it would appear theoretically possible to irrigate almost 2.0 million hectares within Angola, at an average of 15,000 m^3 per hectare. For estimating water use for agriculture in different provinces (catchment areas), different net annual water requirements for crops were considered due to different agro-climatic zones within Angola, based on various reports available within the country. As a matter of computation the water use by catchment is a result of a multiplication between the irrigable area and the net annual water requirement of the main crop. In the case of Cunene catchment area, a daily additional volume of water equal to 518,400 m^3 per day (6 m^3/s) was considered abstracted from the Calueque dam on the Cunene River for water supply and irrigation of the northern region of Namibia. This abstraction of water is done within the framework of an agreement signed in January of 1969 between the former South African government and the Portuguese government during the colonial period. The government of Angola and the government of Namibia subsequently endorsed the agreement after their independence.

The present agricultural water use estimates are based on existing operational irrigation schemes. As many crops are grown in one irrigation scheme for the estimation of agricultural water uses, the annual net requirement of the main crop was considered in the scheme under consideration. In practise there will be little difference between the present agricultural water use estimates and the estimates projected for the year 2005. So figures for the year 2005 were taken as of present. Table 10.4.1 will show the present agricultural water use estimates.

Table 10.4.1 Present Agricultural Water Use Estimates

Catchment Area	Amount of Water in 2005 (m^3/day)
Bengo	549,416
Bero	324,940
Bentiaba	15,460
Balombo	211,233
Cavaco	422,466
Cuanza	808,523
Cubal da Hanha	140,822
Coporolo	262,329
Cunene	1,101,023
Cubango	164,384
Longa	940,274
Queve	1,013,699
Quicombo	49,315
Evale	260,274
Onzo	20,548
Dande	394,835
Loge	167,466
Lucula	1,598
Catumbela	211,233
Zambeze	15,110
Congo / Zaire	-
Lifune	80,137
Lulondo	280,923

Cuvelai	465,754
Equimina	-
Sumbe / Ngunza	109,589
Curoca	40,973
Giraúl	45,096
Inamangando	-
Carujamba	-
Total:	**8,097,420**

10.5 Agricultural Sector Development Water Use Assumptions

Most irrigated agriculture is developed in the coastal areas and in the southern zones of Angola where annual rainfall is insufficient for rainfed agriculture. These are areas where the mean annual precipitation ranges from 100 mm to 800 mm. Irrigated agriculture can also be carried out in the so-called transition zone, where the mean annual precipitation varies between 800 mm and 1,000 mm.

The assumptions made are that most operational or partially operational irrigation schemes will continue to perform well and that all planned irrigation schemes will be fully operational by the year 2025.

10.6 Future Water Demand for Agriculture by Province

For the future water demand for provinces the development of irrigation in the period between 2015 and 2025 was considered. In areas, where irrigation is carried out over the entire year, 365 days of activity per year was considered, while in areas were irrigation is carried out during the dry season only, a dry period of 182 days was considered. For those irrigation schemes only partially operational, between 50% and 75% of their potential was considered during the year 2015. For the year 2025 all irrigation schemes were considered to be working at their full potential (100%).

10.6.1 Benguela Province

Irrigated agriculture in Benguela province is carried out all year round. The demand for water in the province will be shared by the 11 existing irrigation schemes. With the exception of Cavaco and Catumbela irrigation schemes that are presently working at their full potential, by the year 2015 the remaining irrigation schemes are considered to be working online at 50% to 75% of their potential, while in 2025 they are assumed to work at their full potential (100%).

The net annual water requirement varies between 15,000 m^3 for vegetables and 25,700 m^3 for banana. All irrigation schemes surface (using earth open canals).

Table 10.6.1.1 Demand of Water for Irrigation in Benguela Province

Demand in 2015 (m^3/day)	Demand in 2025 (m^3/day)
3,365,165	3,365,165

10.6.2 Bengo Province

Irrigated agriculture is carried out throughout the year in Bengo province. The demand of water in the province will be shared by the 14 existing irrigation schemes. The Bom Jesus, Caquila, Quiminha Valley, Caxito, Alto Dande, Muzondo, AGROINVEST, Kala-Kala and Lifune irrigation schemes are presently operational or partially operational. The remaining five irrigation schemes are in the planning stage. It is assumed that in the year 2015 all irrigation schemes would be working at 50% to 75% of their potential, while in 2025 they will work at their full potential (100%). The net annual water requirement varies between 8,000 m^3 for vegetables and fruits when using micro-sprinkler, sprinkler or drip irrigation schemes and 15,000 m^3 when using surface irrigation schemes for the same crops. There are micro-sprinkler, sprinkler, drip and surface irrigation schemes (using earth open canals) in the province.

Table 10.6.2.1 Demand of Water for Irrigation in Bengo Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
2,646,673	2,864,379

10.6.3 Bié Province

Information is not available for Bié province.

10.6.4 Cabinda Province

In Cabinda province the demand of water for agriculture will be shared by two irrigation schemes, namely Yabi Valley and Chiadede.

The net annual water requirement was assumed to be 11,000 m^3 for vegetables and all irrigation schemes are surface (using earth open canals).

Table 10.6.4.1 Demand of Water for Irrigation in Cabinda Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
331,268	534,010

10.6.5 Cunene Province

For Cunene province, apart from the daily volume of water required by the irrigation schemes, an additional volume of 518,400 m^3/day (6 m^3/s) was considered as a result of abstraction of water from the Cunene River at Calueque dam. This abstraction was agreed

in January of 1969 between South Africa and Portugal. The agreement was later endorsed by Angola and Namibia after their independence.
The net annual water requirement was assumed to be 17,000 m^3 for all the crops and all irrigation schemes are surface (using earth open canals).

Table 10.6.5.1 – Demand of Water for Irrigation in Cunene Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
12,223,650	22,096,162

10.6.6 Huambo Province

In Huambo province the demand of water for agriculture will be shared by two irrigation schemes, namely Chissola 4 and Kalima. Most of the irrigation to be developed in this province will be supplementary irrigation. The net annual water requirement varies between 10,000 m^3 for vegetables when using drip or micro-sprinkler irrigation schemes and 12,000 m^3 when using surface irrigation schemes (earth open canals).

Table 10.6.6.1 Demand of water for Irrigation in Huambo Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
36,759	66,923

10.6.7 Huila Province

Irrigated agriculture in Huíla province is carried out all year round, although in some areas irrigation is of a supplementary character. The demand of water in the province will be shared by the nine existing irrigation schemes. Pira-Babaera irrigation scheme is in the planning stage. Chimúcua I, Chimúcua II, Bata-Bata, Chicungo and Gandjelas irrigation schemes are presently under rehabilitation. The remaining irrigation schemes are presently operational or partially operational. It is assumed that by the year 2015 the irrigation schemes will be working at 50% to 75% of their potential, while in 2025 they should work at their full potential (100%).

The net annual water requirement varies between 12,000 m^3 for vegetables and fruits when using micro-sprinkler or sprinkler irrigation systems and 15,000 m^3 when using surface irrigation schemes (earth open canals) for the same crops.

Table 10.6.7.1 Demand of Water for Irrigation in Huíla Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
484,795	658,028

10.6.8 Kuanza Norte Province

All irrigation schemes in Kuanza Norte province are either under rehabilitation or still in the planning stage. It has been assumed that, by year 2015, the schemes would be constructed and working at 50% to 75% of their potential. It was also assumed that by the year 2025 the schemes would be working at their full potential (100%). In Kuanza Norte province the net annual water requirement was assumed to be 11,000 m^3 for vegetables and fruits and 13,000 m^3 for banana. All irrigation are surface (using earth open canals).

Table 10.6.8.1 Demand of Water for Irrigation in Kuanza Norte Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
125,115	250,232

10.6.9 Kuanza Sul Province

Irrigated agriculture in Kuanza Sul province is carried out the all year round. The demand for irrigation water will be shared by the 7 existing irrigation schemes. With the exception of Cela irrigation scheme which is presently under rehabilitation, the remaining irrigation schemes are either operational or partially operational. It is assumed that by the year 2015 all irrigation schemes would be working at 50% to 75% of their potential, while in 2025 they would all work at their full potential (100%).

The net annual water requirement in Kuanza Sul province was assumed to be 15,000 m^3 for vegetables and 20,000 m^3 for banana. All irrigation schemes are surface (using earth open canals).

Table 10.6.9.1 Demand of water for irrigation in Kuanza Sul province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
3,745,206	5,227,398

10.6.10 Cuando Cubango Province

In Cuando Cubango province the demand of water for agriculture will be shared by three irrigation schemes, namely Menongue I, Menongue II and Cuchi. The net annual water requirement was assumed to be 15,000 m^3 for vegetables and fruits and 11,000 m^3 for rice. All irrigation schemes are surface (using earth open canals).

Table 10.6.10.1 Demand of Water for Irrigation in Cuando Cubango Province

Demand in 2015 (m^3/day)	Demand in 2025 (m^3/day)
239,726	315,069

10.6.11 Luanda Province

Irrigated agriculture in Luanda province is carried out throughout the year. The demand for water in the province will be shared by the 12 existing irrigation schemes. The Kikuxi, Tombo, COPINOL, Fazenda Experimental and Bita irrigation schemes are presently operational or partially operational. By the year 2015 the remaining irrigation schemes are considered to be working at 50% to 75% of their potential, and in 2025 all schemes are assumed to operate at their full potential (100%). In Luanda province the net annual water requirement varies from 8,000 m^3 when using micro-sprinkler or drip irrigation schemes for vegetables and fruits and 23,730 m^3 when using surface irrigation (earth open canals) for the same crops. There are micro-sprinkler, sprinkler and surface irrigation schemes (earth open canals) in the province.

Table 10.6.11.1 Demand of Water for Irrigation in Luanda Province

Demand in 2015 (m^3/day)	Demand in 2025 (m^3/day)
1,113,793	1,495,491

10.6.12 Lunda Norte Province

Information is not available for Lunda Norte province.

10.6.13 Lunda Sul Province

Information is not available for Lunda Sul province.

10.6.14 Malanje Province

Irrigated agriculture is carried out the all year round in Malanje province. The demand for agricultural water in the province will be shared by the nine existing irrigation schemes. The Kissol, Kamatende, and Vânvala irrigation schemes are presently operational or partially operational, and by the year 2015 the remaining irrigation schemes are considered to be working at 50% to 75% of their potential, while in 2025 they are all assumed to work at their full potential (100%). In Malanje province the net annual water requirement was assumed to vary from 11,000 m^3 to 13,000 m^3 for vegetables and fruits. All irrigation schemes are surface (using earth open canals).

Table 10.6.14.1 Demand of Water for Irrigation in Malanje Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
2,464,612	5,651,649

10.6.15 Moxico Province

There is only one irrigation scheme in Moxico province. So Perímetro do Luena will consume the demand of water for agriculture. The net annual water requirement was assumed to be 11,000 m^3 for all crops in Moxico Province. The existing irrigation schemes are surface (using earth open canals).

Table 10.6.15.1 Demand of Water for Irrigation in Moxico Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
30,220	60,440

10.6.16 Namibe Province

Irrigated agriculture in Namibe province is carried out throughout the year. The demand for water in the province will be shared by the eleven existing irrigation schemes. With the exception of the Carunjamba and Inamagando irrigation schemes that presently are not working, the remaining irrigation schemes are either operational or partially operational. It is assumed that in the year 2015 all irrigation schemes would be working at 50% to 75% of their potential, while in 2025 they will all work at their full potential (100%).

The net annual water requirement varies between 9,970 m^3 for olive trees and 15,000 m^3 for fruits and vegetables. All irrigation schemes are surface (using earth open canals).

Table 10.6.16.1 Demand of Water for Irrigation in Namibe Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
679,485	967,260

10.6.17 Uíge Province

There is only one irrigation scheme in Uíge province, Perímetro do Lusselúa. This scheme thus represents the demand for water for agriculture.

The net annual water requirement figure for rice for Uíge province was assumed to be 11,000 m^3. The existing irrigation scheme is surface (using earth open canals).

Table 10.6.17.1 Demand of Water for Irrigation in Uíge Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
45,206	90,411

10.6.18 Zaire Province

There is only one irrigation scheme in Zaire province, Perímetro do Soyo-Benza. This thus constitutes the demand for irrigated agriculture water for the province.

In Zaire province the net annual water requirement was assumed to be 13,000 m^3 for all crops. The existing irrigation scheme is surface (using earth open canals).

Table 10.6.18.1 Demand of Water for Irrigation in Zaire Province

Demand in 2015 (m^3/day)	**Demand in 2025 (m^3/day)**
373,973	747,945

10.7 Future Agricultural Water Demand by Catchment

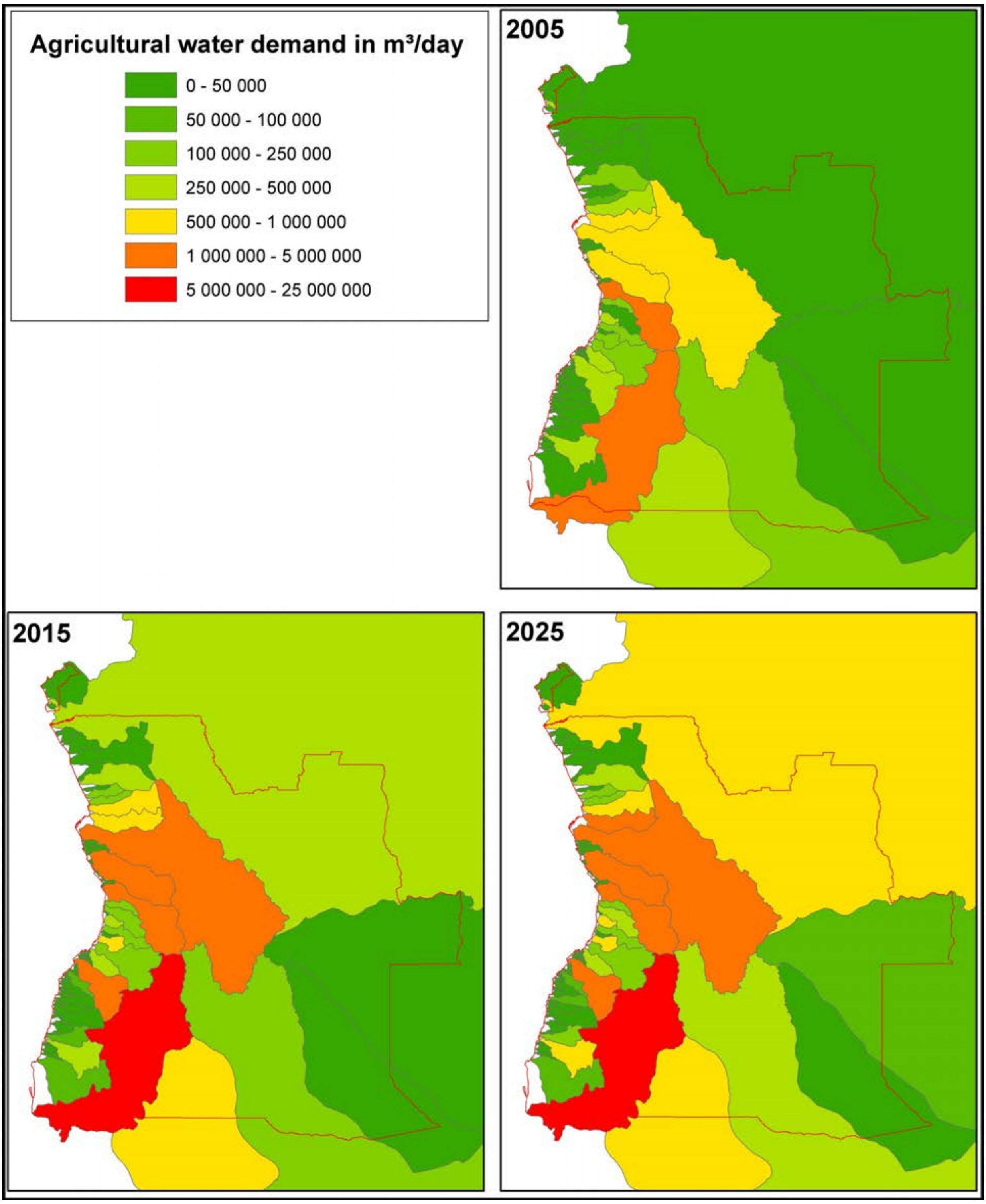
It is assumed that beginning, from the year 2015, the existing and the planned irrigation schemes will perform at 50% to 75% of their potential, and that by year 2025 all irrigation schemes will perform at 100% of their potential. Here it is important to mention that, due to the lack of information on irrigation activities in provinces like Bié (Cuanza catchment area), Lunda Norte (Congo/Zaire catchment area) and Lunda Sul (Congo/Zaire catchment area), the given data might not be to representative, although efforts have been made to assess this.

Table 10.7.1 lists the future irrigated agriculture water demand estimates by catchment. These are illustrated graphically in Figure 10.7.1.

Table 10.7.1 Future Irrigated Agriculture Water Demands by Catchment

Catchment	Amount of water in 2015 (m^3/day)	Amount of water in 2025 (m^3/day)
Bengo	808,628	1,064,359
Bero	487,710	649,880
Bentiaba	21,151	26,831
Balombo	211,233	211,233
Cavaco	422,466	422,466
Cuanza	4,470,323	4,670,262
Cubal da Hanha	711,151	711,151
Coporolo	1,830,138	1,894,521
Cunene	11,311,734	22,096,162
Cubango	239,726	315,069
Longa	1,643,836	2,350,685
Queve	1,571,233	2,075,343
Quicombo	212,672	283,562
Evale	328,767	520,548
Onzo	236,302	236,302
Dande	672,959	672,959
Loge	435,617	435,617
Lucula	1,598	1,598
Catumbela	211,233	211,233
Zambeze	30,220	60,440
Congo / Zaire	419,178	838,356
Lifune	160,274	160,274
Lulondo	329,671	532,412
Cuvelai	652,055	931,507
Equimina	74,836	74,836
Sumbe / Ngunza	164,384	219,178
Curoca	61,459	81,946
Giraúl	68,493	108,904
Inamangando	13,658	27,315
Carujamba	27,315	72,385
Total:	**27,830,020**	**42,039,280**

Figure 10.7.1 Future Irrigated Agriculture Water Demand by Catchment



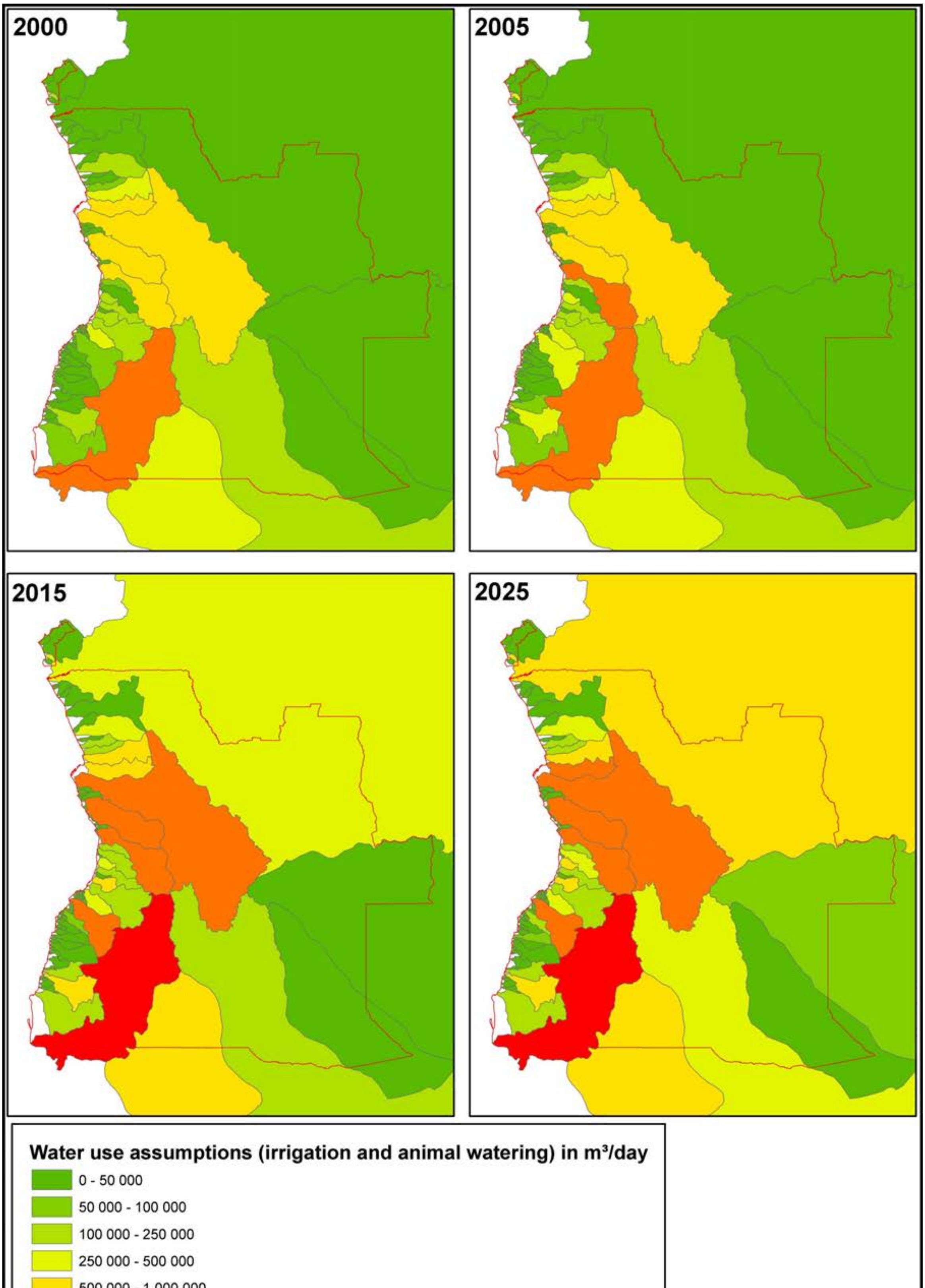
(For catchment names/numbers see Figures 12.1 a, b, c and d)

Table 10.7.2 lists the future irrigation and animal watering water demand estimates sorted by catchment. These are illustrated graphically in Figure 10.7.2.

Table 10.7.2 Water Use Assumptions by Catchments (Irrigation and Animal watering)

Catchment	Amount of water in 2000 (m^3/day)	Amount of water in 2005 (m^3/day)	Amount of water in 2015 (m^3/day)	Amount of water in 2025 (m^3/day)
Bengo	545,711	550,986	810,856	1,067,643
Bero	181,667	347,267	517,915	690,767
Bentiaba	7,735	15,460	21,150	26,831
Balombo	211,233	211,233	211,233	211,233
Cavaco	430,046	431,350	434,684	439,299
Cuanza	509,778	822,747	4,489,858	4,697,133
Cubal da Hanha	140,822	140,822	711,151	711,151
Coporolo	75,324	278,284	1,851,859	1,924,125
Cunene	1,036, 862	1,183,202	11,422,476	22,096,162
Cubango	169,904	170,825	248,502	328,059
Longa	590,621	943,839	1,649,046	2,358,304
Queve	505,730	1,022,137	1,583,170	2,092,269
Quicombo	30,822	49,315	212,671	283,562
Evale	130,137	260,274	328,767	520,548
Onzo	20,548	20,548	236,302	236,302
Dande	394,834	394,834	672,959	672,959
Loge	167,466	167,466	435,617	435,617
Lucula	1,598	1,598	1,598	1,598
Catumbela	213,038	213,353	214,162	215,287
Zambeze	-	15,110	30,220	60,440
Congo / Zaire	2,765	3,257	423,690	844,626
Lifune	80,137	80,137	160,274	160,274
Lulendo	140,462	280,923	329,671	532,412
Cuvelai	490,954	495,036	686,470	978,053
Equimina	12,720	14,787	94,828	101,881
Sumbe / Ngunza	55,760	110,750	115,033	221,679
Curoca	54,687	80,689	115,033	153,997
Giraúl	48,998	74,149	113,152	169,275
Inamangando	-	-	13,658	27,315
Carujamba	-	-	27,315	72,385
Angola Total	**6,250,359**	**8,380,378**	**28,163,320**	**42,330,916**

Figure 10.7.2 Water Use Assumptions by Catchments (Irrigation and Animal watering)



(For catchment names/numbers see Figures 12.1 a, b, c and d)

11. SHARED WATER RESOURCES

11.1 Background to International Treaties on Shared Water Resources

Population growth, economic development, and changing regional values have intensified competition over water resources worldwide, leading to predictions of increasing future conflicts over shared water supplies. Of particular concern to the international community is the potential for conflict within the world's 263 international basins[1]. To mitigate the likelihood of conflict as well as to resolve existing disputes, the international community has devised principles for international watercourse management. Over the past century, these principles have been refined and, most recently, codified in the 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses. Likewise, basin communities, building on their own rich treaty history, have accelerated the development of cooperative institutions to manage internationally shared river systems.

The complex physical, political, and human interactions within international river basins can make the management of these shared water systems especially difficult. Issues of increasing water scarcity, degrading water quality, rapid population growth, unilateral water development, and uneven levels of economic development are commonly cited as potentially disruptive factors in co-riparian water relations. The combination of these factors has led academics and policy-makers alike to warn of impending conflict over shared water resources. Despite these seemingly formidable obstacles, however, co-riparian states have demonstrated a remarkable ability to cooperate over their shared water supplies.

To pre-empt potential conflict and resolve existing disputes, the international community has focused considerable attention in the 20th century on developing and refining principles of international freshwater management. The Institute of International Law (IIL) published a set of basic recommendations in its 1911 Madrid Declaration on the International Regulation regarding the Use of International Watercourses for Purposes other than Navigation. Included in these recommendations, the IIL discouraged unilateral basin alterations and harmful modifications of international rivers, while advocating the creation of joint water commissions.

Expanding on these guidelines, the International Law Association developed the Helsinki Rules of 1966 on the Uses of the Waters of International Rivers. The Helsinki Rules outlined principles related to the equitable utilization of shared watercourses and the commitment not to cause substantial injury to co-riparian states. Four years later, in 1970, the United Nations commissioned its own legal advisory body, the International Law Commission (ILC) to codify the law on the non-navigational uses of international watercourses. In 1997, the ILC's task was completed with the United Nations General Assembly's adoption of the Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Convention), which regularized principles of equitable and reasonable utilization and the obligation not to cause significant harm and established a framework for the exchange of data and information, the protection and preservation of shared water bodies, the creation of joint management mechanisms, and the settlement of disputes.

Despite the fact that 103 countries approved the United Nations resolution adopting the document, the UN Convention's ultimate practicality has been called into question due to its vague and sometimes contradictory language and the slow progress that has been made towards its ratification. However, while explicit approval of the UN Convention may prove difficult, implicit support of the international water management principles it contains is clearly evident through such international statements as the 1972 Declarations of the United Nations

1 Atlas of International Freshwater Agreements, United Nations Environment Programme, 2002, ISBN: 92 807 2232 8.

Conference on the Human Environment, the 1977 Declarations and Resolutions of the United Nations Water Conference, the 1992 Dublin Statement from the International Conference on Water and the Environment, and the 2000 Second World Water Forum's Ministerial Declaration.

Initiatives of regional organizations have further served to encourage co-riparian cooperation. Through the creation of region-specific guidelines, multinational bodies such as the Organization for Economic Cooperation and Development (OECD), the European Union, and the Southern African Development Community (SADC) have formulated agreements and protocols supporting collaborative water resource initiatives. In the 1970s, the OECD Council, for example, issued a series of recommendations concerning the management and protection of transboundary resources relevant to international rivers. European governments have addressed regional water issues through such agreements as the Convention on Environmental Impact Assessment in a Transboundary Context (1991) and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992). Similarly, in the southern African context, the SADC member states, drawing heavily from the language contained in the UN Convention, have established the Protocol on Shared Watercourses in the Southern African Development Community (2000).

11.2 Angola's International River Basins and their Treaties[2]

Angola has five international rivers that have been the subject of international treaties and agreements.

11.2.1 River Zaire/Congo

Total catchment area: 3,699,100 km^2, shared as follows:

	Area of Basin in Country	
Countries	***km^2***	***%***
Democratic Republic of Congo, (Kinshasa)	2,307,800	62.39
Central African Republic	402,000	10.87
Angola	291,500	7.88
Republic of the Congo (Brazzaville)	248,400	6.72
Zambia	176,600	4.77
United Republic of Tanzania	166,800	4.51
Cameroon	85,300	2.31
Burundi	14,300	0.39
Rwanda	4,500	0.12
Gabon	460	0.01
Malawi	90	0.00

[2] Atlas of International Freshwater Agreements, United Nations Environment Programme, 2002, ISBN: 92 807 2232 8.

The following particular treaties were found to be in effect for this basin:

Date	***Treaty Basin***	***Signatories***	***Treaty Name***
20.7.1927	M'Pozo	Belgium; Portugal	Convention regarding various questions of economic interest.
26.2.1885	Congo	Niger, Austria-Hungary; Belgium; Denmark; France; Germany; Great Britain; Italy; Netherlands; Norway; Portugal; Russia; Spain; Sweden; Turkey; United States of America	General act of the conference of Berlin, respecting: 1) Freedom of trade in the basin of the Congo; 2) The slave trade; 3) Neutrality of the territories in the basin of the Congo; 4) Navigation of the Congo; 5) Navigation of the Niger; and 6) Rules for future occupation of the coast of the African continent

11.2.2 Cunene River

Total area: 110,000 km^2, shared as follows:

	Area of Basin in Country	
Countries	***km^2***	***%***
Angola	95,300	86.68
Namibia	14,700	13.32

The following particular treaties were found to be in effect for this basin:

Date	***Treaty Basin***	***Signatories***	***Treaty Name***
1.1.1996	Frontier or shared waters	Mozambique; South Africa	Joint Water Commission terms of reference
21.1.1969	Cunene	Portugal; South Africa, Republic of	Agreement between the government of the Republic of South Africa and the government of Portugal in regard to the first phase of development of the water resource of the Cunene River Basin
29.4.1931	Cunene	Portugal; South Africa	Exchange of notes... respecting the boundary between the mandated territory of South Africa and Angola
1.7.1926	Cunene, Kunene	Portugal; South Africa	Agreement between South Africa and Portugal regulating the use of the water of the Cunene River

11.2.3 Okavango River

Total area: 706,900 km^2, shared as follows:

	Area of Basin in Country	
Countries	***km^2***	***%***
Botswana	358,000	50.65
Namibia	176,200	24.93
Angola	150,100	21.23
Zimbabwe	22,600	3.19

The following particular treaties were found to be in effect for this basin:

Date	***Treaty Basin***	***Signatories***	***Treaty Name***
16.9.1994	Okavango	Republic of Angola; Republic of Botswana; Republic of Namibia	Agreement between the governments of the Republic of Angola, the Republic of Botswana, and the Republic of Namibia on the establishment of a permanent Okavango River Basin Water Commission (OKACOM)

11.2.4 Zambezi River

Total area: 1,385,300 km^2, shared as follows:

	Area of Basin in Country	
Countries	***km^2***	***%***
Zambia	576,900	41.64
Angola	254,600	18.38
Zimbabwe	215,500	15.55
Mozambique	163,500	11.81
Malawi	110,400	7.97
United Republic of Tanzania	27,200	1.97
Botswana	18,900	1.37
Namibia	17,200	1.24
Democratic Republic of Congo (Kinshasa)	1,100	0.08

The following particular treaties were found to be in effect for this basin:

Date	***Treaty Basin***	***Signatories***	***Treaty Name***
July 28, 1987	Zambesi	Republic of Zambia Republic of Zimbabwe	Agreement between the Republic of Zimbabwe and the Republic of Zambia concerning the utilization of the Zambesi River
May 28, 1987	Zambesi	Botswana; People's Republic of Mozambique; United Republic of Tanzania; Zambia; Zimbabwe	Agreement on the action plan for the environmentally sound management of the common Zambesi River System
May 2, 1984	Zambesi	Mozambique, People's Republic of; Portugal, Republic of; South Africa, Republic of	Agreement between the governments of the Republic of Portugal, the People's Republic of Mozambique and the Republic of South Africa relative to the Cahora Bassa Project
April 1, 1967	Zambesi	Portugal; South Africa	Agreement between South Africa and Portugal relating to hydropower development on the Zambesi River [untitled]
November 25,1963	Kariba, Zambezi	Northern Rhodesia; Southern Rhodesia	Agreement relating to the Central African Power Corporation
November 18,1954	Kwando	Great Britain; Great Britain on behalf of the Federation of Rhodesia and Nyasaland; Portugal	Agreement between the government of the United Kingdom of Great Britain and Northern Ireland on their own behalf and on behalf of the government of the Federation of Rhodesia and Nyasaland and the government of Portugal with regard to certain Angolan and Northern Rhodesian natives living on the Kwando River
January 21, 1953	Zambesi	Great Britain; Portugal	Exchange of notes constituting an agreement between Her Majesty's government in the United Kingdom of Great Britain and Northern Ireland and the Portuguese government providing for the Portuguese participation in the Shiré Valley Project
June 11, 1891	Busi, Limpopo, Pungwe, Sabi, Shiré, Zambesi	Great Britain; Portugal	Treaty between Great Britain and Portugal defining their respective spheres of influence in Africa

11.2.5 Cuvelai/Etosha

Total area: 159,620 km^2, shared as follows:

	Area of Basin in Country	
Countries	***km^2***	***%***
Angola	52,158	32.68
Namibia	107,462	67.32

No formalised/registered international treaties were found for this basin

11.3 Elements of the Shared River Basins

11.3.1 The Cunene River

The Cunene River originates in the Huambo Province in the Sierra Encoco Mountains in southwestern Angola. The river flows in a southerly direction to the Ruacana Falls where it turns to the west and proceeds to the Atlantic Ocean. The lower section of the river cuts through a deep gorge that starts at the Ruacana Falls. In the 340 km between Ruacana and the Atlantic Ocean,, the river falls more than 1100 m and this important feature provides the Cunene River Basin with a hydroelectric power potential of some 2400 MW. Between 1926 and 1969 the Portuguese and South African Governments entered into three Water Use Agreements on the Cunene. In the first agreement of 1926, it was agreed that Namibia has the right to half of the flow of the Cunene, provided that a water scheme for such a purpose would be feasible. The second agreement in 1964 related in general to the utilization of rivers of mutual interest between the Parties, inferring the inclusion of other rivers like the Cuvelai and the Okavango in Angola or river systems like the Limpopo and Incomati in Mozambique as well. In that agreement the principle of best joint utilization was accepted and was defined as the allocation and utilisation, on an equitable basis, of shared water resources with a view to achieving the optimum benefit for the states concerned, within the limits of the available quantity of water. One other country, the Kingdom of Swaziland in 1967, has also acceded to this agreement.

The detailed feasibility investigations and related activities for that first phase of the development of the hydropower potential of the Cunene River and the diversion of water into northern Namibia set in motion by the 1964 agreement culminated in the Third Water Use Agreement of 1969 which initiated the construction of the proposed Cunene River Scheme. This agreement established a Permanent Joint Technical Commission (PJTC) and made provision for Namibia to abstract water at 6 m^3/s at Calueque for diversion to the Cuvelai basin in Northern Namibia. The project comprised the Gove dam to regulate the flow of the Cunene, the Calueque dam and pump station for the diversion of water into Namibia, the Ruacana weir for the diversion of water into Ruacana Power Station, and the power station itself. Of this infrastructure, the Calueque Dam was never completed due to the war in Angola at the time. The Gove Dam was completed in 1975 and the works at Ruacana in 1978. The Ruacana Power Station, with an installed capacity of 240 MW and generation capacity of 1055 GWh/year located in Namibia has not been operating at its full capacity due to the lack of continuous regulation of Cunene flows at Gove.

The total development of the Cunene River includes the multipurpose hydropower and irrigation scheme at Matala in Angola. The hydropower facilities at Matala were upgraded from 27 MW to 40 MW in 1989, but the planned land available for irrigation was not cultivated due to damage to the canal system. However, the Matala system presently has a potential of 10,000 hectares, of which 5,000 hectares were recently rehabilitated by the Brazilian contractor ODEBRECHT, and the remaining 5,000 hectares will be rehabilitated when funds become available). Namibia can divert 6 m^3/s from the Cunene River at Calueque across the catchment to the Cuvelai drainage basin for domestic water supply the domestic and irrigation water demand in northern Namibia.

In September 1990, some 6 months after the independence of Namibia, the Governments of the Republic of Angola and Namibia endorsed and affirmed the previous agreements reached between Portugal and South Africa. The Permanent Technical Commission was reinstated and a Joint Operating Authority for the Cunene Basin was planned but has not, to the Consultant's knowledge, as yet been formalised. This bi-national authority would be created if the governments of Angola and Namibia could approve the feasibility study for the construction of either Epupa or Baynes (Marienflus) hydropower plant. Both Epupa and Baynes hydropower schemes are located in the international reach of Cunene River.

11.3.2 The Cuvelai River

The Cuvelai River rises in the southern foothills of the Sierra Encoco in southwestern Angola. It drains southwards towards the Etosha Pan in northern Namibia. The Cuvelai is perennial for about 100 km before it ramifies into a delta of ephemeral watercourses, which cross a broad plain of low relief. This delta converges again to terminate in the ephemeral Etosha Pan. The watercourses, called oshanas, are the lifeblood of an area where 650000 people, or just less than half the population of Namibia live.

Due to the arid climatic conditions, surface waters and shallow wells dry up from time to time. The groundwater is saline and the only way to augment these rather unreliable water supplies is to import water from the perennial Cunene River. This is the main reason for diverting water from the Cunene River Basin to the Cuvelai Basin. The water scheme is operated by the Namibian Department of Water Affairs on Angolan territory and serves as an excellent example of cooperation between the states. The existing water supply network, distributing water through canals and pipelines to the population, is one of the largest in Southern Africa.

It is clear that any alteration to this international watercourse system in Angola or Namibia will have major repercussions for the fragile, semi-arid ecosystem and the people living on the flood plains. However, there is no specific international agreement between Angola and Namibia on water allocation or further studies in the Cuvelai Basin.

In a project document[3] dated April 2004 named “Joint Water Resources Management Programme for the Cuvelai-Cunene Shared Watercourses”, the main intention is to reinforce the international cooperation between Angola and Namibia. This programme is to be funded by the Finnish government but has not as yet, to the Consultant's knowledge, been started.

11.3.3 The Okavango River Basin

The Okavango River Basin rises in the southwestern Angolan highlands, near and just east of the source of the Cunene and the Cuvelai rivers. The Cubango flows for more than 600 km through the upper catchment inn a southerly direction until it reaches the west-east cutline border between Angola and Namibia. From that point, the river forms the border between Angola and Namibia over a distance of some 400 km. It then turns southwards again, and ends in the Okavango Swamps in Botswana. The mean Annual runoff of the Okavango River at Muhembo on the border between Botswana and Namibia is 10,000 million m^3.

3 Programa de Gestão Conjunta “Angola –Namíbia” dos Recursos Hídricos Partilhados dos Cursos de Água do Cuvelai-Cunene, Documento de Projecto, Abril 2004, Programa Financiado pelo Ministério dos Negócios Estrangeiros da Finlândia.

The main tributaries of the Okavango are the perennial Cuito River and the ephemeral Omatako River. The Cuito River rises in the highlands in the central Bié Province of Angola and contributes half of the flow of the Okavango River. Very little is known about water resource development in the upper reaches of the Cubango and Cuito in Angola. It is thought that virtually no development took place in the catchment since the civil wars in Angola. It has been estimated that some 20 million m^3 of water is abstracted per annum from the Okavango River for domestic and irrigation consumption in Namibia. A dam was built in the upper catchment of the Omatako River to divert water for domestic and industrial consumption in the Windhoek-Okahandja complex in the Swakop River catchment in central Namibia. No major development of the water resources of the Okavango River or the delta took place in Botswana, except for the Mopopi Dam. The dam was built to supply water to the Orapa diamond mine and was created by using the basin of the Putimolonwane Pan and constructing earth embankments around it to impound more water. The reservoir capacity is 100 million m^3 and it covers 24.3 km^2 at full supply level. Water is pumped into the dam from the Boteti River, which is the outflow of the Okavango Delta.

The institutional arrangements concerning the utilization of the Okavango Basin were under discussion in the first half of the 1990's that led eventually to the establishment of the Permanent Okavango River Basin Water Commission (OKACOM). This is described in more detail in a subsequent section of this report.

11.3.4 The Zambezi River Basin

The Zambezi River Basin is the largest of the African river systems flowing into the Indian Ocean. It is shared by eight basin states and supports a population of more than 20 million people. The major tributaries of the Zambezi rise in Angola, Malawi, Tanzania, Zambia and Zimbabwe. There are five major swamps, the Borotse, the Eastern Caprivi, the Kafue, the Busanga and the Lukanga, covering an area of 20000 km2 at high flood periods.

Apart from a number of smaller lakes, the most significant natural lake is Lake Malawi (30,000 km^2), but there are also two major artificial lakes, namely Kariba (5,180 km^2), and Cahora Bassa (2,660 km^2). Other reservoirs with large surface areas are the Kafue Dam (809 km^2) and the Ithezithezi Dam (365 km^2). It has been estimated that more than 160,000 tonnes of fish is caught per annum in these water bodies. More than 28 dams with a storage capacity in excess of 12 million m^3 of which Kariba is the largest (160,000 million m^3) and Cahora Bassa the second largest (52,000 million m^3) have been built for domestic, industrial and mining water supply, irrigation and power generation. The countries with dams are Malawi, Mozambique, Zambia and Zimbabwe. At present the major hydropower facilities are in that Victoria Falls, Kafue Gorge, Kariba, Cahora Bassa, and on the Shire River at Nkula, Tedzani, Kapichira. More dams are possible at various locations.

Although the available water resources in the Zambezi Basin in general exceeds the demand, this situation may deteriorate as a result of the increase in population, more industrial and mining development, increased irrigated food production, a higher standard of living of the population and by taking the environmental water demand of the system into account. However, it is envisaged that the most significant increase in water consumption will be due to irrigation projects. The Zambezi River Basin is thus clearly the main life supporting artery of eight basin states and an effective River Basin Commission is desirable to ensure its well-being. Such a commission has not as yet been established, although the Zambezi River Authority has been formed as detailed in a subsequent section.

11.3.5 The Zaire River

The Zaire (Congo) River originates in the highlands located in eight co-basin states. However, most of the contribution to the runoff at the mouth of the Zaire River is generated in the middle courses of the river in the central tropical rainforests of the Zaire Basin on the equator. The flow in the upper reaches of the drainage basin is of lesser magnitude, especially in Angola, the Central African Republic, and Tanzania. The annual average runoff in the Zaire is 1,260,000 million m^3, and the average flow is 40,000 m^3/s. The historic minimum and maximum flows vary between 21,400 and 73,600 m^3/s respectively, but for 98% of the time the river flow exceeds 26,400 m^3/s.

The main potential of the Zaire River is for the generation of hydropower. There are many falls and rapids, which provide potential sites for development. The river has a total theoretical generating capacity of some 100,000 MW and only a tiny fraction of this is today developed. In spite of the many waterfalls and rapids, the Zaire River is a very important waterway because the river is navigable over long distances and provides good opportunities for boat transport and trade between the basin states. There are large wetlands and lakes in the Zaire Basin within Zambia and Tanzania, which provide important grazing, fish and wildlife resources to the population. About 20 large dams have been built on the tributaries of the Zaire River but none within the SADC region. Most of the dams are used for water and power supply. There are plans for further development of water or electricity supply infrastructure on the Zaire River within the SADC States.

11.4 Institutions, Organisations and Protocols for Shared Water Resources

11.4.1 The Permanent Okavango River Basin Water Commission (OKACOM)

The Permanent Okavango River Basin Water Commission (OKACOM) agreement was made on 15th September 1994 in Windhoek (Namibia). OKACOM is an agreement between the three countries of Angola, Namibia and Botswana. Through OKACOM all the member states of Angola, Namibia and Botswana understood the importance of working together before a conflict situation would arise. Although OKACOM is a relatively young institution, it is still evolving to become a major driving force in the sustainable development of the Okavango Basin. The objective of OKACOM among other issues include the provision of advise to the governments of Angola, Namibia and Botswana about the technical matters relating to the sustainable development, beneficial utilization, integrated management and conservation of water resources of common interests in the Okavango Basin. In order to achieve this objective, each of the three riparian states has appointed a commissioner to represent the country's interests. In addition, OKACOM has appointed the Okavango Basin Steering Committee to manage projects and advice where necessary. The steering committee is composed of individuals from member countries. OKACOM provides a forum upon which the countries of Angola, Namibia and Botswana can discuss common issues affecting the use of water resources in the Okavango River Basin.

The three nations sharing the Okavango river basin, Angola, Namibia, and Botswana, acting under the auspices of the Permanent Okavango River Basin Commission (OKACOM), have launched a process to develop an Integrated Management Plan (IMP). The IMP will be a comprehensive study of management options in each country's water sector and a detailed environmental assessment of each option to provide essential background for negotiating the equitable and reasonable allocation of water to the Okavango Basin States. Ideally this process will meticulously and openly weigh the legitimate water supply needs and opportunities of the basin states against the preservation of the unique Okavango Delta.

11.4.2 The Southern African Development Community (SADC) Protocol on Shared Watercourses

The Revised Southern African Development Community (SADC) Protocol on Shared Water Courses of 2001 was signed by each of the member states in 2001. The new protocol replaced the earlier one of 1990. Both these protocols indicate that shared and heightened awareness of the critical importance of water resources for the entire Southern African region (Ashton and Neal, 2003). Among some of the key provisions of the revised protocol include obligations that; member states within a shared watercourse system undertake to establish close cooperation with their neighbours in the study and execution of all projects likely to have an effect on the regime of the watercourse system; and that member states shall utilize a shared watercourse system in an equitable manner.

A shared watercourse system shall be used and developed by member states to attain its optimum utilization and for the benefits consistent with the adequate protection of the watercourse system. The revised protocol has also made provision upon which the countries of Angola, Botswana and Namibia should develop water systems that flow within the boundaries of their sovereign territories. The critical part of the provisions are that each state should inform its neighbours of any plans to develop or modify a shared river system, to work together to ensure that each state shares in the benefits of such plans, and to ensure that environmental degradation is minimized.

11.4.3 The Zambezi River Authority

The Zambezi River Authority[4] was established as a corporate body in 1987 by parallel legislation in the Parliaments of Zambia and Zimbabwe and is jointly owned by the governments of Zambia and Zimbabwe. The functions of the Authority include:

- Operation and maintenance of the Kariba Dam and Hydropower Complex and any other dams on the river
- Investigation and development of new dams on the Zambezi River
- Collection and processing of hydrological and environmental data on the Zambezi River

Although instigated and owned by Zambia and Zimbabwe, the ZRA has begun to take an interest in the entire Zambezi basin, which includes the headwaters in Angola. Since 1998 the ZRA has been implementing an “Environmental Monitoring Programme (EMP)”. The EMP is a comprehensive programme that is sub-regional in coverage, encompassing the Lake Kariba and the Zambezi Basin upstream of the Lake. The strategies for the future sustainability of the outcomes of the EMP are contained in a resolution made at the EMP Concluding Stakeholder Workshop in Victoria Falls Town, Zimbabwe in December 2002. Recognising the transboundary nature of watercourses and environmental concerns, the Workshop recommended that in the long-term, the EMP should be extended to include all the Zambezi River Basin Riparian countries through Joint Permanent Commissions.[5]

The Zambezi River Action Plan (ZACPLAN) developed and being implemented by the Southern African Development Community Water Division (SADC-WD) contains the major framework for region-wide activities. The ZACPLAN core project, Zambezi River Action Project (ZACPRO) No. 6 Phase 2 is housed at ZRA. This project aims at developing an integrated water resources management strategy for the Zambezi River Basin and the establishment of basin-wide collaboration. Its immediate overall objective is the

[4] http://www.zaraho.org.zm

[5] Zambezi River Authority – Proceedings of the Concluding Stakeholders Workshop on the EMP held from 16-17th December 2003 in Victoria Falls, Zimbabwe

Development of an Integrated Water Resources Management Strategy for the Zambezi River Basin. The overall objective is expanded as follows:

- Setting up regional and national enabling environment necessary for strategic and integrated water resources management among and for the stakeholder institutions and interest groups. The objective is confined to facilitating the adoption of the Zambezi Basin Commission (ZAMCOM) and setting up other legal agreements, establishment of National and Project Steering Committees (NSC & PSC), conducting awareness campaigns, and technical capacity building.
- Establishment of Water Resources Management Systems including models, tools and agreed guidelines for joint planning and management in the Zambezi River Basin; and
- Development of an indicative Integrated Water Resources Management Strategy that should propose capacity building strategies and consolidate the existing plans and management schemes into basin-wide Strategy and preparations for Phase III.

The main specific outputs expected from the Project are:

- Functioning ZAMCOM and sample joint water resources development agreements
- Functioning project institutional and supervisory arrangements
- Functioning ZACBASE and regional network of key hydrometric stations
- Versatile and appropriate planning and management models and tools; and
- Basin-wide Integrated Water Resources Management Strategy

These outputs are intended to establish regional commitment among riparian states to work together in the utilisation of the common water resources of the Zambezi River that would make them prosper in a peaceful and secure environment. The strategy itself is intended to establish expectations for infrastructure and other water management systems that would improve water availability, protection of water resources from over-exploitation and pollution and flood protection, based on co-ordinated, integrated and strategic planning, development and management in the basin.

11.4.4 The Ramsar Convention on Wetlands of International Importance

Botswana ratified the Ramsar Convention on Wetlands of International Importance in 1997. The Ramsar Convention on Wetlands of International Importance is an international agreement that seeks to promote awareness and cooperation in the conservation of threatened wetlands (Ramsar Convention, 1971). The Convention is particularly important to ecosystems that support a wide diversity of species. The Okavango Delta has as a result been listed as a wetland of International Importance under Article 2 of the Convention. Through Article 3 of the same Convention, Botswana is obliged to ensure that the wetland together with all the natural resources found in it are conserved. Botswana has since drawn a National Wetland Policy and Strategy in 2000 and has also decided to produce an Integrated Management Plan for the Okavango Delta. The Okavango Delta Management Plan study started mid-2003. Namibia has so far ratified the Convention and Angola has not done so[6].

11.4.5 The United Nations Convention on Biological Diversity

The United Nations Convention on Biological Diversity is another international agreement aimed at promoting the conservation and sustainable use of biodiversity (UNCBD, 1992). Angola, Botswana and Namibia are signatories to the Convention. The Convention notes

6 Causes and possible solutions to potential water resource conflicts in the Okavango River Basin: The case of Angola, Namibia and Botswana Joseph E. Mbaiwa, University of Botswana, Harry Oppenheimer Okavango Research Centre, Private Bag 285, Maun, Botswana

that individual states retain sovereign rights to use their resource in their respective countries based on their environmental policies. However, it also notes that in the case of shared resources, activities of an individual state should not cause damage to the environment beyond its borders where other states become affected (UNCBD, 1992). The United Nations Convention on Biological Diversity is important for Angola, Namibia and Botswana as it will ensure that none of the member states can under the terms of the Convention have activities on the Okavango Basin that may have detrimental effects on the biodiversity and ecological functioning located outside their borders. This means that socio-economic developments by any of the riparian members states particularly the use of water resources from the Okavango River should be done in consultation and the agreement of other member states in order to sustain the biodiversity of the basin.

11.5 Sustainable use of Angola's Shared Water Resources[7]

There are potential water resource conflicts between Angola, Namibia and Botswana over the use of water resources in the Okavango River Basin. The increasing water demands in each of the basin member states is characterized by the need for water abstraction from the Okavango River. Agriculture, particularly irrigation, industrialization, urbanization, hydropower generation, tourism as well as resettlement are some of the socio-economic activities in the basin that requires water from the Okavango river. While each of the basin member states have the sovereign right to implement water projects in their respective countries, the failure to seek cooperation and the agreement of other member states has the potential to cause conflicts. The need to avoid potential water resource conflicts between the Okavango River Basin states suggest that strategies need to be developed to promote sustainable water use in the basin. Sustainable water resource use in the Okavango River Basin depends on the cooperation of riparian states. Basin states can demonstrate cooperation through the observation of both international and regional agreements over the use of water in shared watercourses. They can also show their commitment to sustainable water use through their national water policies and acts. That is, the need for coordination at a regional level, as well as at a national level between relevant water agencies should be recognized as a priority of sustainable water use by basin member states. Mbaiwa[8] et al (2003) note that the integrated management of transboundary water resources is guided by three fundamental principles:

- The inherent sovereignty of each watercourse state;
- The obligation that one state should not cause significant harm to another state in the utilization of water from a commonly shared resource;
- The requirement that the water use must be equitable and reasonable.

These principles cannot be enforced nor can any third party be called upon to resolve a conflict, unless all parties concerned have agreed to such an intervention. The foundation for the prevention of conflicts therefore lies primarily in the development of fundamental institutional mechanisms to facilitate a dialogue between the parties about their internationally shared watercourses. Some general recommendations are given here:

1. Adaptable management structure. Effective institutional management structures incorporate a certain level of flexibility, allowing for public input, changing basin priorities, and new information and monitoring technologies. The adaptability of management structures must also extend to nonsignatory riparians by incorporating provisions addressing their needs, rights, and potential accession.

7 Atlas of International Freshwater Agreements, United Nations Environment Programme, 2002, ISBN: 92 807 2232 8.

8 Causes and possible solutions to potential water resource conflicts in the Okavango River Basin: The case of Angola, Namibia and Botswana Joseph E. Mbaiwa, University of Botswana, Harry Oppenheimer Okavango Research Centre, Private Bag 285, Maun, Botswana.

2. Clear and flexible criteria for water allocations and quality. Allocations, which are at the heart of most water disputes, are a function of water quantity and quality, as well as political fiat. Thus, effective institutions must identify clear allocation schedules and water quality standards that simultaneously provide for extreme hydrological events, new understanding of basin dynamics, and changing societal values. Additionally, riparian states may consider prioritising uses throughout the basin. Establishing catchment-wide water precedents may not only help to avert inter-riparian conflicts over water use, but also protect the environmental health of the basin as a whole.

3. Equitable distribution of benefits. This concept, subtly yet powerfully different from equitable use or allocation, is at the root of some of the world's most successful institutions. The idea concerns the distribution of benefits from water use - whether from hydropower, agriculture, economic development, aesthetics, or the preservation of healthy aquatic ecosystems - not the benefits from water itself. Distributing water use benefits allows for positive-sum agreements, whereas dividing the water itself only allows for winners and losers.

4. Detailed conflict resolution mechanisms. Many basins continue to experience disputes even after a treaty is negotiated and signed. Thus, incorporating clear mechanisms for resolving conflicts is a prerequisite for effective, long-term basin management.

12. WATER BALANCES FOR THE ANGOLAN CATCHMENTS

For each of the 77 Angolan catchments the following information has been calculated:

- Catchment area
- Catchment perimeter
- Mean and maximum elevation
- Mean, maximum and minimum specific discharge
- Mean annual and monthly discharge
- Mean annual and monthly precipitation

The following information on water use has been gathered as described in other parts of this study:

- Population, population forecast and their use of water
- Animal watering and irrigation, present and future

This information is listed in figures and numbers, together with a map of each catchment in the following catchment sheets.

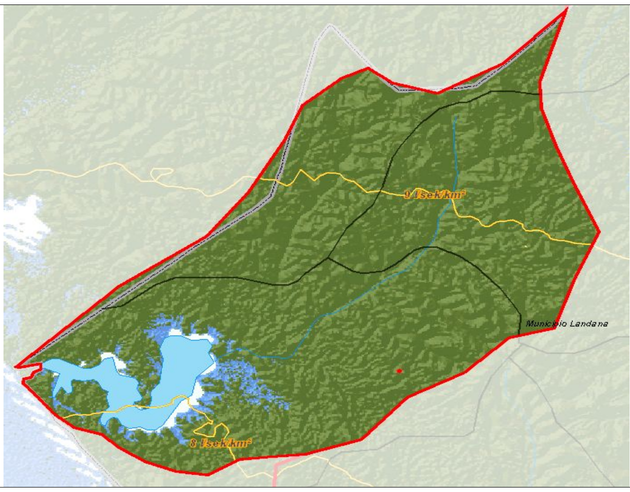
For each catchment a calculation is made of possible existing or future deficits of water. If water use exceeds the discharge in any given months, a water deficit is “flagged”. Especially in the southwestern part of the country, along the Namibe coast, every catchment with registered population will be “flagged” due to the method of distributing annual discharge in time.

When referring to the runoff and rainfall information presented in the catchment sheets the extent of the available data and the assumptions made as laid out in Chapter 2 should be borne in mind. Local discrepancies can be expected between runoff values presented in the catchment sheets and those actually existing in the rivers. This will typically be the case for catchments in areas where there is low or no rainfall, for example in the coastal catchments in the southwest, some of which are shown to have no flow regime even though local knowledge may indicate that there is at times a limited flow regime. The best way to improve this aspect of the analysis is to provide more flow data for such areas in the continued updating of the assessment so that generalised assumptions on flow regimes based on rainfall data can be avoided.

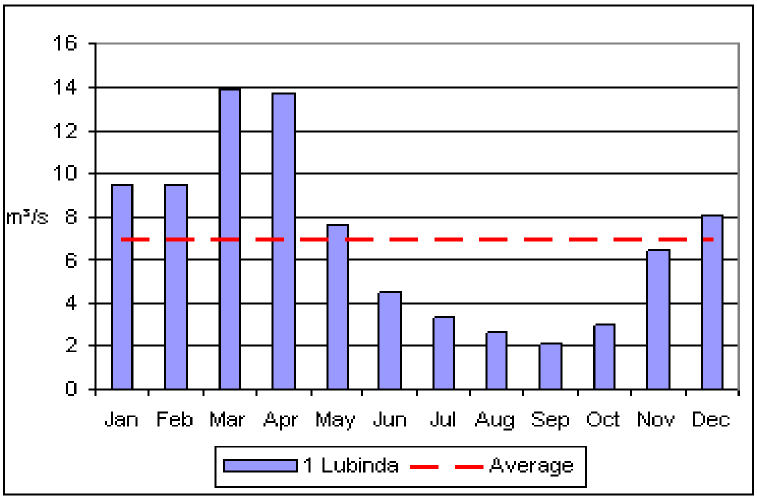
This evaluation does not consider use of groundwater. Calculated water deficit is based solely on the extraction of surface water for water use.

An overview map of Angolan catchments showing their location in the country as well as province boundaries is presented in four foldout A3 sheets at the end of this chapter as follows:

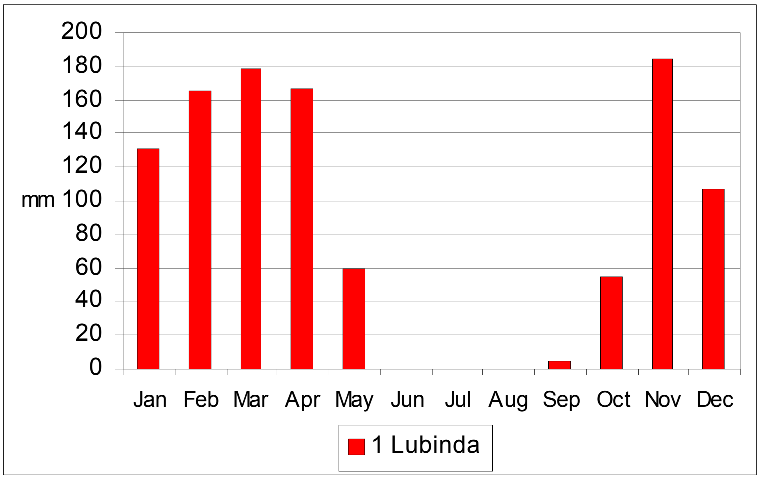
Figure 12.1 a – Angolan Catchments (north-west)
Figure 12.1 b – Angolan Catchments (north-east)
Figure 12.1 c – Angolan Catchments (south-west)
Figure 12.1 d – Angolan Catchments (south-east)



4001	
Lubinda	
Area in km²	
810.1	
Perimeter in km	
129.3	
Elevation (m.a.s.l)	
Mean	Maximum
62.6	209



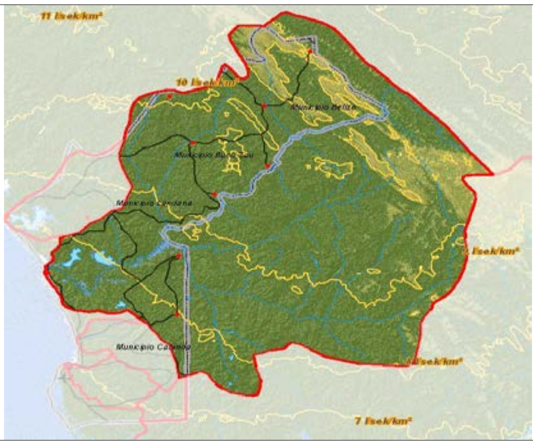
Annual mean discharge m³/s (Q)	
7.01	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*8.7*
Max	9.6
Min	7.9



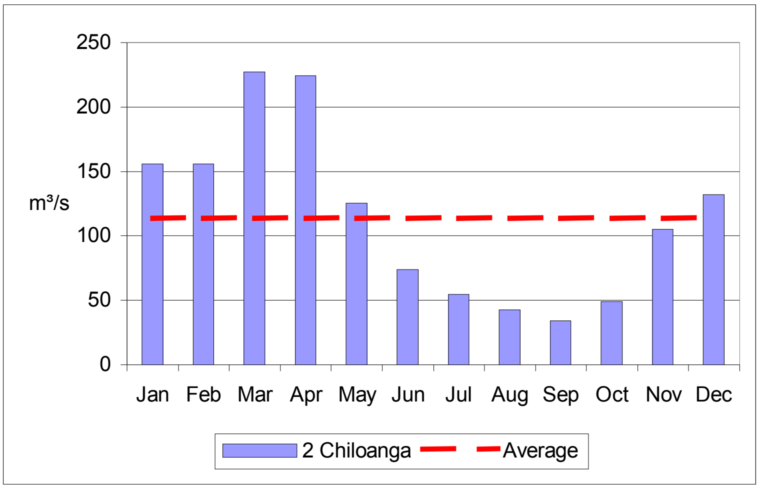
Annual precipitation in mm	
1054	

Population and Water use				
	2000	2005	2015	2025
Population	3200	4907	5120	3413
Water use (m³/day)	48	74	154	102
Water use (m³/s)	0.001	0.001	0.002	0.001

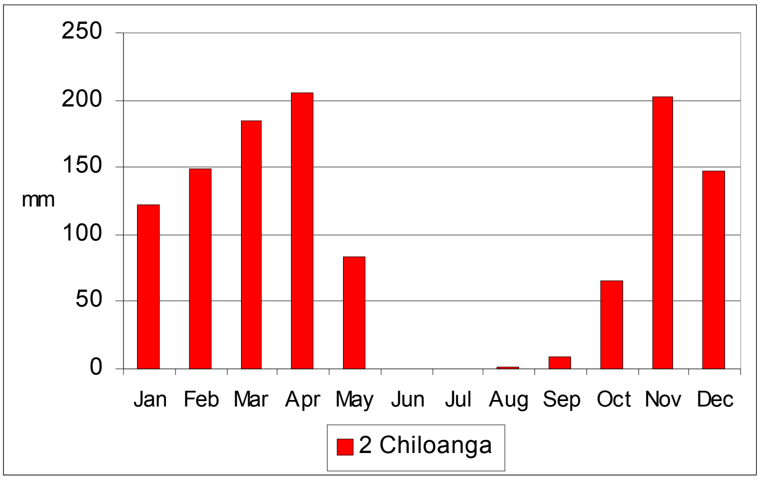
Animal Watering and Irrigation					
	2002	2005	2015	2025	Existing water deficit
					NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



4002	
Chiloango	
Area in km²	
12570.5	
Perimeter in km	
515.0	
Elevation (m.a.s.l)	
Mean	Maximum
237	880



Annual mean discharge m³/s (Q)	
114.9	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*9.1*
Max	10.9
Min	7.3

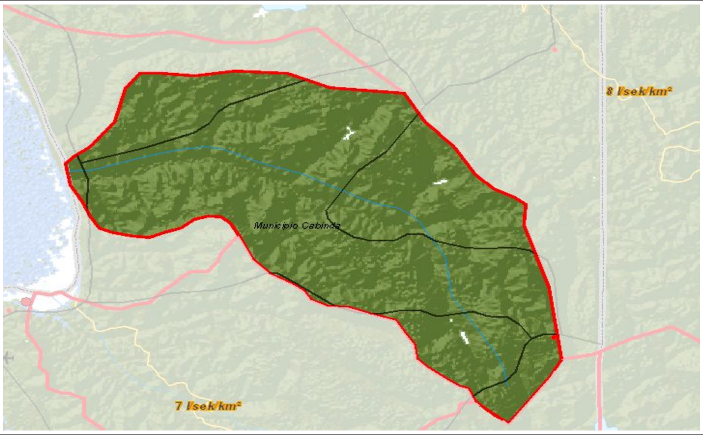


Annual precipitation in mm
1170

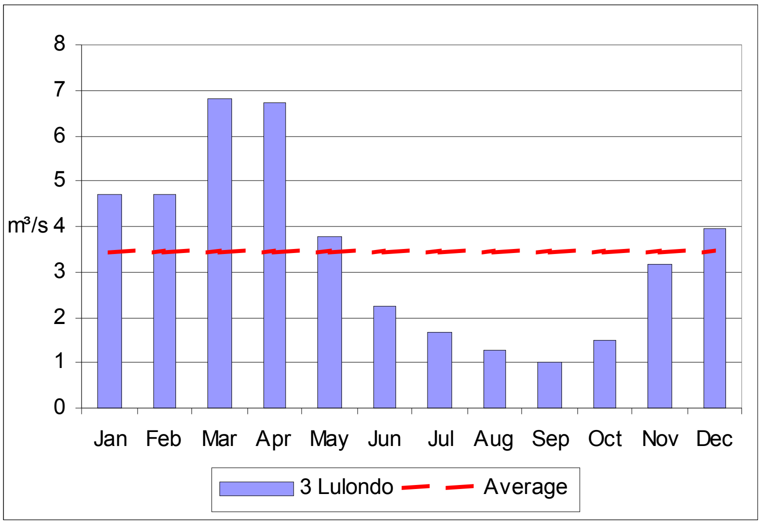
Population and Water use				
	2000	2005	2015	2025
Population	24000	36800	38400	25600
Water use (m³/day)	360	552	1152	768
Water use (m³/s)	0.004	0.006	0.013	0.009

Animal Watering and Irrigation					
	2002	2005	2015	2025	
Water use (m³/day)					
Water use (m³/s)					

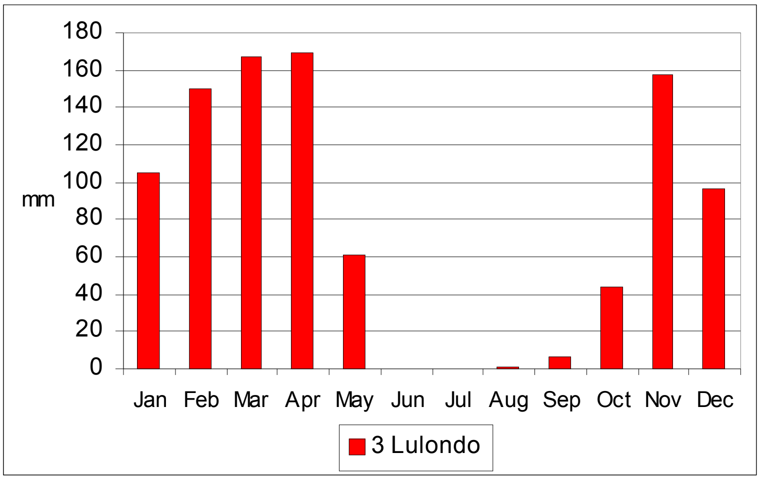
Existing water deficit
NO
Future water deficit
NO



4003	
Lulondo	
Area in km²	
458.1	
Perimeter in km	
97.6	
Elevation (m.a.s.l)	
Mean	Maximum
136	248



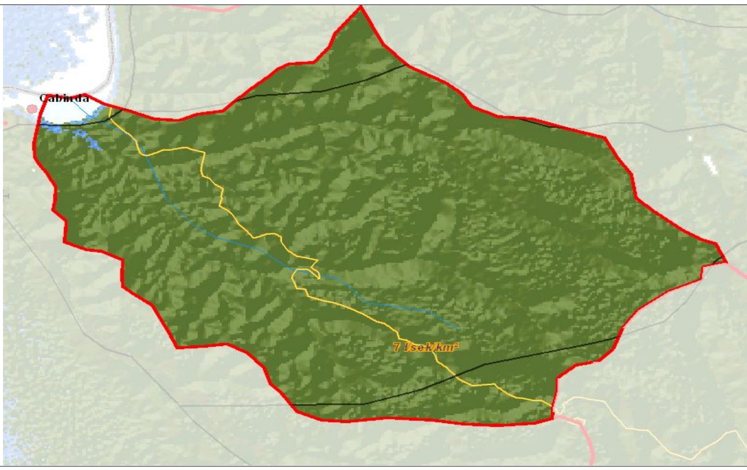
Annual mean discharge m³/s (Q)	
3.46	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*7.5*
Max	7.9
Min	7.2



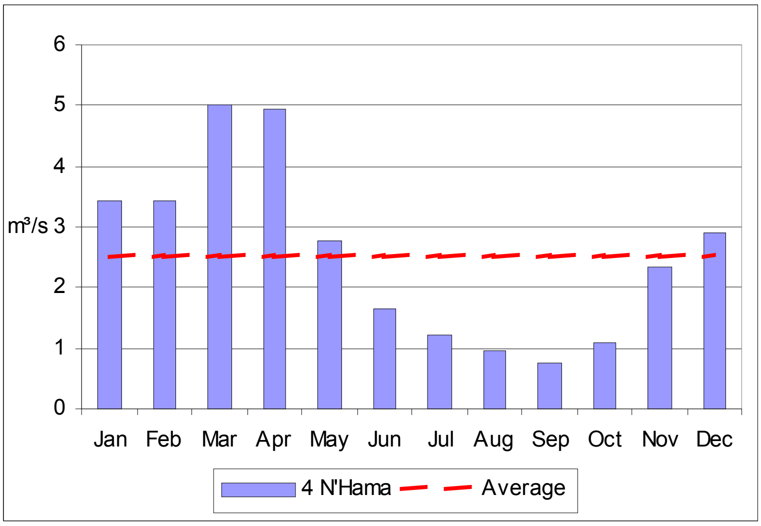
Annual precipitation in mm
959

Population and Water use				
	2000	2005	2015	2025
Population	2000	3067	3200	2133
Water use (m³/day)	30	46	96	64
Water use (m³/s)	0.000	0.001	0.001	0.001

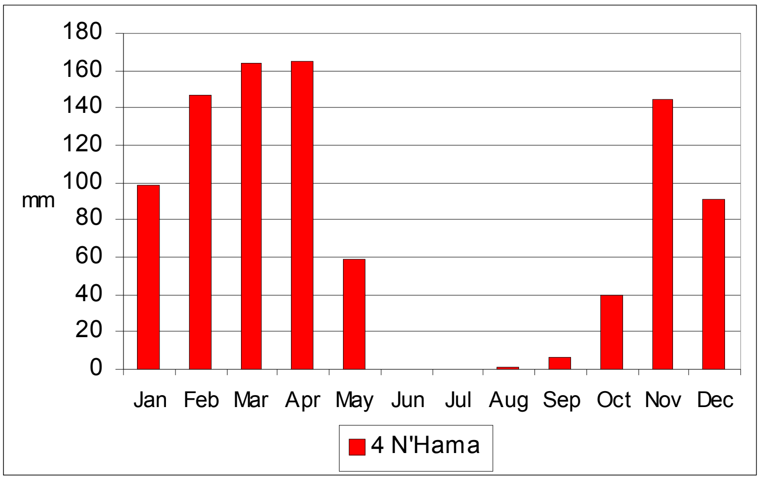
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	YES
Water use (m³/day)	140462	280923	329670	532412	Future water deficit
Water use (m³/s)	1.6	3.3	3.8	6.2	YES



4004	
Lucula	
Area in km²	
357	
Perimeter in km	
83.4	
Elevation (m.a.s.l)	
Mean	Maximum
116	211



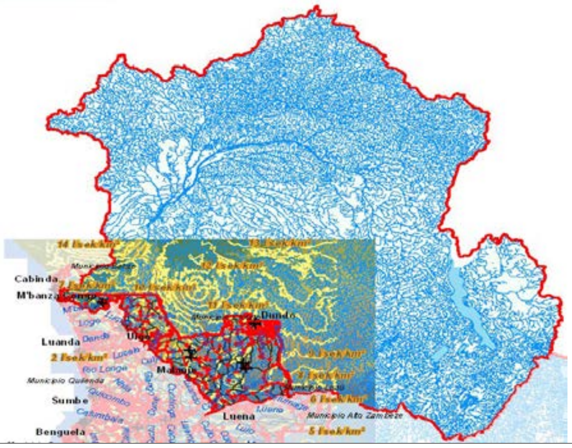
Annual mean discharge m³/s (Q)	
2.54	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*7.1*
Max	*7.5*
Min	6.8



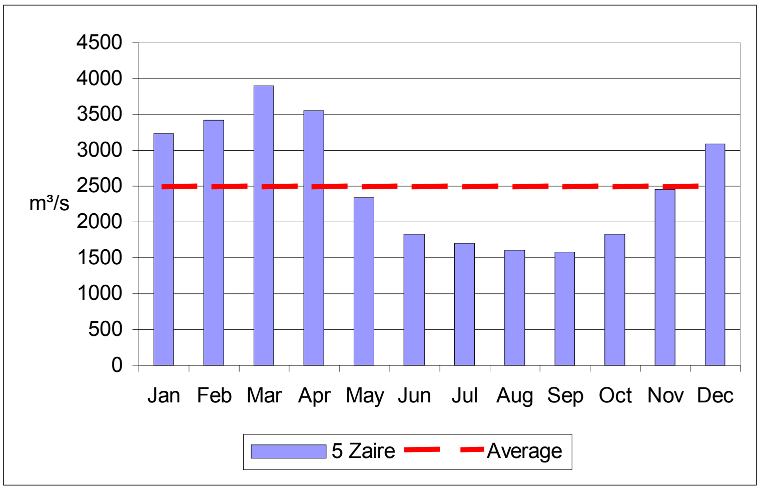
Annual precipitation in mm
916

Population and Water use				
	2000	2005	2015	2025
Population	172000	204000	288000	406000
Water use (m³/day)	7215	11380	21035	34680
Water use (m³/s)	0.084	0.132	0.243	0.401

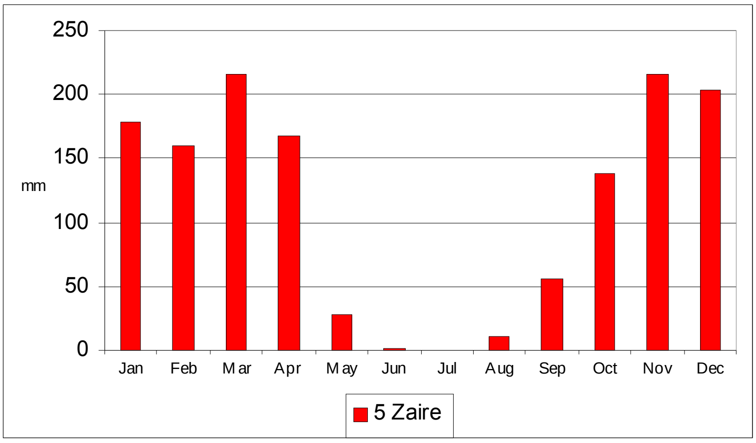
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	1597	1597	1597	1597	Future water deficit
Water use (m³/s)	0.0	0.0	0.0	0.0	NO



4305	
Zaire	
Area in km²	
Total : 3866544 In Angola: 290395	
Perimeter in km	
Total: 11895	
Elevation (m.a.s.l) (Angola)	
Mean	Maximum
955	1548



Annual mean discharge m³/s (Q) (Angola)	
2540.9	
Annual mean specific discharge (q) l s^{-1} km^{-2} (Angola)	
Mean	*8.7*
Max	11.6
Min	5.5



Annual precipitation in mm
1375

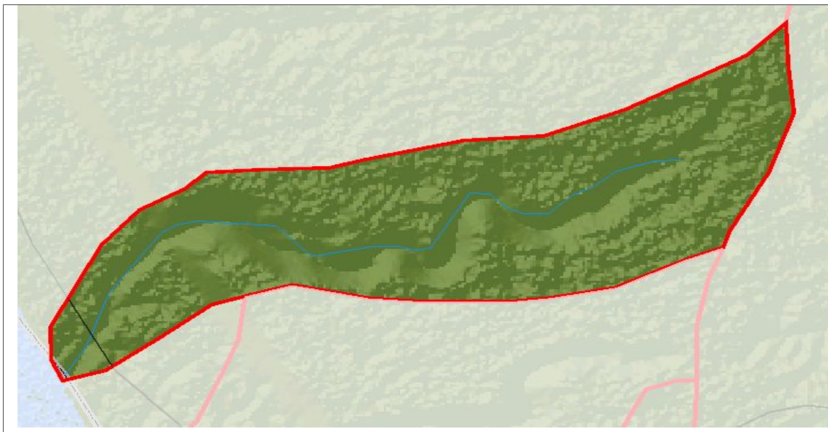
Population and Water use in Angola				
	2000	2005	2015	2025
Population	1177731	1270671	1643190	216483
Water use (m³/day)	22226	22685	62126	90549
Water use (m³/s)	0.257	0.263	0.719	1.048

Comments

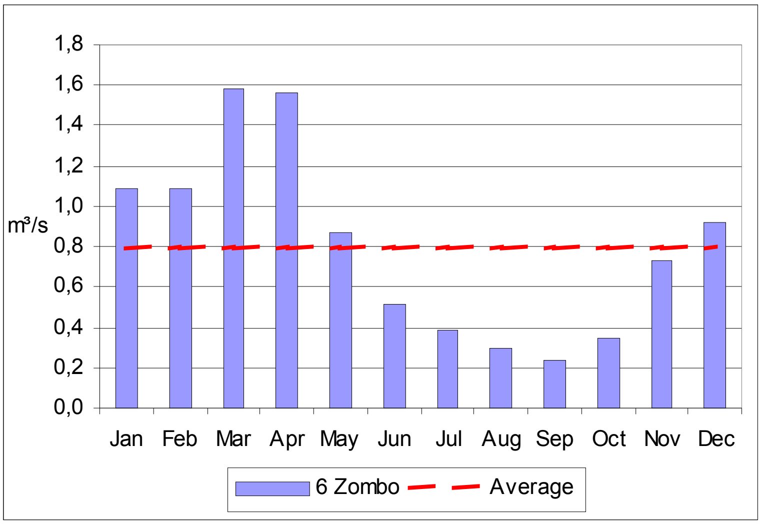
Discharge, precipitation and elevation is only calculated for the Angolan part of the basin due to missing data.

Animal Watering and Irrigation in Angola				
	2002	2005	2015	2025
Water use (m³/day)	2765	3254	423690	844626
Water use (m³/s)	0.0	0.0	4.9	9.8

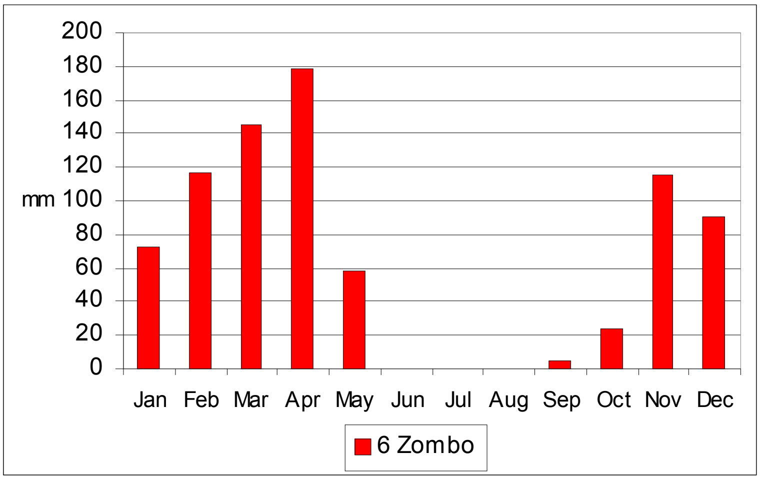
Existing water deficit
NO
Future water deficit
NO



6006	
Zombo	
Area in km²	
146.4	
Perimeter in km	
64.9	
Elevation (m.a.s.l)	
Mean	Maximum
123	171



Annual mean discharge m³/s (Q)	
0.80	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*5.5*
Max	5.7
Min	5.2

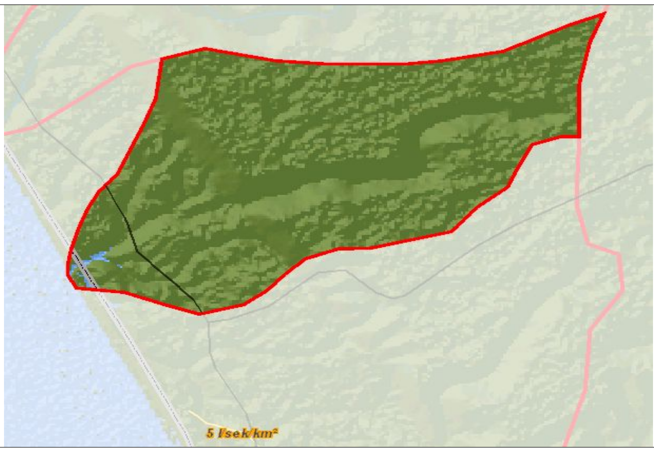


Annual precipitation in mm
807

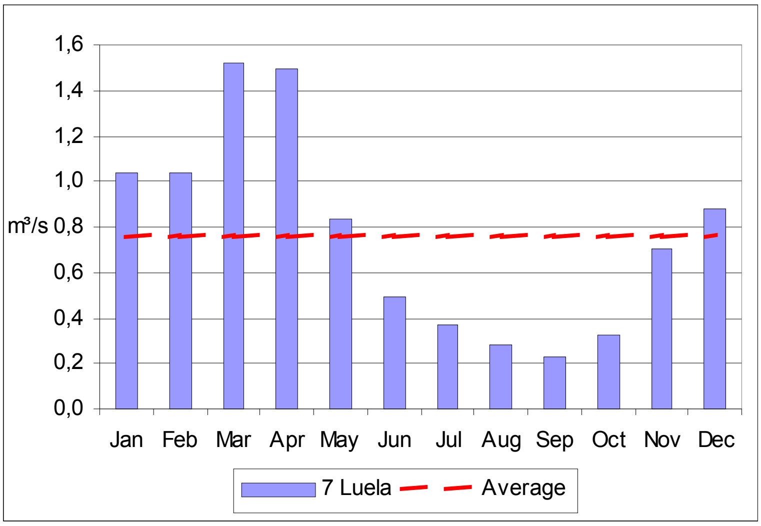
Population and Water use				
	2000	2005	2015	2025
Population	2472	2472	1625	1792
Water use (m³/day)	37	37	49	54
Water use (m³/s)	0.000	0.000	0.001	0.001

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

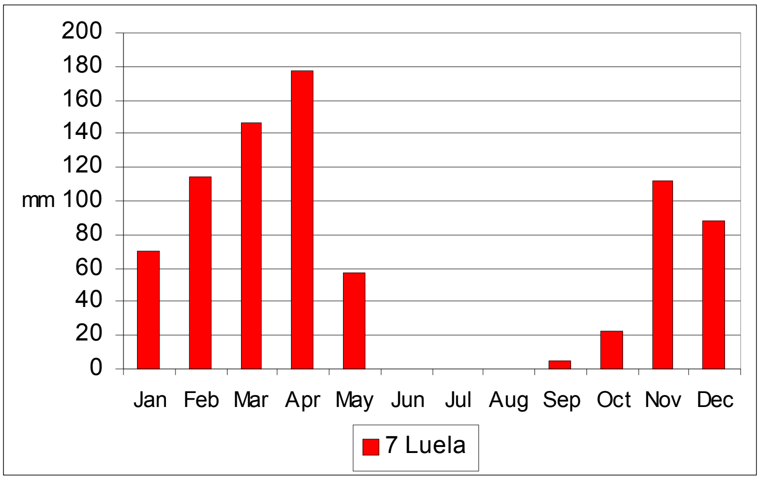
Existing water deficit
NO
Future water deficit
NO



6007	
Luela	
Area in km²	
144.3	
Perimeter in km	
54.5	
Elevation (m.a.s.l)	
Mean	Maximum
109	164



Annual mean discharge m³/s (Q)	
0.77	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*5.6*
Max	6.0
Min	4.7

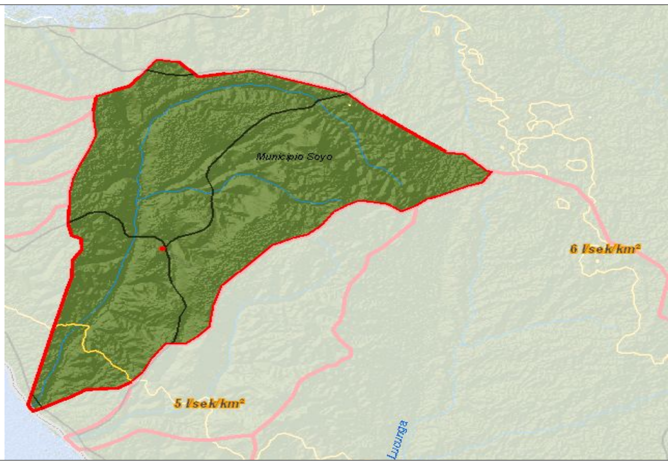


Annual precipitation in mm
793

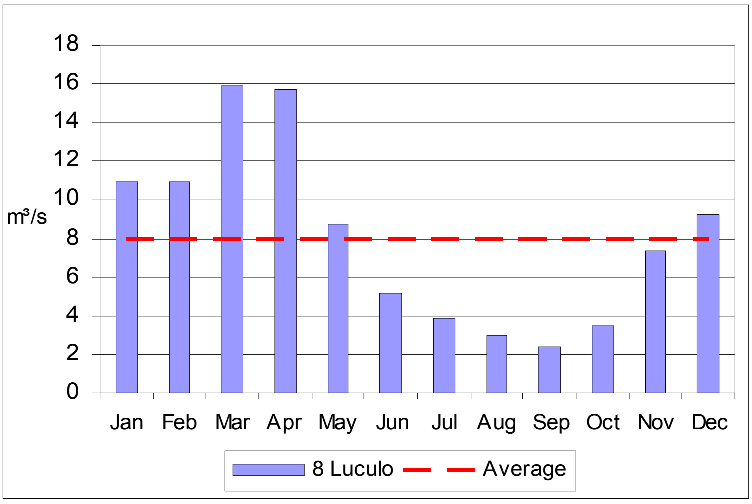
Population and Water use				
	2000	2005	2015	2025
Population	2472	2472	1625	1792
Water use (m³/day)	37	37	49	54
Water use (m³/s)	0.000	0.000	0.001	0.001

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

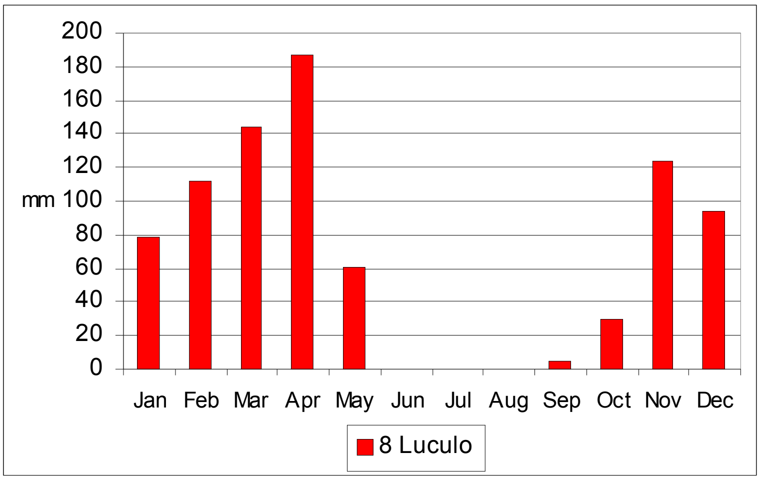
Existing water deficit
NO
Future water deficit
NO



6008	
Lucolo	
Area in km²	
1449	
Perimeter in km	
185.2	
Elevation (m.a.s.l)	
Mean	Maximum
151	315



Annual mean discharge m³/s (Q)	
8.05	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*5.6*
Max	6.0
Min	4.7

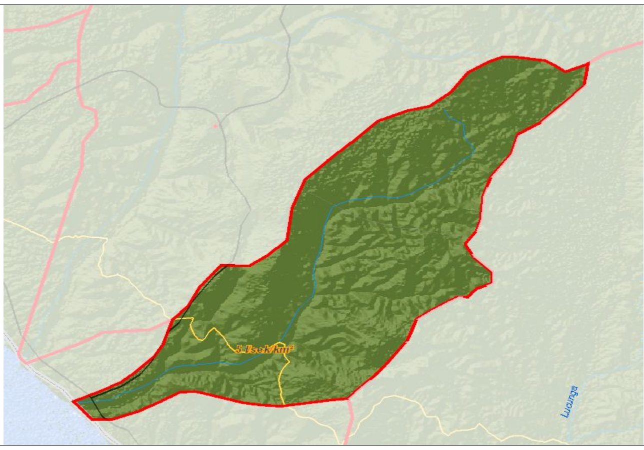


Annual precipitation in mm
836

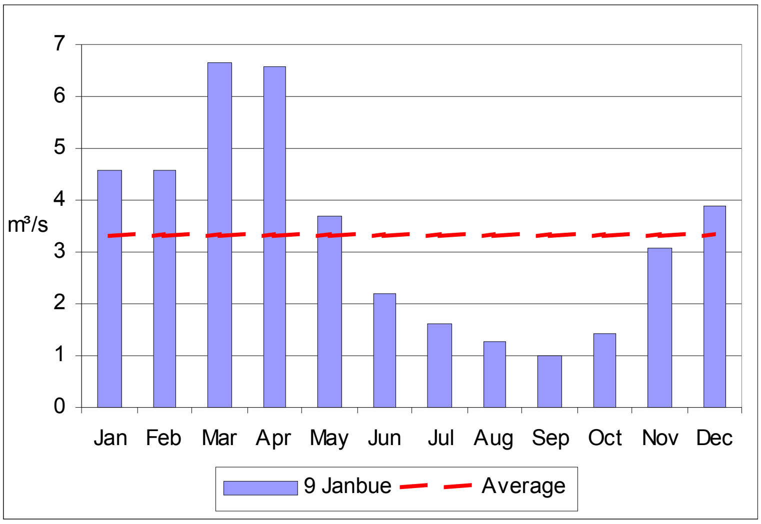
Population and Water use				
	2000	2005	2015	2025
Population	17306	17306	11375	12542
Water use (m³/day)	260	260	341	376
Water use (m³/s)	0.003	0.003	0.004	0.004

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

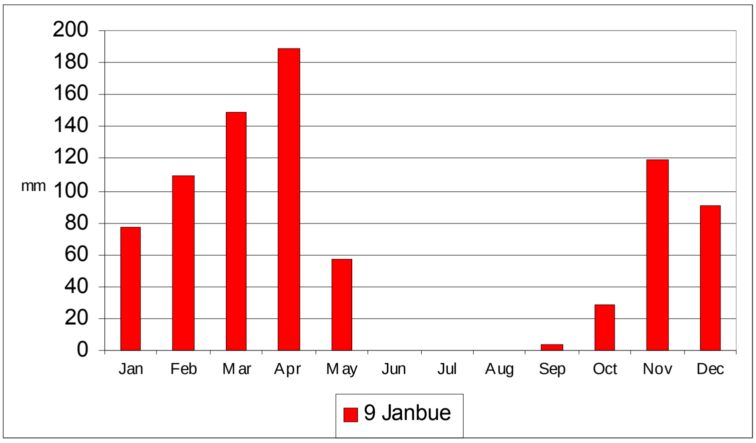
Existing water deficit
NO
Future water deficit
NO



6009	
Sange	
Area in km²	
634.1	
Perimeter in km	
134.7	
Elevation (m.a.s.l)	
Mean	Maximum
157	302



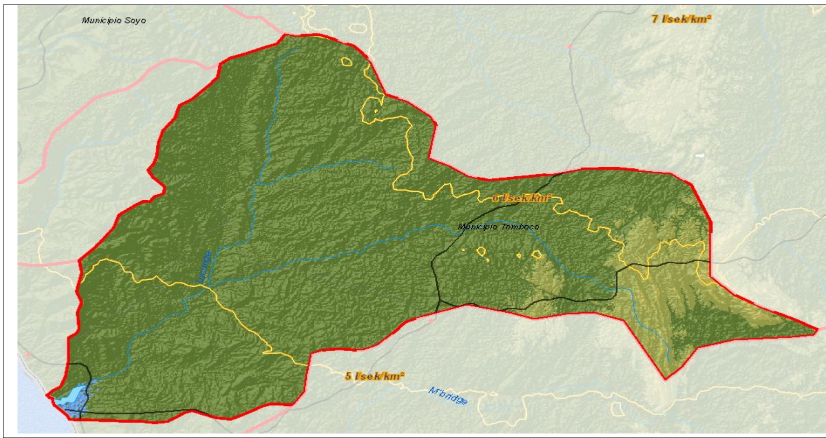
Annual mean discharge m³/s (Q)	
3.37	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*5.3*
Max	*5.9*
Min	4.7



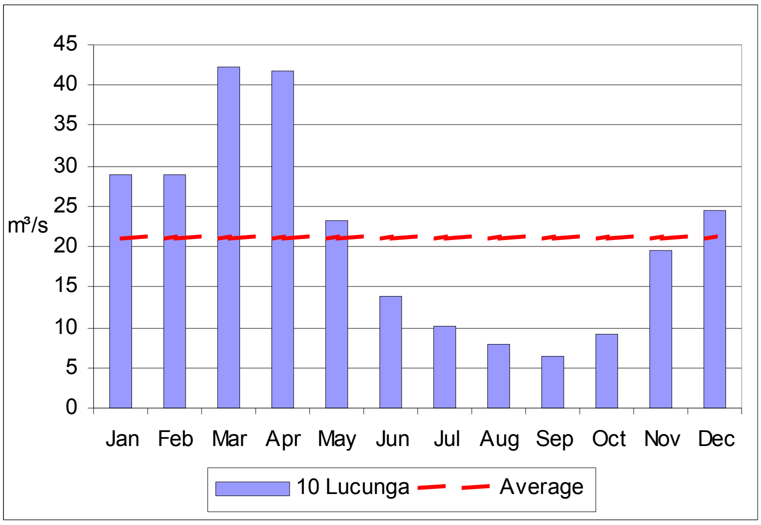
Annual precipitation in mm
822

Population and Water use				
	2000	2005	2015	2025
Population	4944	4944	3250	3583
Water use (m³/day)	74	74	98	108
Water use (m³/s)	0.001	0.001	0.001	0.001

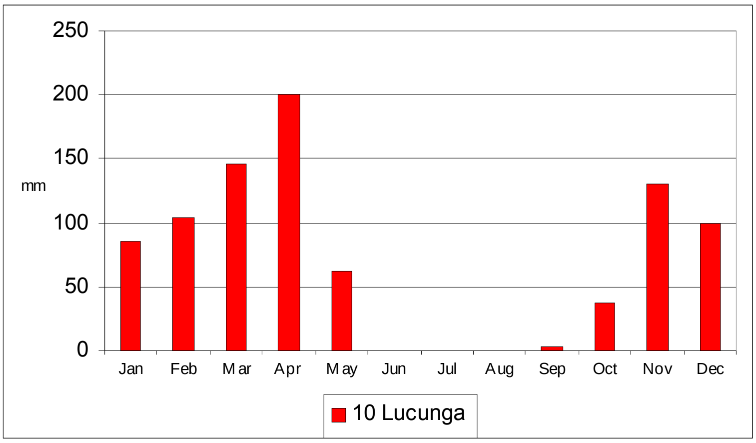
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6010	
Lucunga	
Area in km²	
3892.0	
Perimeter in km	
332.9	
Elevation (m.a.s.l)	
Mean	Maximum
222	733



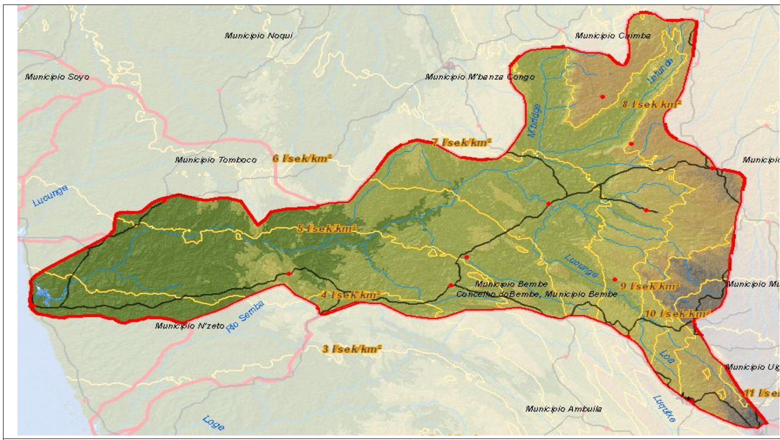
Annual mean discharge m³/s (Q)	
21.39	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*5.5*
Max	6.3
Min	4.3



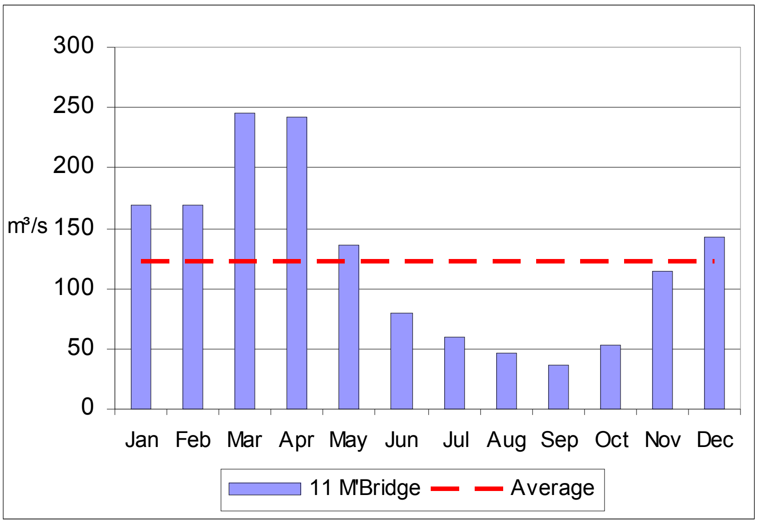
Annual precipitation in mm
870

Population and Water use				
	2000	2005	2015	2025
Population	19778	19778	13000	14333
Water use (m³/day)	297	297	390	430
Water use (m³/s)	0.003	0.003	0.005	0.005

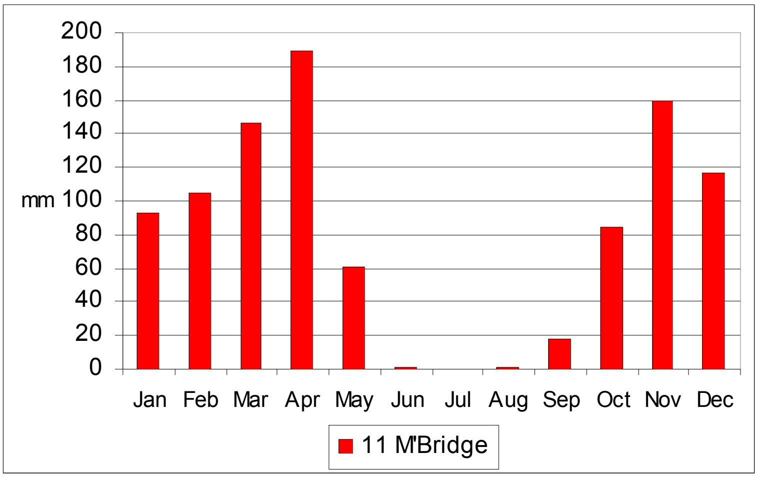
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6011	
M'Bridge	
Area in km²	
19071.2	
Perimeter in km	
890.2	
Elevation (m.a.s.l)	
Mean	Maximum
589.3	1295.0



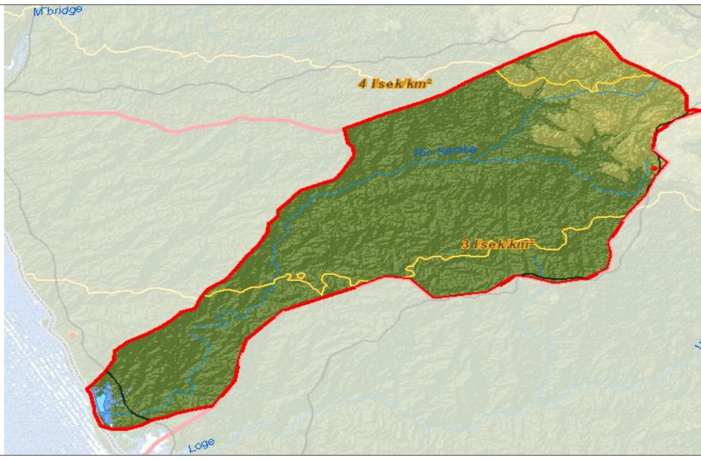
Annual mean discharge m³/s (Q)	
124.45	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*6.5*
Max	*11.4*
Min	3.5



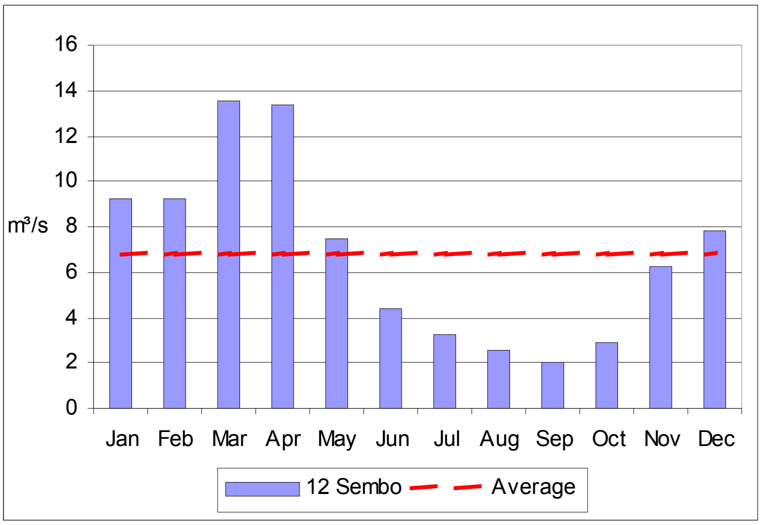
Annual precipitation in mm	
974	

Population and Water use				
	2000	2005	2015	2025
Population	505076	580180	725269	998155
Water use (m³/day)	9871	12203	27358	41305
Water use (m³/s)	0.114	0.141	0.317	0.478

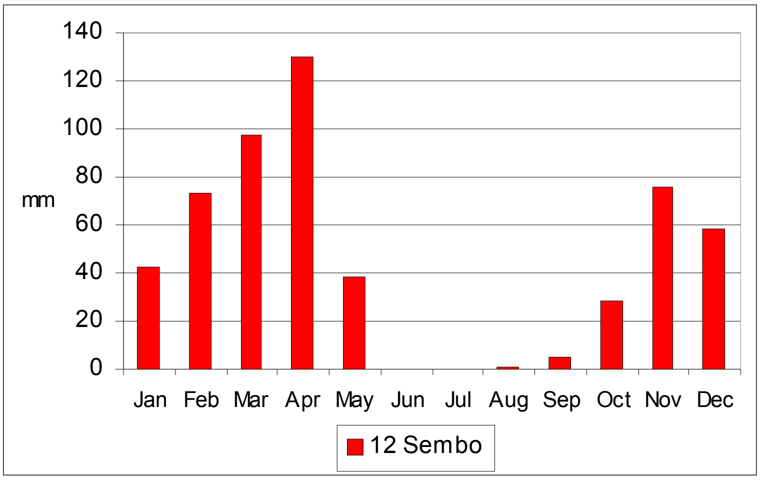
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6012	
Sembo	
Area in km²	
2093.2	
Perimeter in km	
250.3	
Elevation (m.a.s.l)	
Mean	Maximum
284	734



Annual mean discharge m³/s (Q)	
6.84	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*3.3*
Max	4.4
Min	2.6

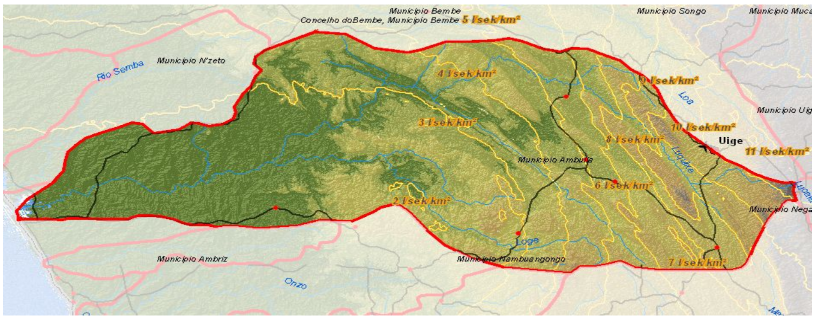


Annual precipitation in mm
550

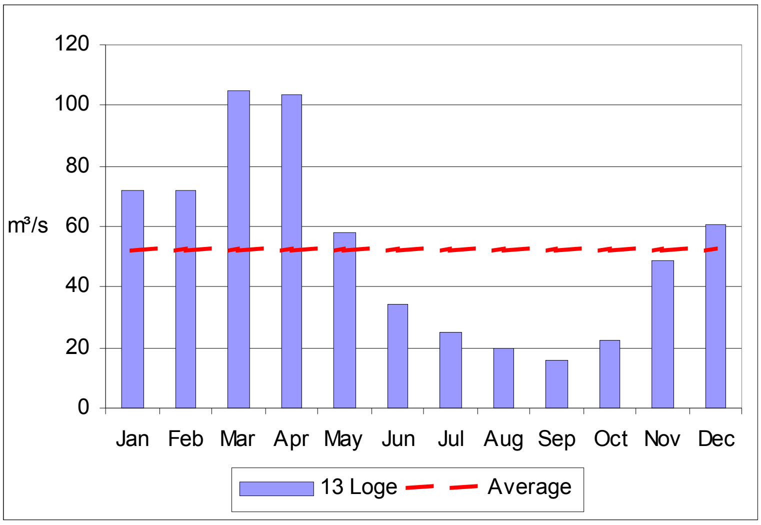
Population and Water use				
	2000	2005	2015	2025
Population	7417	7417	4875	5375
Water use (m³/day)	111	111	146	161
Water use (m³/s)	0.001	0.001	0.002	0.002

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

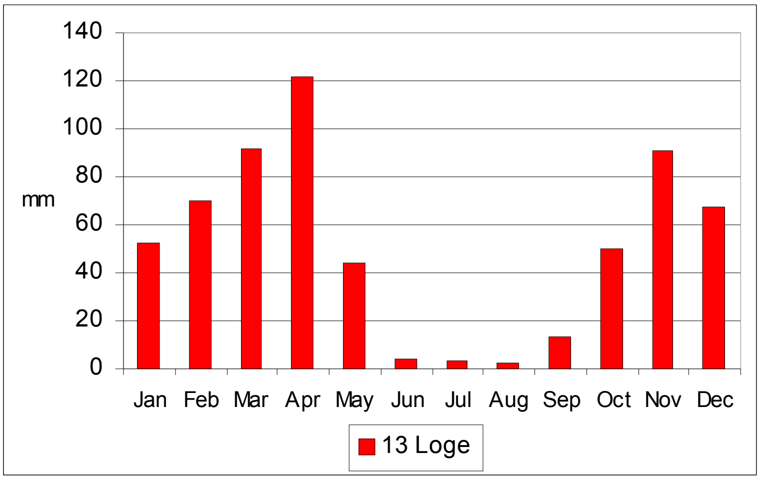
Existing water deficit
NO
Future water deficit
NO



6013	
Loge	
Area in km²	
12819.2	
Perimeter in km	
581.2	
Elevation (m.a.s.l)	
Mean	Maximum
531	1281



Annual mean discharge m³/s (Q)	
53.0	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.1*
Max	10.4
Min	1.9

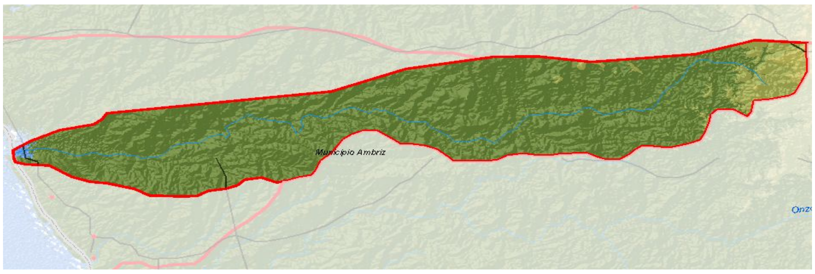


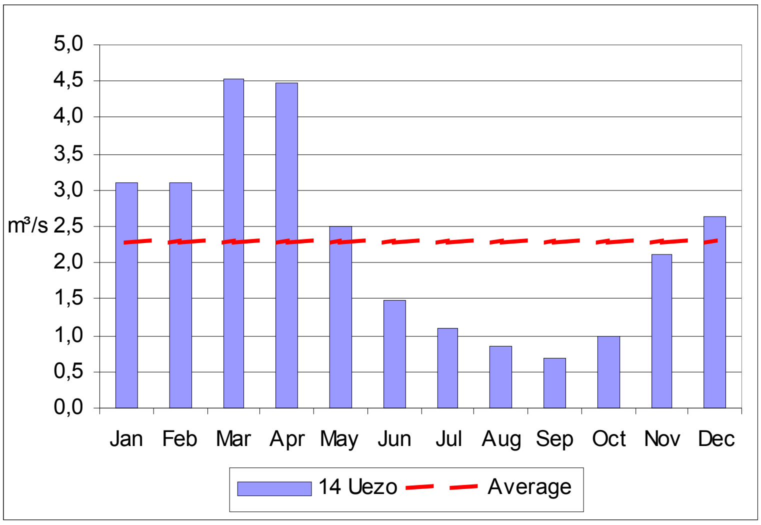
Annual precipitation in mm
612

Population and Water use				
	2000	2005	2015	2025
Population	86938	104222	146491	206249
Water use (m³/day)	1304	1563	4404	6187
Water use (m³/s)	0.015	0.018	0.051	0.072

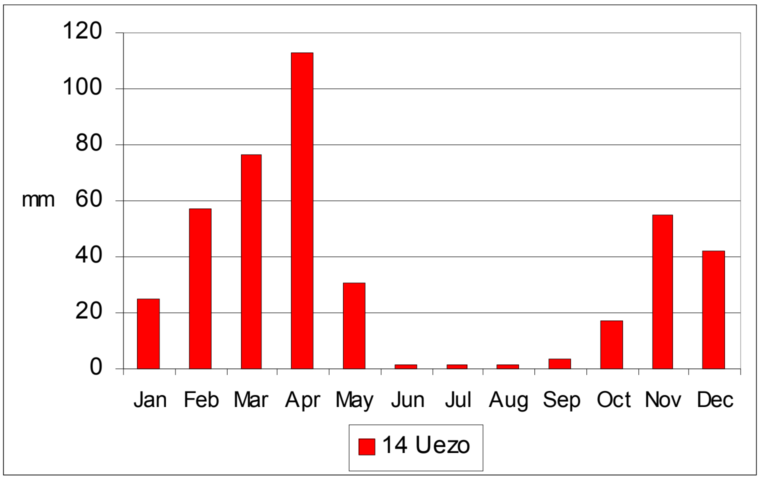
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	167466	167466	435617	435617	Future water deficit
Water use (m³/s)	1.9	1.9	5.0	5.0	NO

6014	
Uezo	
Area in km²	
968.0	
Perimeter in km	
203.4	
Elevation (m.a.s.l)	
Mean	Maximum
229	783





Annual mean discharge m³/s (Q)	
2.30	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*2.4*
Max	2.6
Min	2.1

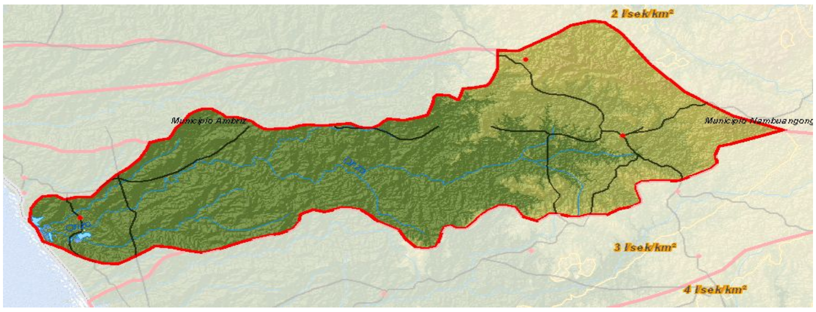


Annual precipitation in mm	
424	

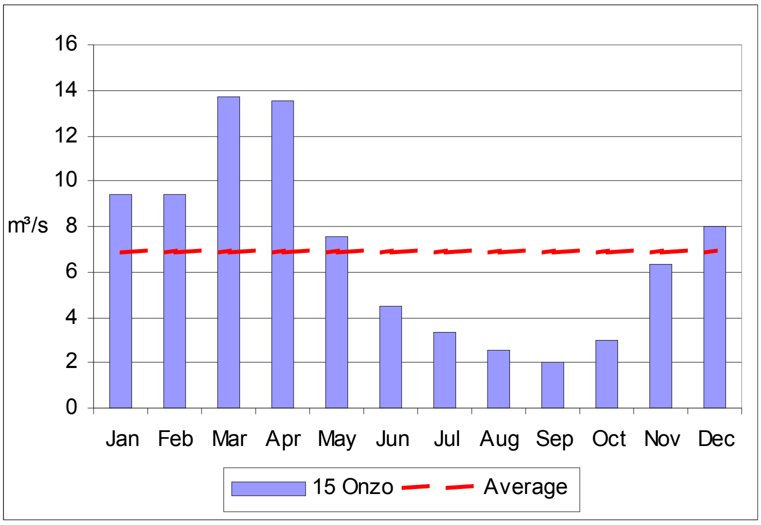
Population and Water use				
	2000	2005	2015	2025
Population	601	700	940	1296
Water use (m³/day)	9	10	29	39
Water use (m³/s)	0.000	0.000	0.000	0.000

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

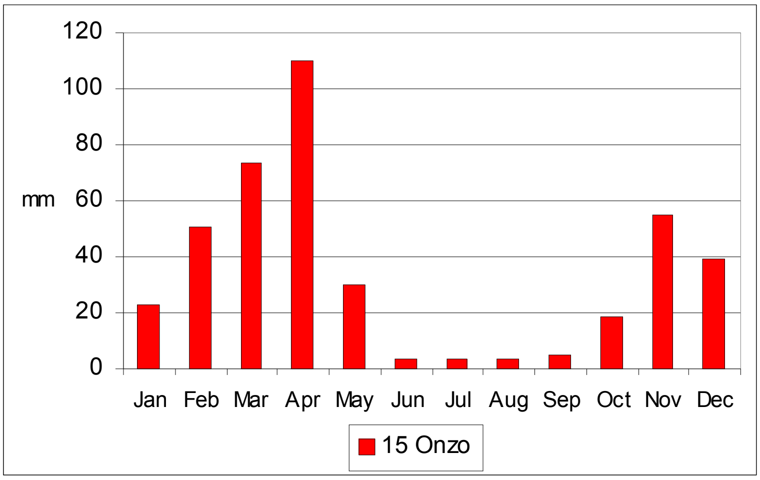
Existing water deficit
NO
Future water deficit
NO



6015	
Onzo	
Area in km²	
2941.7	
Perimeter in km	
323.5	
Elevation (m.a.s.l)	
Mean	Maximum
359	913



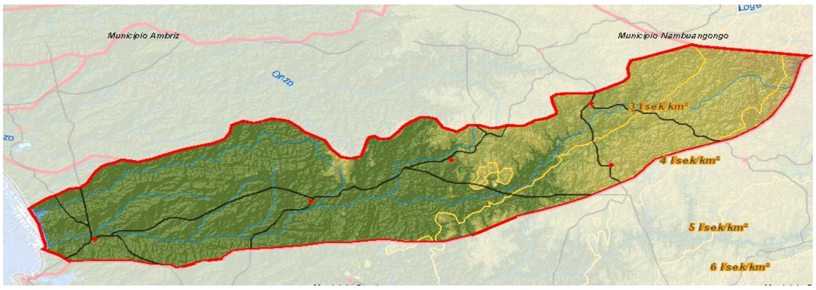
Annual mean discharge m³/s (Q)	
6.93	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*2.4*
Max	2.8
Min	2.0



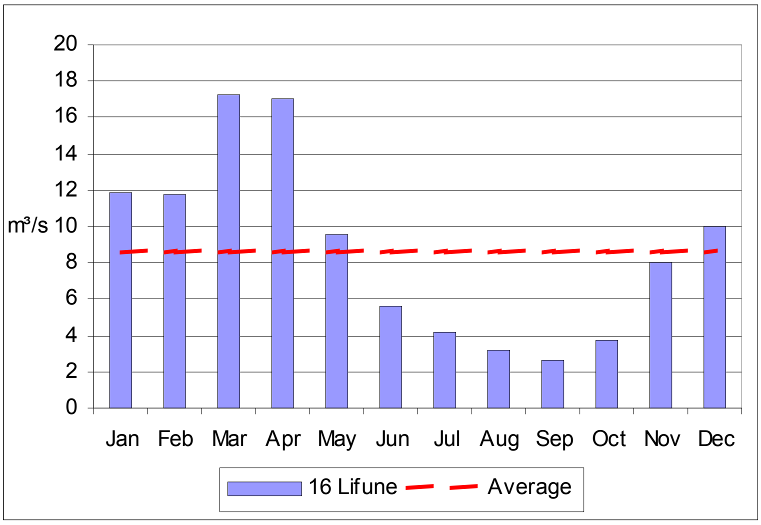
Annual precipitation in mm
415

Population and Water use				
	2000	2005	2015	2025
Population	9614	11193	15039	20738
Water use (m³/day)	144	168	464	622
Water use (m³/s)	0.002	0.002	0.005	0.007

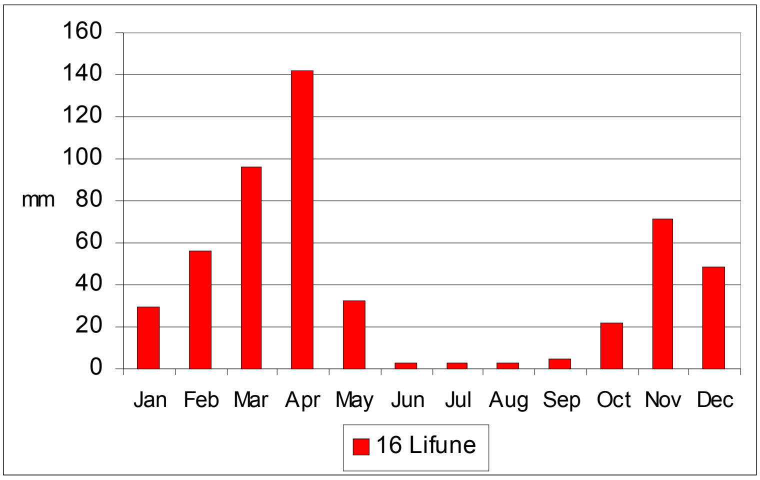
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	20548	20548	236301	236301	Future water deficit
Water use (m³/s)	0.2	0.2	2.7	2.7	YES



6016	
Lifune	
Area in km²	
3018.5	
Perimeter in km	
334.1	
Elevation (m.a.s.l)	
Mean	Maximum
376	1133



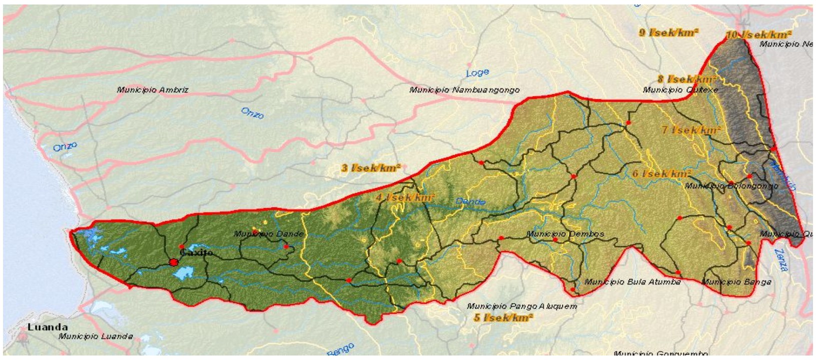
Annual mean discharge m³/s (Q)	
8.72	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*2.9*
Max	*4.5*
Min	2.4



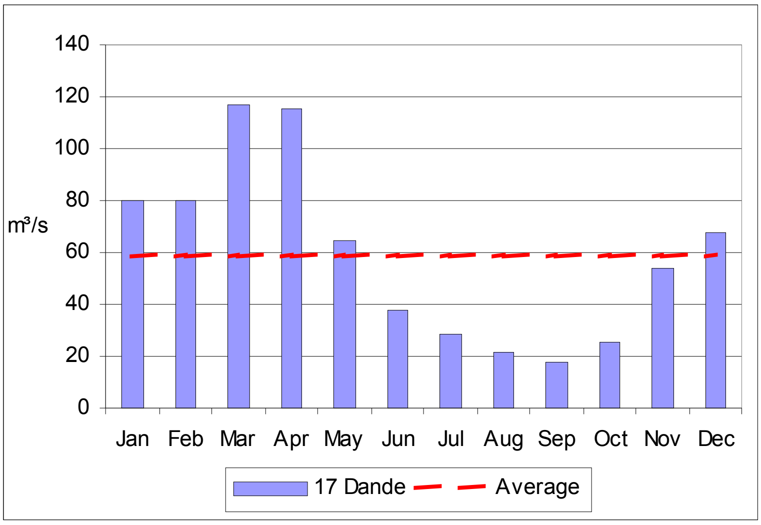
Annual precipitation in mm	
513	

Population and Water use				
	2000	2005	2015	2025
Population	19828	23086	31017	42773
Water use (m³/day)	297	346	956	1283
Water use (m³/s)	0.003	0.004	0.011	0.015

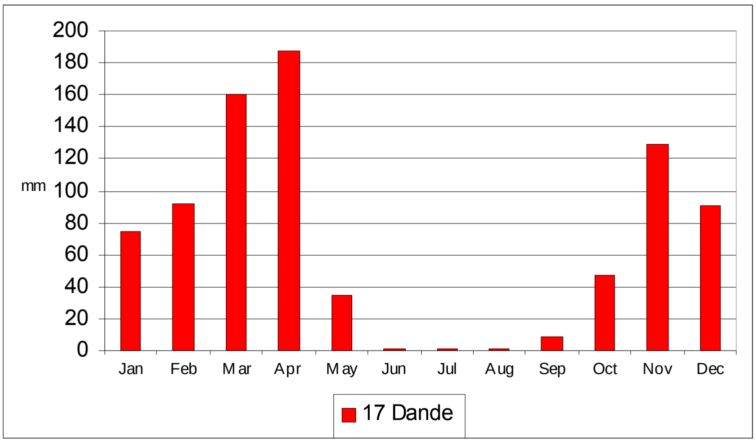
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	80137	80137	160274	160274	Future water deficit
Water use (m³/s)	0.9	0.9	1.9	1.9	NO



6017	
Dande	
Area in km²	
11446.4	
Perimeter in km	
649.3	
Elevation (m.a.s.l)	
Mean	Maximum
621	1474



Annual mean discharge m³/s (Q)	
59.01	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*5.2*
Max	10.0
Min	2.4

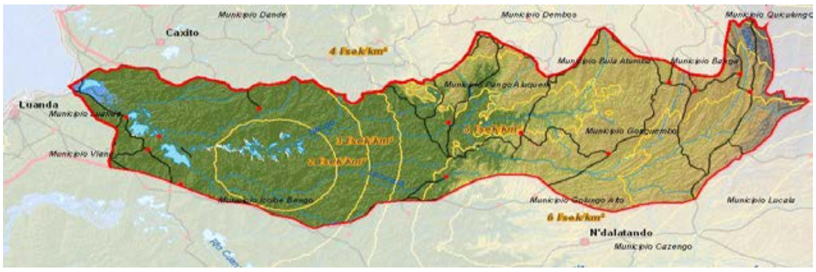


Annual precipitation in mm
832

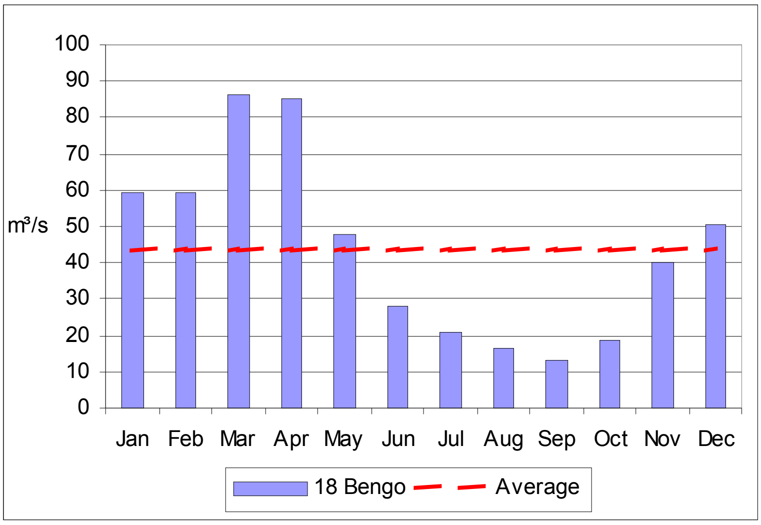
Population and Water use				
	2000	2005	2015	2025
Population	632509	839857	1203740	1607959
Water use (m³/day)	15856	20840	46939	68983
Water use (m³/s)	0.184	0.241	0.543	0.798

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	394834	394834	672959	672959
Water use (m³/s)	4.6	4.6	7.8	7.8

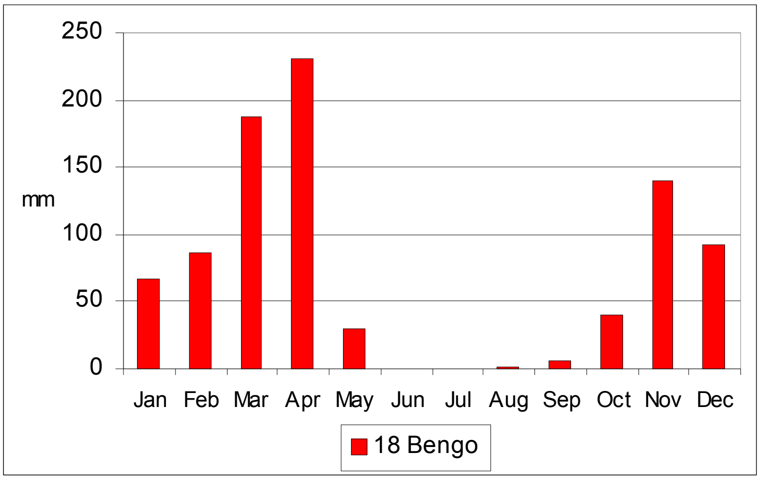
Existing water deficit
NO
Future water deficit
NO



6018	
Bengo	
Area in km²	
11088.9	
Perimeter in km	
663	
Elevation (m.a.s.l)	
Mean	Maximum
483	1530



Annual mean discharge m³/s (Q)	
43.78	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*3.9*
Max	*7.4*
Min	1.5

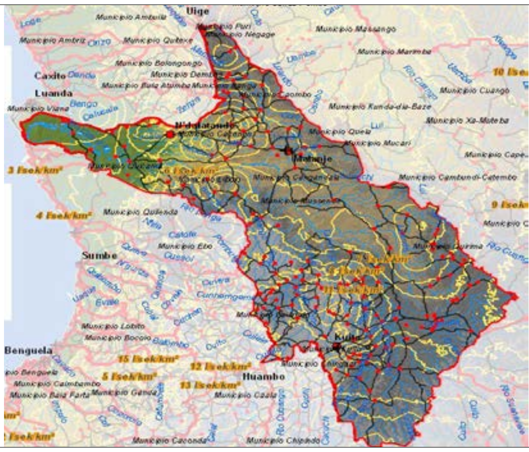


Annual precipitation in mm	
883	

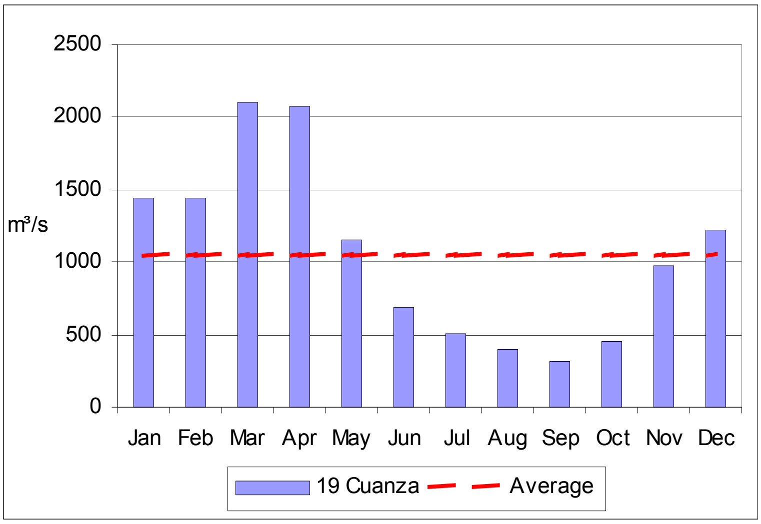
Population and Water use				
	2000	2005	2015	2025
Population	2151693	2985128	4376232	5839697
Water use (m³/day)	58569	78492	174923	257775
Water use (m³/s)	0.678	0.908	2.025	2.984

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	545710	550985	810856	1067643
Water use (m³/s)	6.3	6.4	9.4	12.4

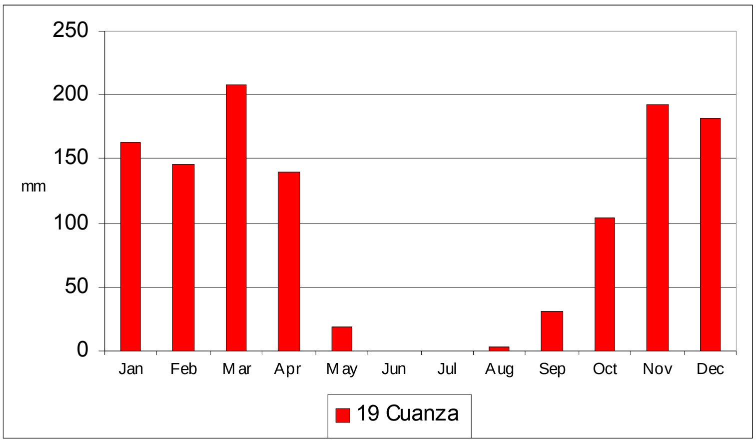
Existing water deficit	
NO	
Future water deficit	
NO	



6019	
Cuanza	
Area in km²	
150445.6	
Perimeter in km	
2701.7	
Elevation (m.a.s.l)	
Mean	Maximum
1200	1964



Annual mean discharge m³/s (Q)	
1064.4	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*7.1*
Max	14.2
Min	1.6

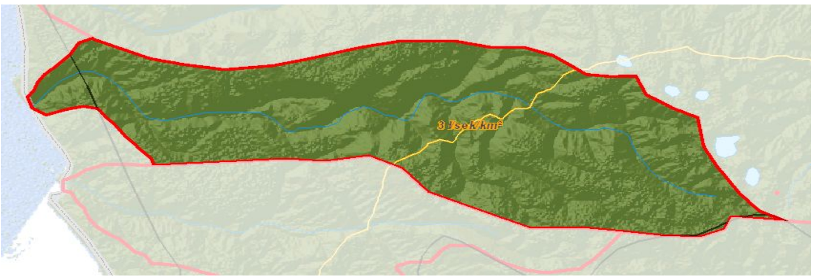


Annual precipitation in mm
1188

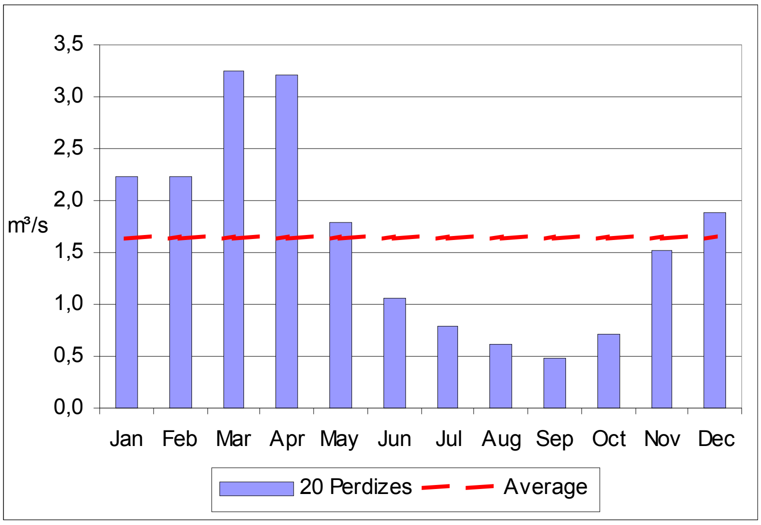
Population and Water use				
	2000	2005	2015	2025
Population	2844186	3411304	4622503	6221152
Water use (m³/day)	52916	67412	160486	277347
Water use (m³/s)	0.612	0.780	1.857	3.210

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	509777	822747	4489858	469713
Water use (m³/s)	5.9	9.5	52.0	54.4

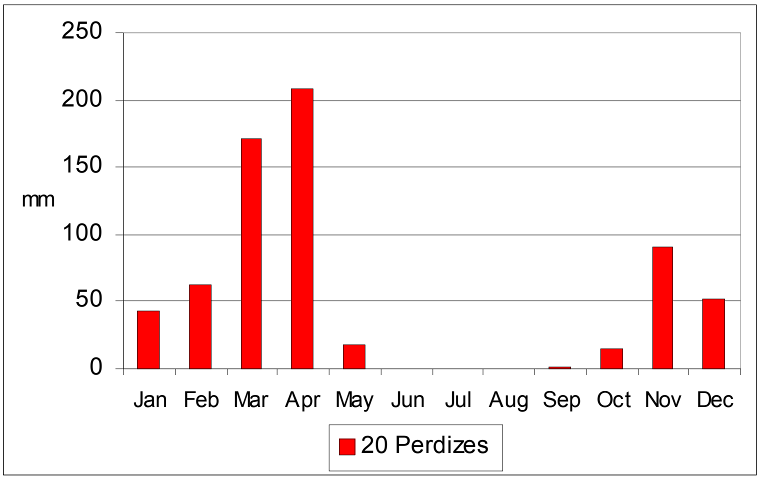
Existing water deficit
NO
Future water deficit
NO



6020	
Perdizes	
Area in km²	
558.7	
Perimeter in km	
130.5	
Elevation (m.a.s.l)	
Mean	Maximum
173	239



Annual mean discharge m³/s (Q)	
1.65	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*3.0*
Max	3.4
Min	2.5

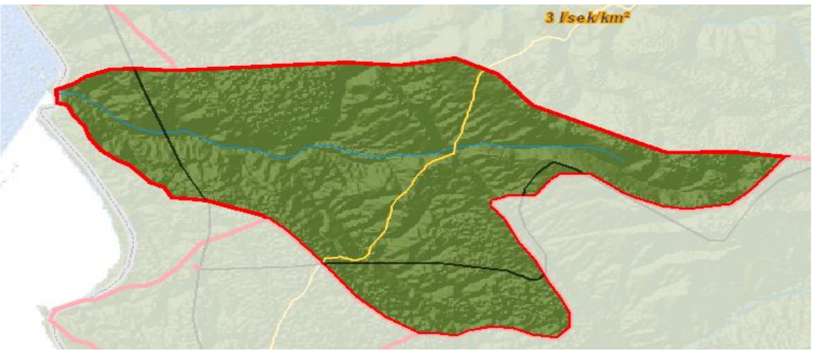


Annual precipitation in mm
662

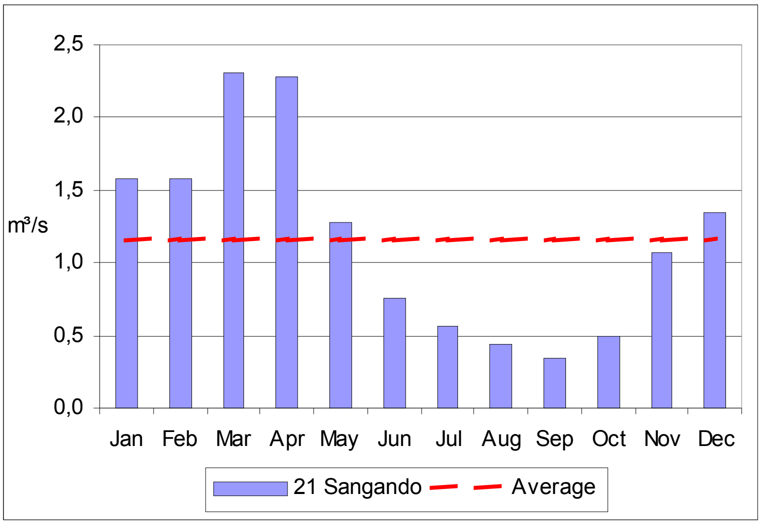
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

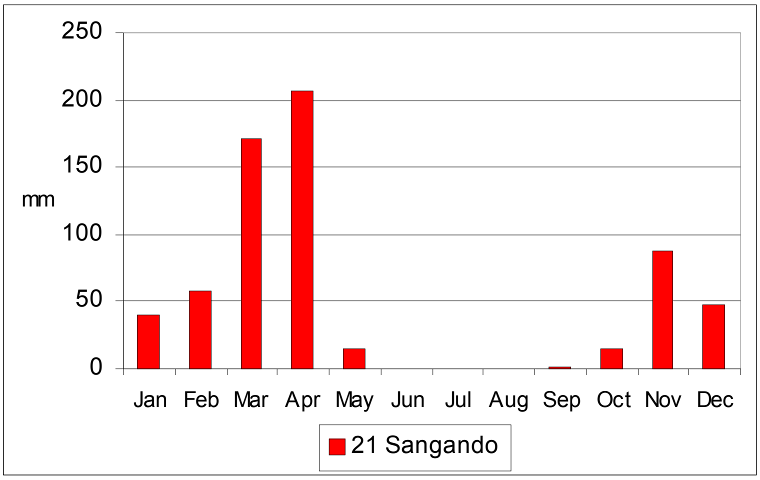
Existing water deficit
NO
Future water deficit
NO



6021	
Sangando	
Area in km²	
392.1	
Perimeter in km	
111.3	
Elevation (m.a.s.l)	
Mean	Maximum
131	233



Annual mean discharge m³/s (Q)	
1.17	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*3.0*
Max	3.4
Min	2.6

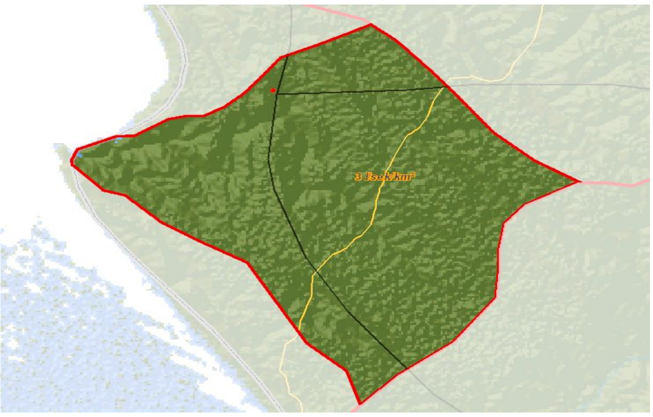


Annual precipitation in mm
644

Population and Water use				
	2000	2005	2015	2025
Population	601	700	940	1296
Water use (m³/day)	9	10	29	39
Water use (m³/s)	0.000	0.000	0.000	0.000

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

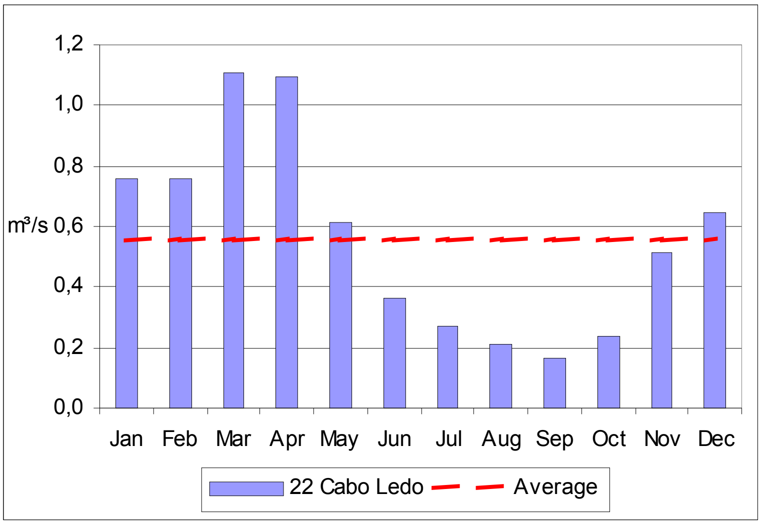
Existing water deficit
NO
Future water deficit
NO



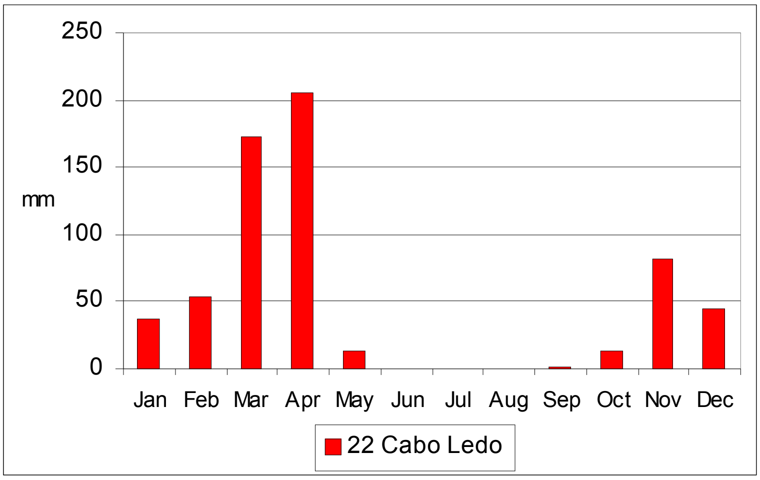
6022

Cabo Ledo

Area in km²	
188.7	
Perimeter in km	
59.8	
Elevation (m.a.s.l)	
Mean	Maximum
111	137



Annual mean discharge m³/s (Q)	
0.56	
Annual mean specific discharge (q) $l\ s^{-1}\ km^{-2}$	
Mean	*3.0*
Max	3.1
Min	2.7

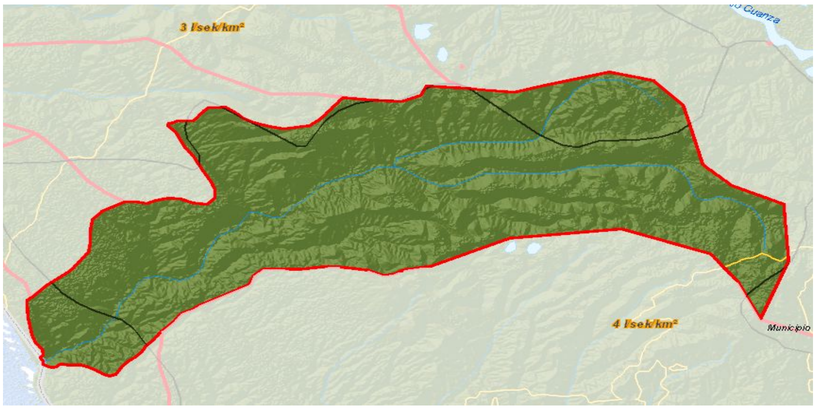


Annual precipitation in mm
623

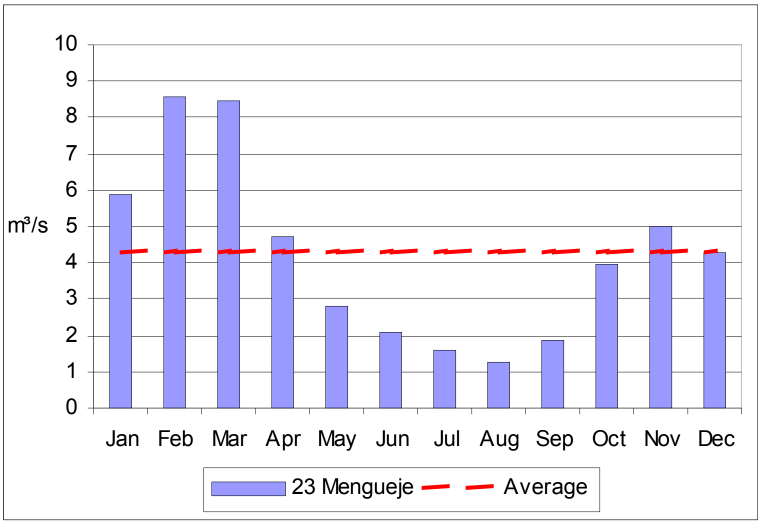
Population and Water use				
	2000	2005	2015	2025
Population	601	700	940	1296
Water use (m³/day)	9	10	29	39
Water use (m³/s)	0.000	0.000	0.000	0.000

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

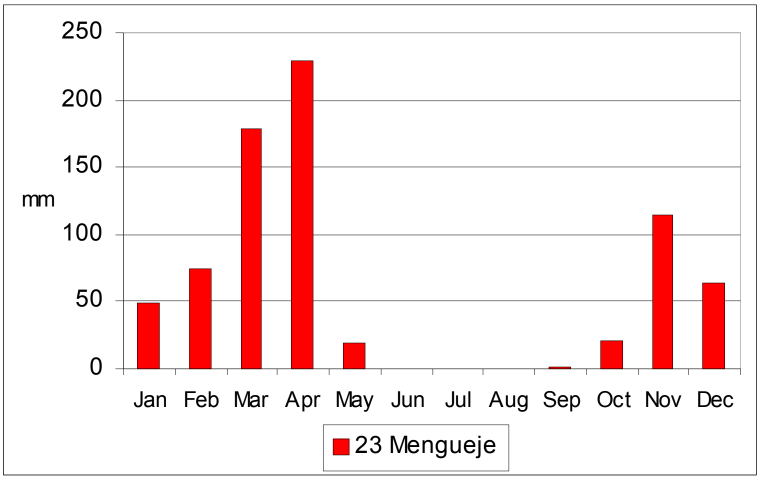
Existing water deficit
NO
Future water deficit
NO



6023	
Mengueje	
Area in km²	
1234.6	
Perimeter in km	
209.6	
Elevation (m.a.s.l)	
Mean	Maximum
170	291



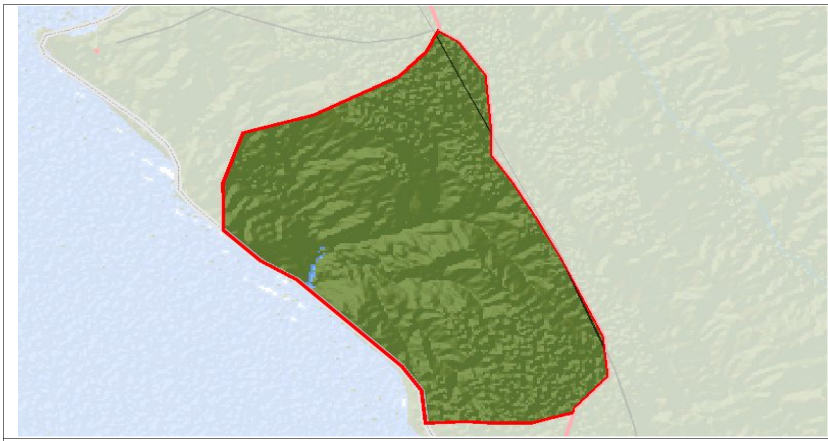
Annual mean discharge m³/s (Q)	
4.34	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*3.5*
Max	4.1
Min	3.1



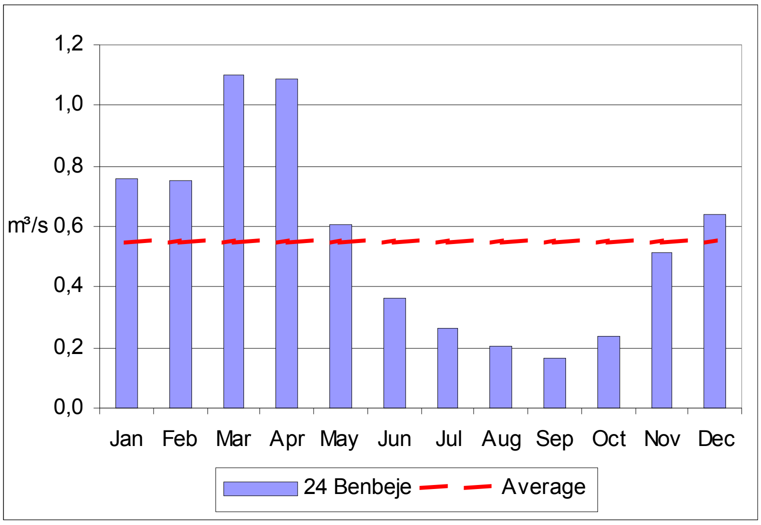
Annual precipitation in mm
754

Population and Water use				
	2000	2005	2015	2025
Population	601	700	940	1296
Water use (m³/day)	9	10	29	39
Water use (m³/s)	0.000	0.000	0.000	0.000

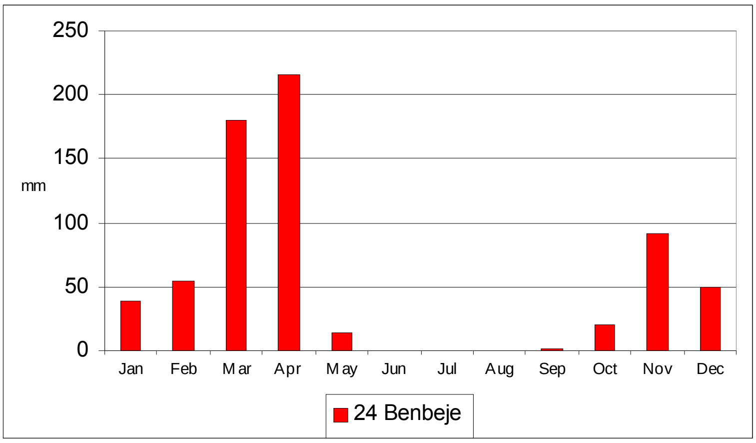
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6024	
Tanda	
Area in km²	
155.0	
Perimeter in km	
52.7	
Elevation (m.a.s.l)	
Mean	Maximum
83	123



Annual mean discharge m³/s (Q)	
0.56	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*3.6*
Max	3.8
Min	3.4

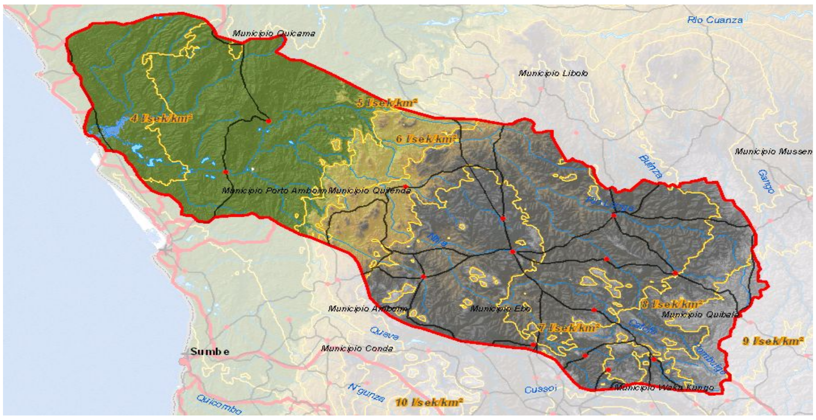


Annual precipitation in mm
666

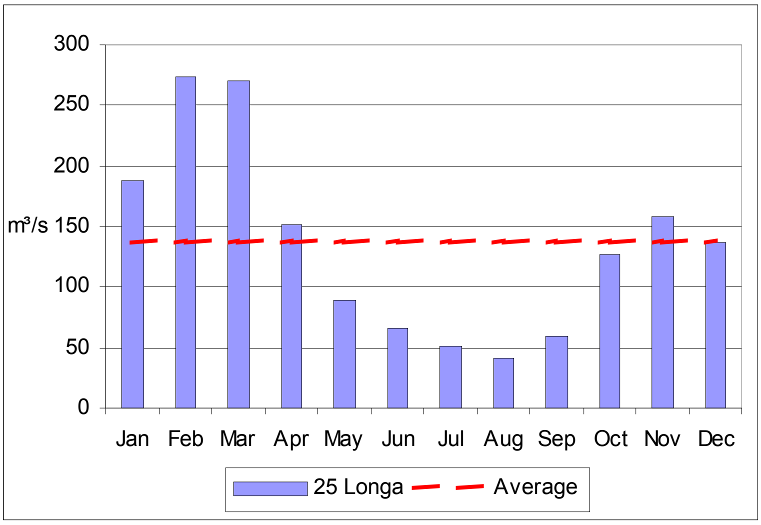
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

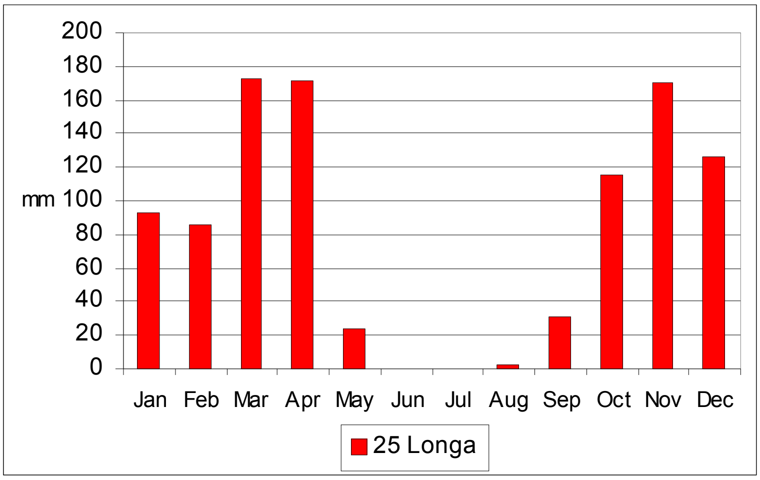
Existing water deficit
NO
Future water deficit
NO



6025	
Longa	
Area in km²	
23031.0	
Perimeter in km	
790.7	
Elevation (m.a.s.l)	
Mean	Maximum
888	2099



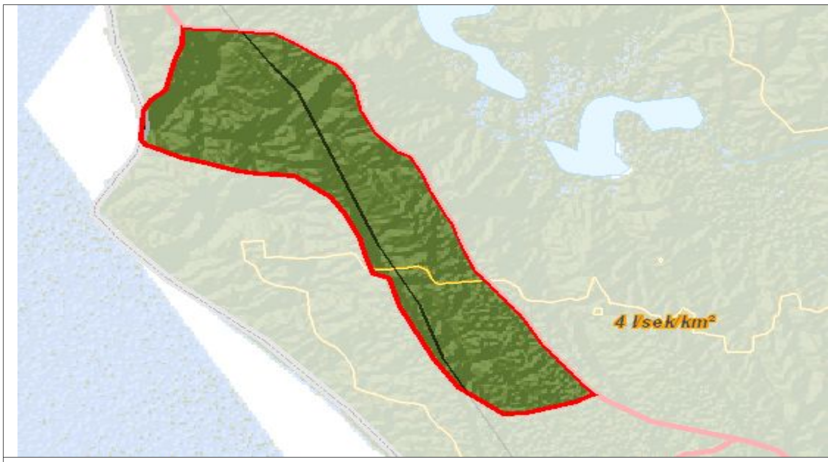
Annual mean discharge m^3/s (Q)	
138.4	
Annual mean specific discharge (q) $l\ s^{-1}\ km^{-2}$	
Mean	*6.0*
Max	9.1
Min	3.3



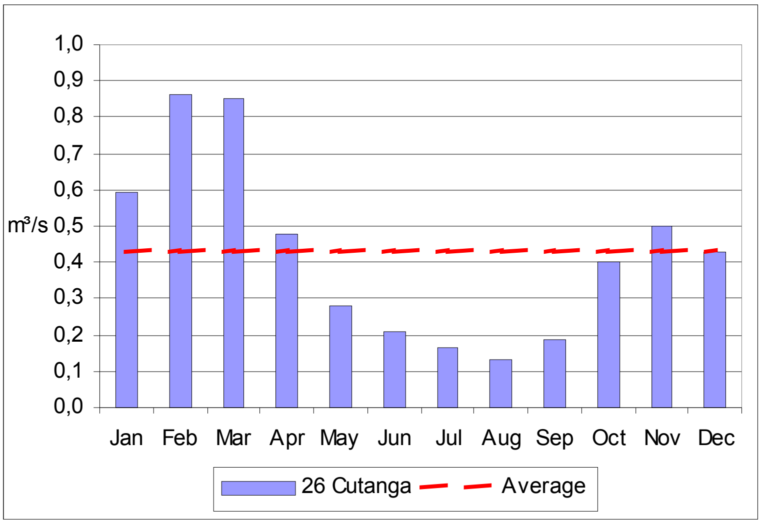
Annual precipitation in mm
991

Population and Water use				
	2000	2005	2015	2025
Population	67900	74286	69387	63717
Water use (m³/day)	1018	1114	2097	1912
Water use (m³/s)	0.012	0.013	0.024	0.022

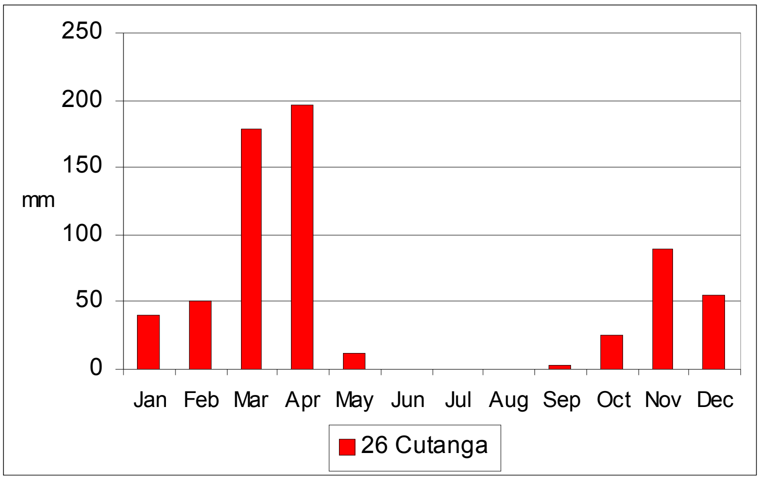
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	590621	943839	1649046	2358304	Future water deficit
Water use (m³/s)	6.8	10.9	19.1	27.3	NO



6026	
Cutanga	
Area in km²	
112.0	
Perimeter in km	
59.1	
Elevation (m.a.s.l)	
Mean	Maximum
91	123



Annual mean discharge m³/s (Q)	
0.44	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*3.9*
Max	4.2
Min	3.7

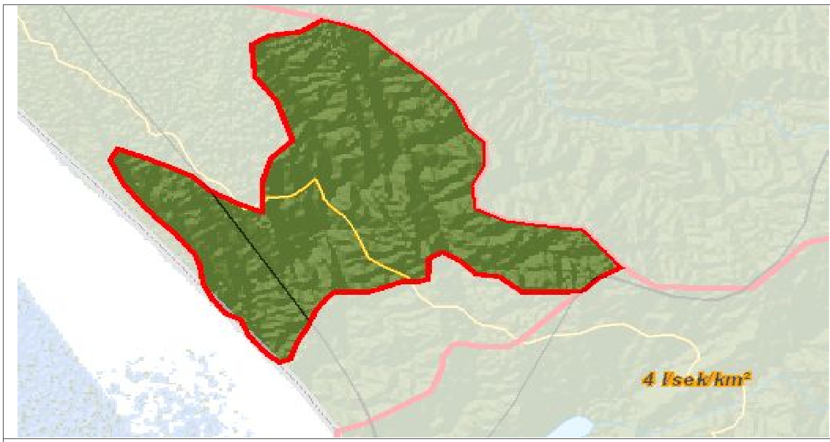


Annual precipitation in mm
653

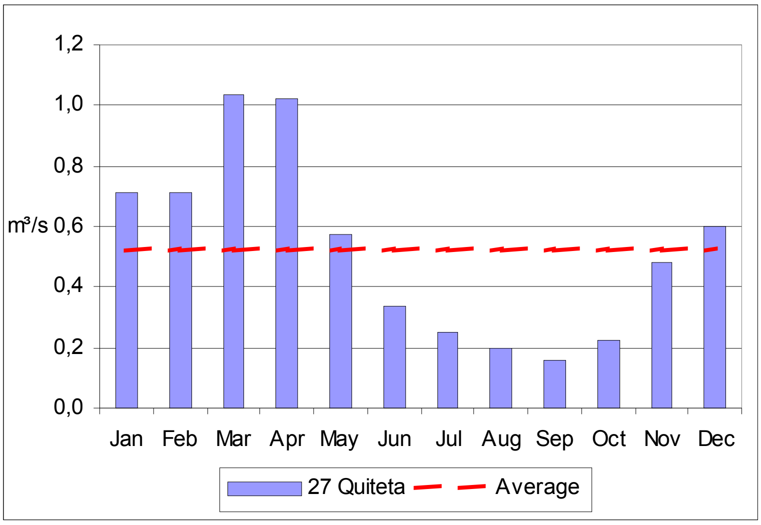
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

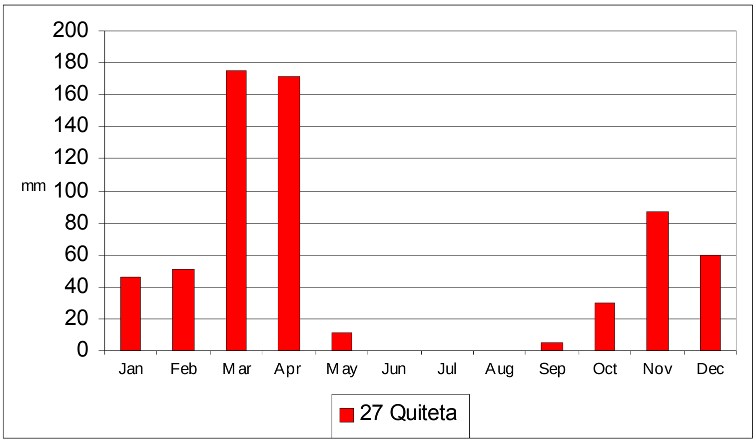
Existing water deficit
NO
Future water deficit
NO



6027	
Quiteta	
Area in km²	
130.3	
Perimeter in km	
66.4	
Elevation (m.a.s.l)	
Mean	Maximum
112	136



Annual mean discharge m³/s (Q)	
0.52	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.0*
Max	4.1
Min	3.9

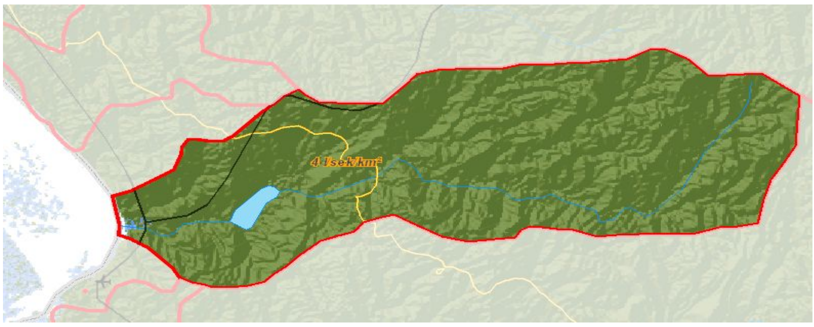


Annual precipitation in mm
637

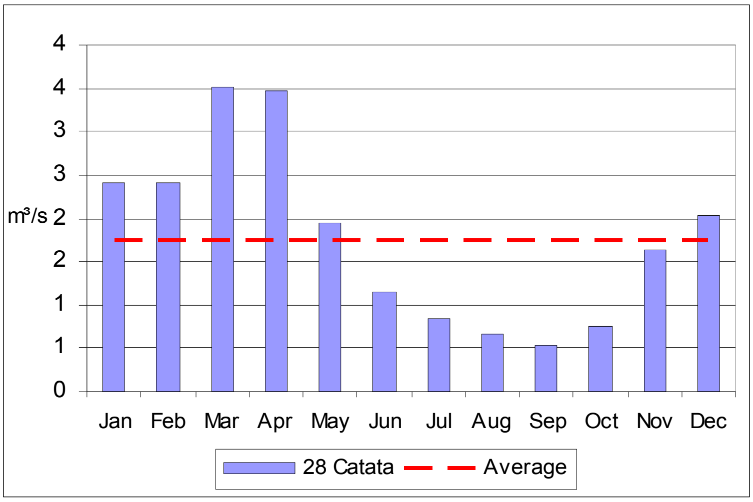
Population and Water use				
	2000	2005	2015	2025
Population	657	709	595	445
Water use (m³/day)	10	11	18	13
Water use (m³/s)	0.000	0.000	0.000	0.000

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

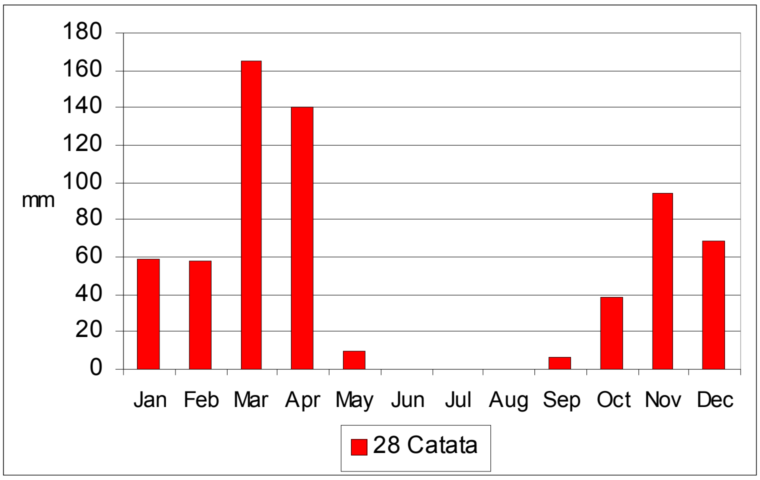
Existing water deficit
NO
Future water deficit
NO



6028	
Catata	
Area in km²	
430.0	
Perimeter in km	
101.5	
Elevation (m.a.s.l)	
Mean	Maximum
113	237



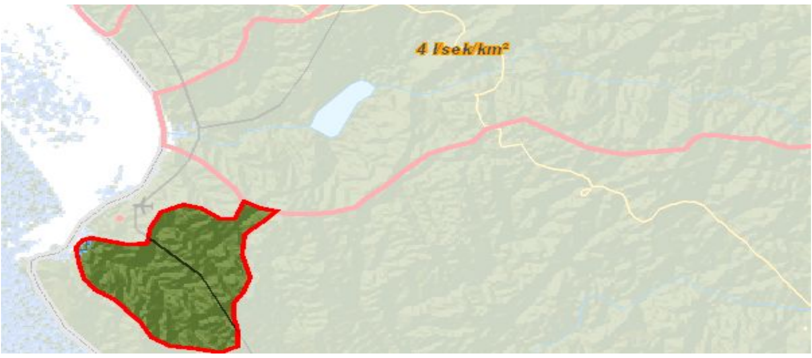
Annual mean discharge m³/s (Q)	
1.78	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.1*
Max	4.7
Min	3.7



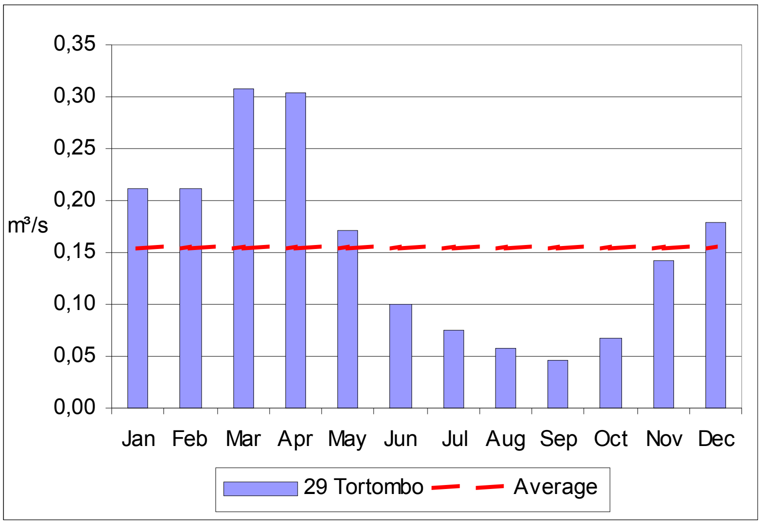
Annual precipitation in mm
638

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

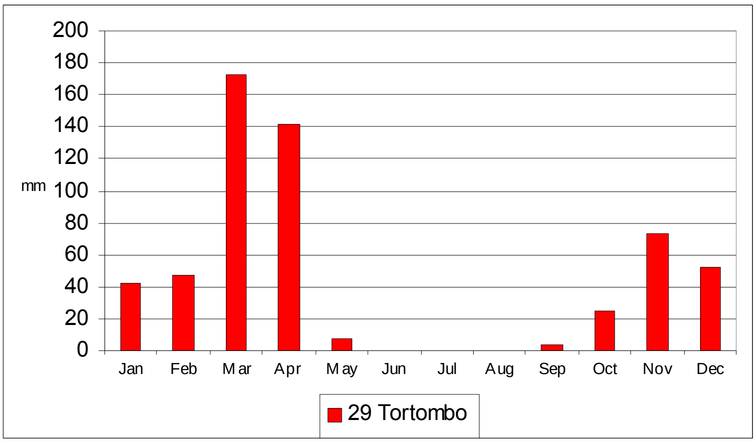
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6029	
Tortombo	
Area in km²	
43.3	
Perimeter in km	
30.4	
Elevation (m.a.s.l)	
Mean	Maximum
66	128



Annual mean discharge m³/s (Q)	
0.16	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*3.6*
Max	3.8
Min	3.5

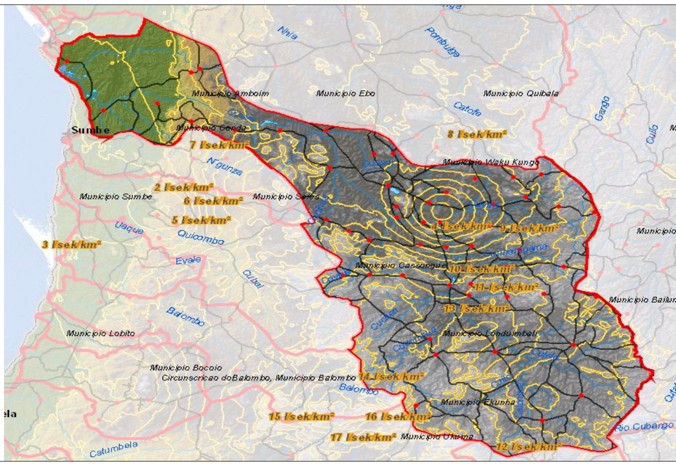


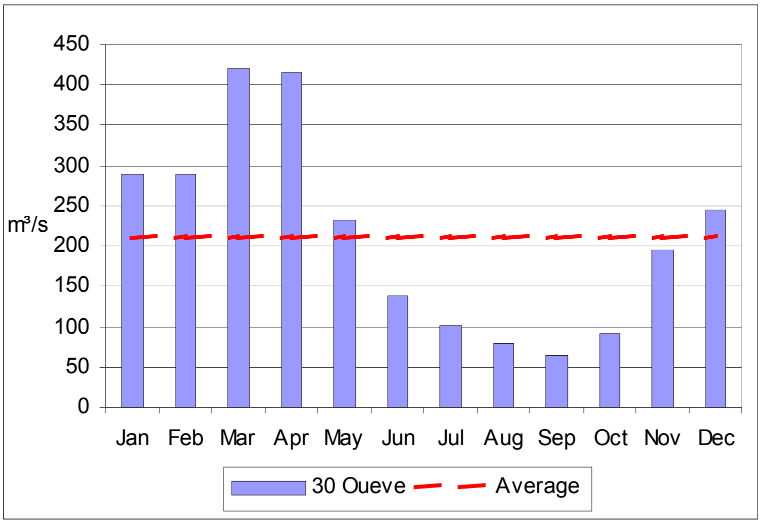
Annual precipitation in mm
566

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

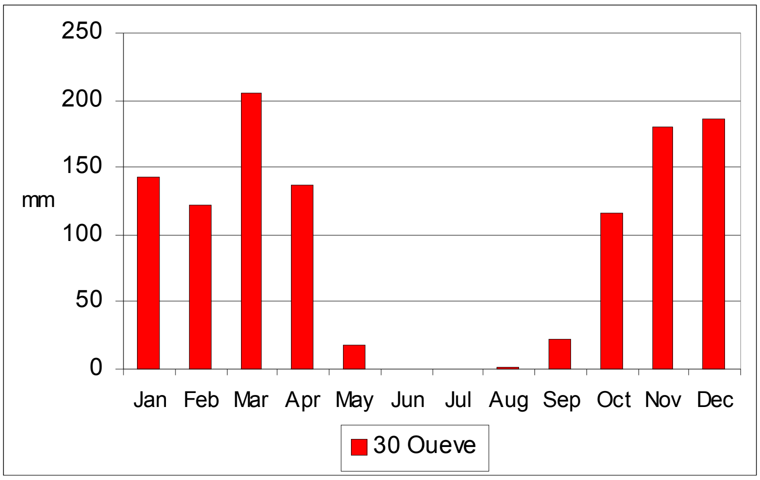
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO

6030	
Queve	
Area in km²	
22814.5	
Perimeter in km	
899.4	
Elevation (m.a.s.l)	
Mean	Maximum
1360	2575





Annual mean discharge m³/s (Q)	
213.4	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*9.4*
Max	16.3
Min	2.6



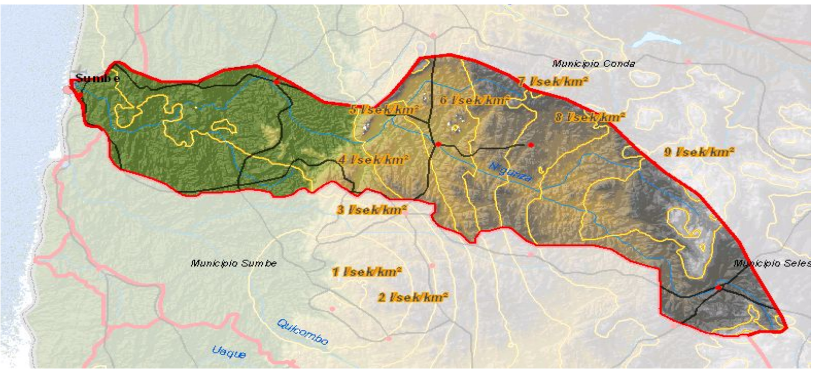
Annual precipitation in mm
1131

Population and Water use				
	2000	2005	2015	2025
Population	230241	302212	291044	275906
Water use (m³/day)	3454	4533	8731	8277
Water use (m³/s)	0.040	0.052	0.101	0.096

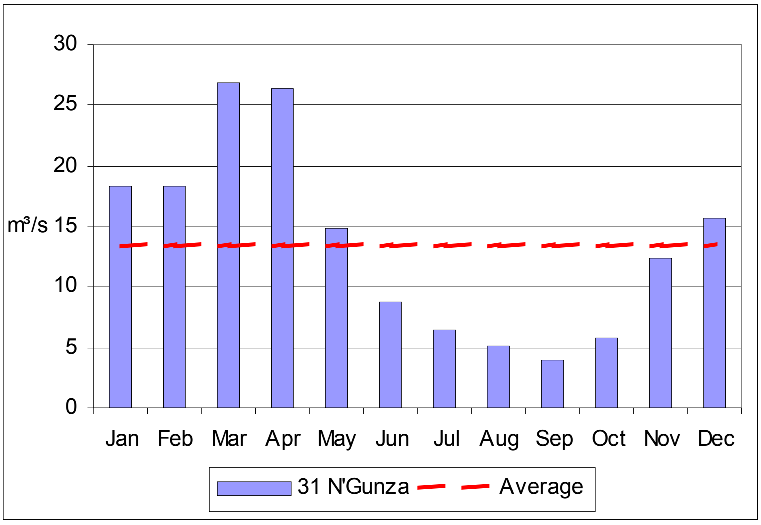
Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	505730	1022137	1583170	2092269
Water use (m³/s)	5.9	11.8	18.3	24.2

Existing water deficit
NO
Future water deficit
NO

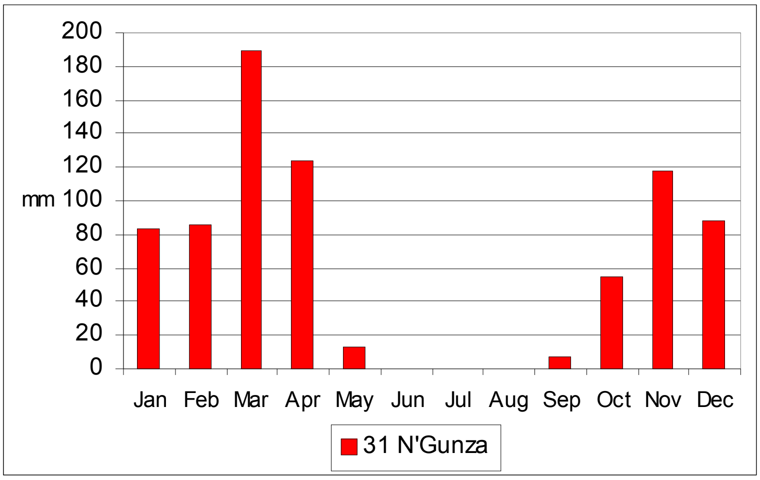
6031	
N'Gunza	
Area in km²	
2308.9	
Perimeter in km	
286.4	
Elevation (m.a.s.l)	
Mean	Maximum
867	2260



Annual mean discharge m³/s (Q)	
13.57	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*5.9*
Max	10.9
Min	2.6

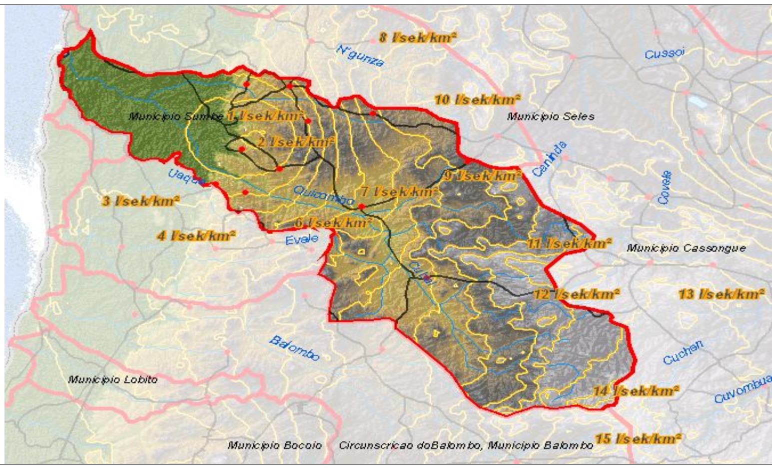


Annual precipitation in mm
763

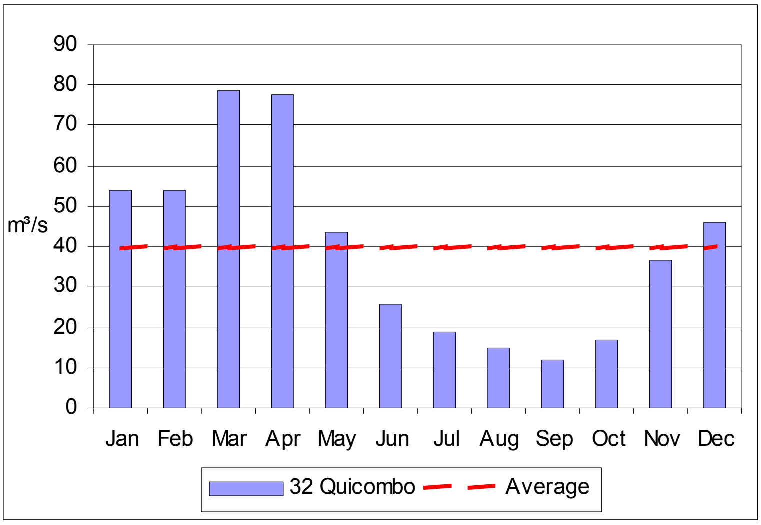


Population and Water use				
	2000	2005	2015	2025
Population	184706	198235	242471	301235
Water use (m³/day)	4661	5599	11274	16705
Water use (m³/s)	0.054	0.065	0.130	0.193

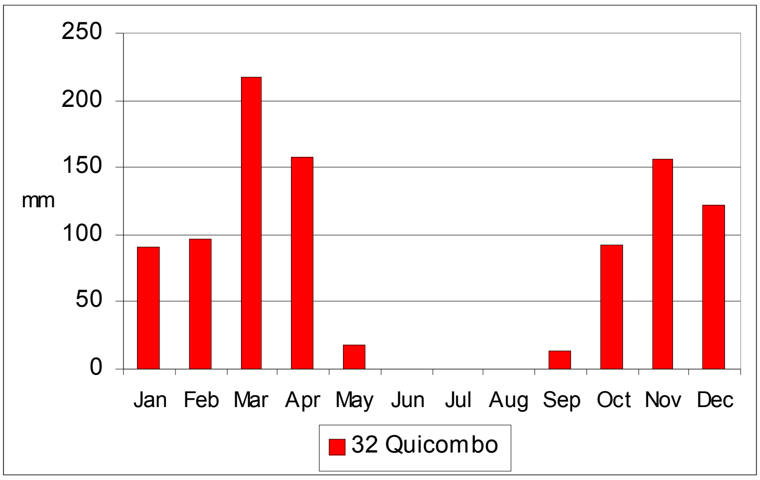
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	548461	110750	166091	221679	Future water deficit
Water use (m³/s)	6.3	1.3	1.9	2.6	NO



6032	
Quicombo	
Area in km²	
5511.7	
Perimeter in km	
434.3	
Elevation (m.a.s.l)	
Mean	Maximum
1081	2545



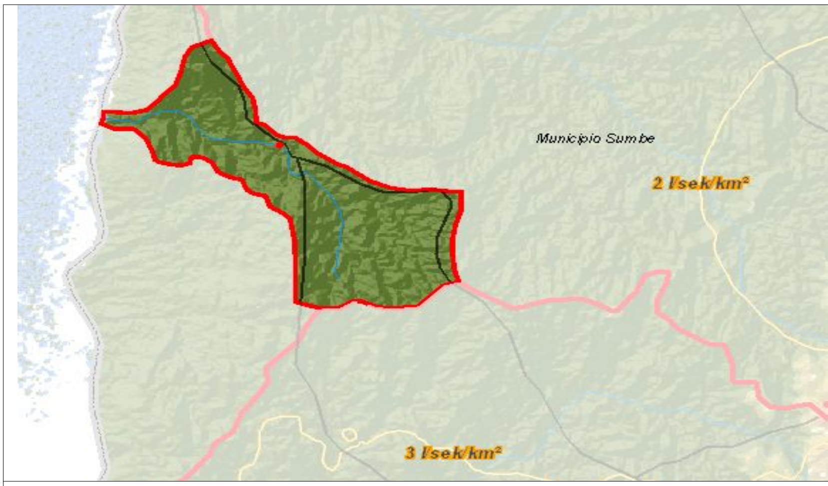
Annual mean discharge m³/s (Q)	
39.9	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*7.2*
Max	15.6
Min	0.9



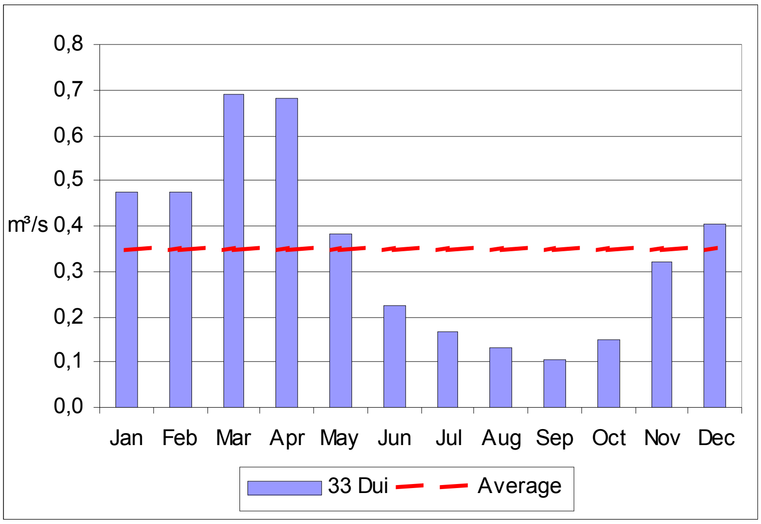
Annual precipitation in mm
965

Population and Water use				
	2000	2005	2015	2025
Population	83871	90823	79036	63612
Water use (m³/day)	1258	1362	2371	1908
Water use (m³/s)	0.015	0.016	0.027	0.022

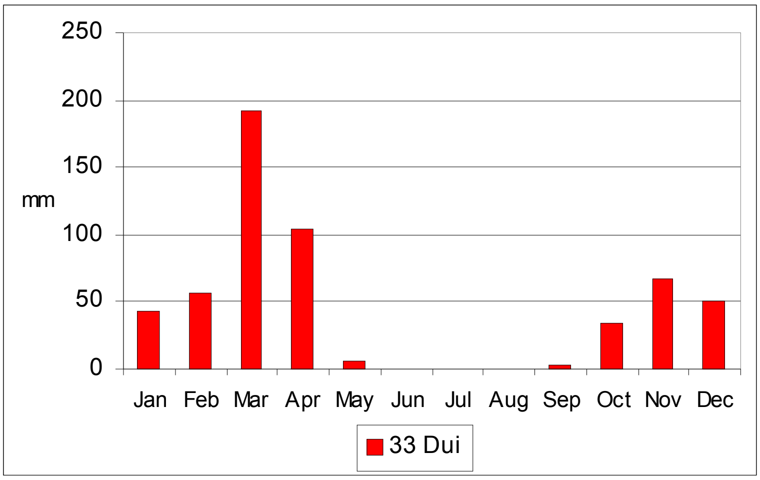
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	30822	49315	212671	283562	Future water deficit
Water use (m³/s)	0.4	0.6	2.5	3.3	NO



6033	
Dui	
Area in km²	
123.8	
Perimeter in km	
62.5	
Elevation (m.a.s.l)	
Mean	Maximum
264	348



Annual mean discharge m³/s (Q)	
0.35	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*2.8*
Max	2.9
Min	2.7

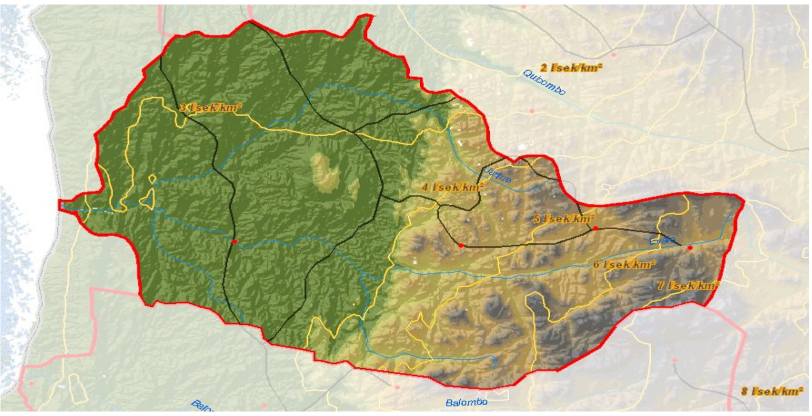


Annual precipitation in mm
557

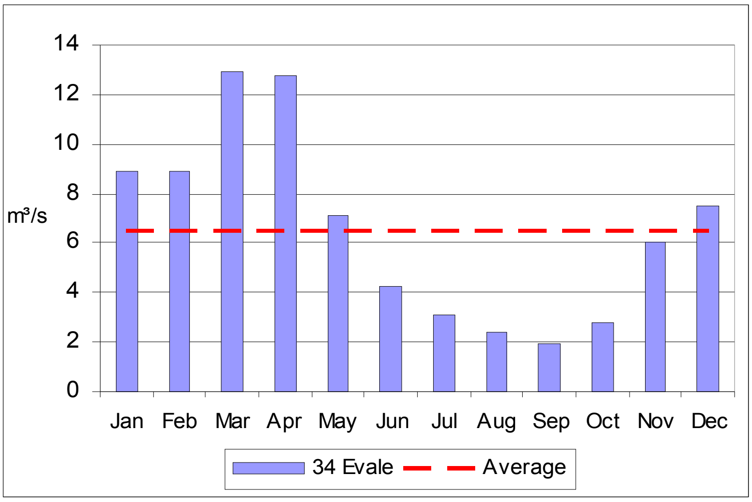
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

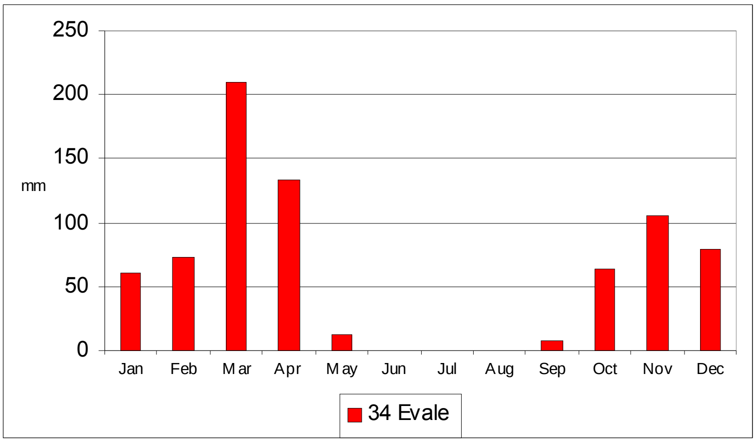
Existing water deficit
NO
Future water deficit
NO



6034	
Evale	
Area in km²	
1617.4	
Perimeter in km	
189.7	
Elevation (m.a.s.l)	
Mean	Maximum
582	1583



Annual mean discharge m³/s (Q)	
6.56	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.1*
Max	7.4
Min	2.3

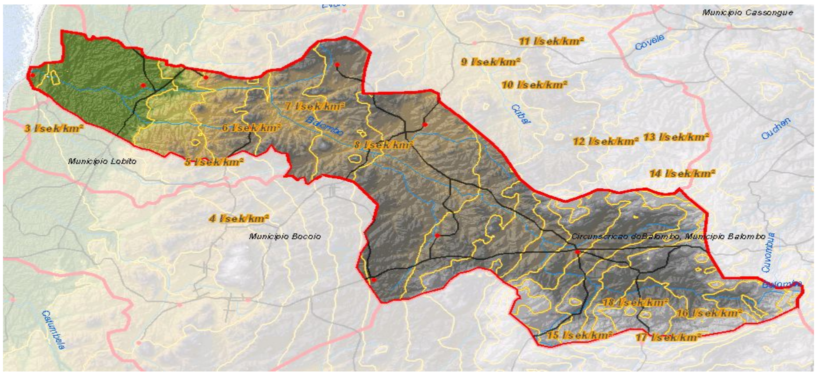


Annual precipitation in mm
745

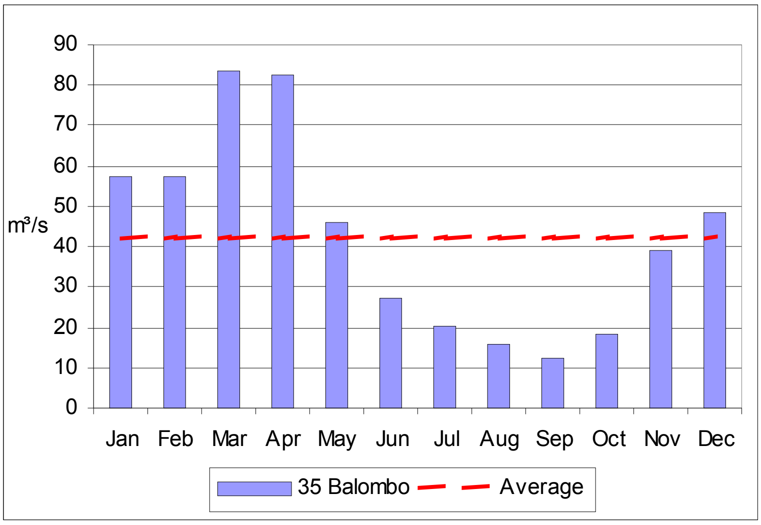
Population and Water use				
	2000	2005	2015	2025
Population	12868	14214	14759	15591
Water use (m³/day)	193	213	443	468
Water use (m³/s)	0.002	0.002	0.005	0.005

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	130137	260274	328767	520548
Water use (m³/s)	1.5	3.0	3.8	6.0

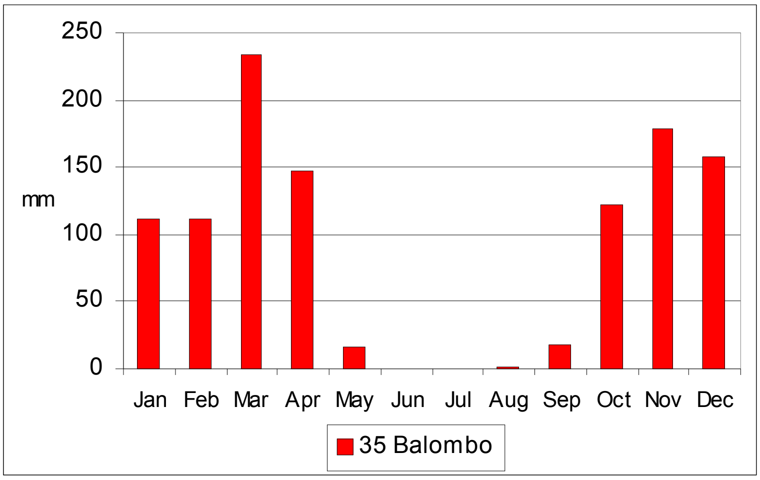
Existing water deficit
NO
Future water deficit
YES



6035	
Balombo	
Area in km²	
4413.8	
Perimeter in km	
450.7	
Elevation (m.a.s.l)	
Mean	Maximum
1186	2609



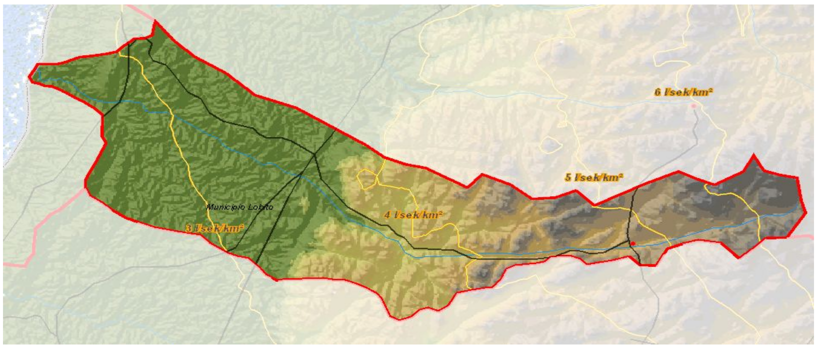
Annual mean discharge m³/s (Q)	
42.4	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*9.6*
Max	18.4
Min	2.8



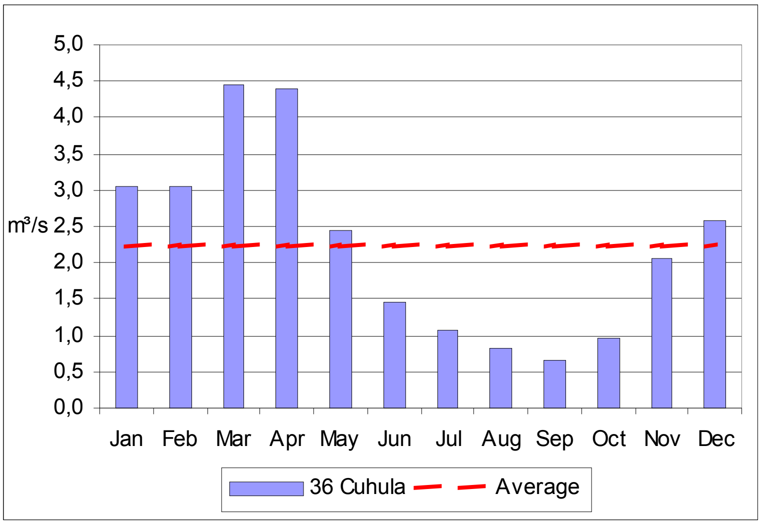
Annual precipitation in mm	
1100	

Population and Water use				
	2000	2005	2015	2025
Population	73647	84086	110209	146242
Water use (m³/day)	1105	1261	3306	4387
Water use (m³/s)	0.013	0.015	0.038	0.051

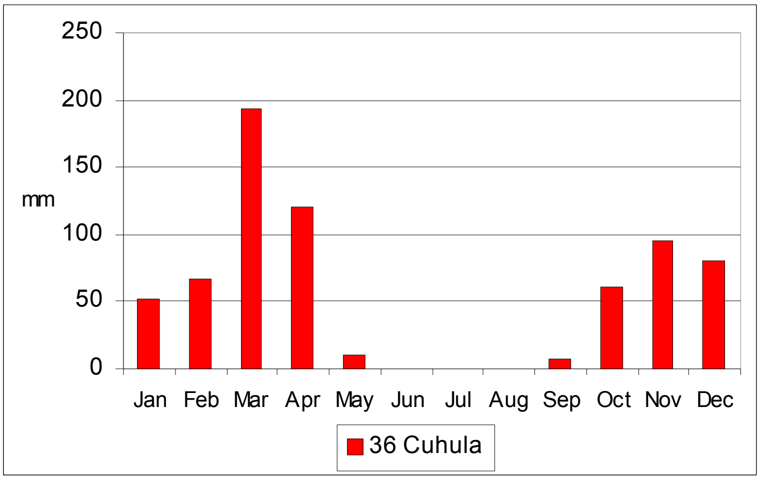
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	211233	211233	211233	211233	Future water deficit
Water use (m³/s)	2.4	2.4	2.4	2.4	NO



6036	
Cuhula	
Area in km²	
591.5	
Perimeter in km	
152.0	
Elevation (m.a.s.l)	
Mean	Maximum
609	1424



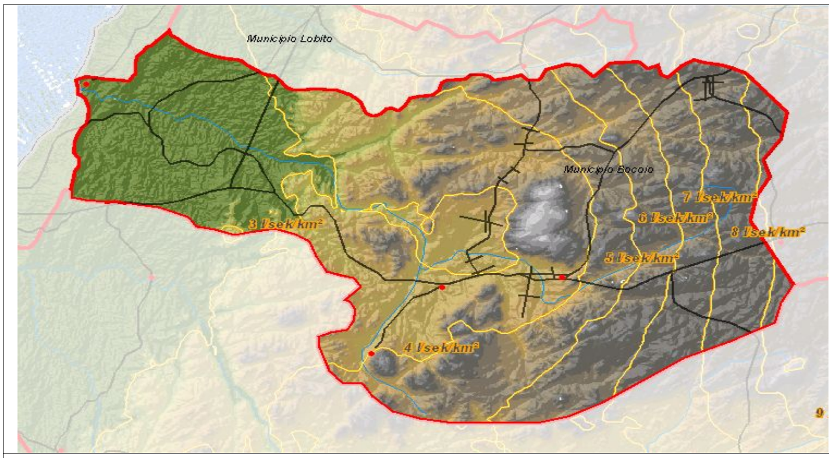
Annual mean discharge m³/s (Q)	
2.25	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*3.8*
Max	6.6
Min	2.7



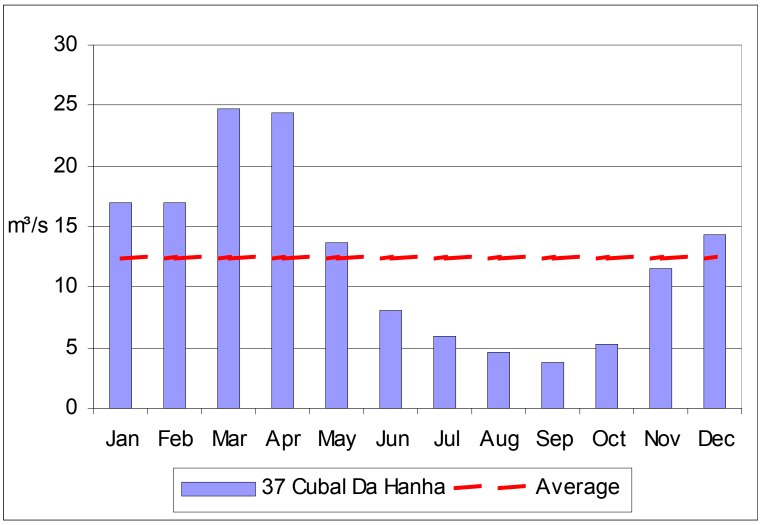
Annual precipitation in mm
690

Population and Water use				
	2000	2005	2015	2025
Population	3319	3801	5078	6837
Water use (m³/day)	50	57	152	205
Water use (m³/s)	0.001	0.001	0.002	0.002

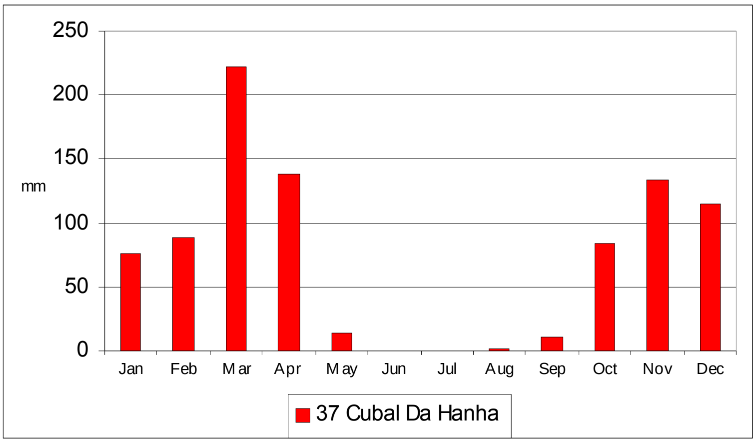
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6037	
Cubal Da Hanha	
Area in km²	
2880.5	
Perimeter in km	
265.7	
Elevation (m.a.s.l)	
Mean	Maximum
949	2142



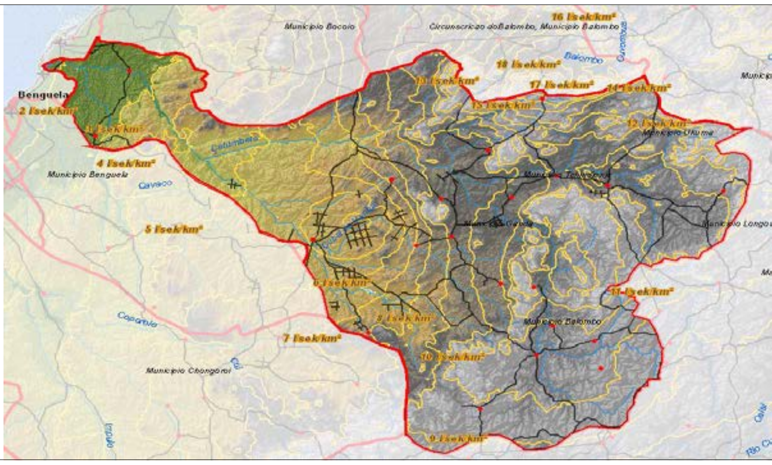
Annual mean discharge m³/s (Q)	
12.52	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.3*
Max	8.4
Min	2.3



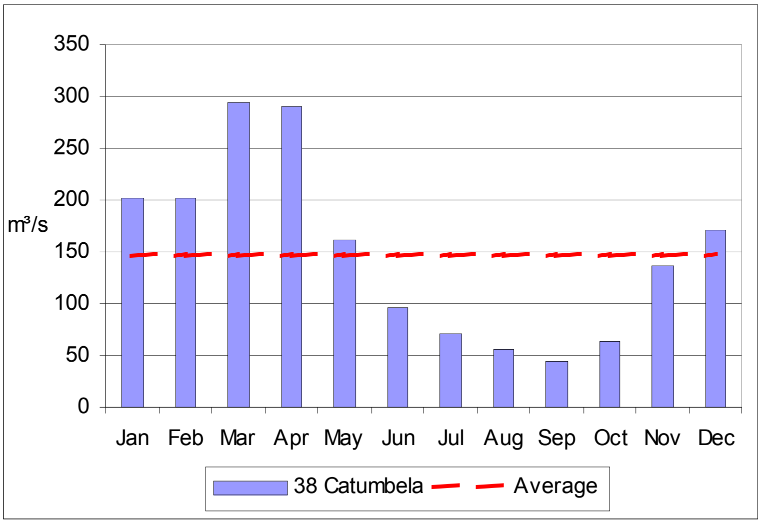
Annual precipitation in mm
883

Population and Water use				
	2000	2005	2015	2025
Population	43149	49418	66014	88879
Water use (m³/day)	647	741	1980	2666
Water use (m³/s)	0.007	0.009	0.023	0.031

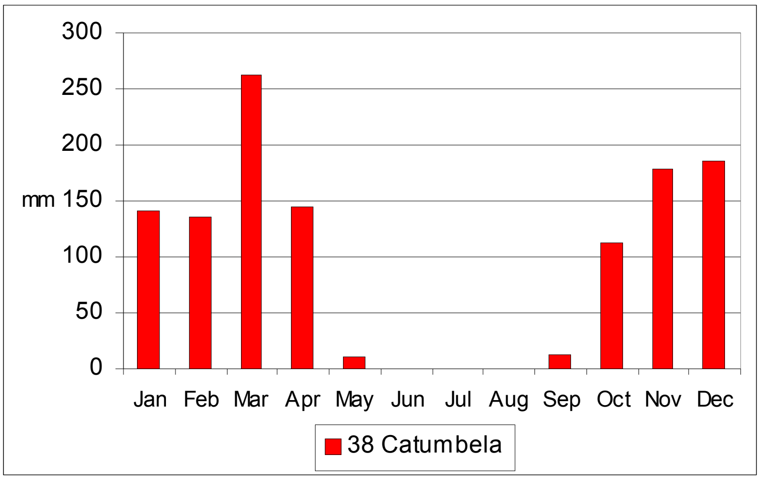
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	140822	140822	711151	711151	Future water deficit
Water use (m³/s)	1.6	1.6	8.2	8.2	YES



6038	
Catumbela	
Area in km²	
16532.6	
Perimeter in km	
747.9	
Elevation (m.a.s.l)	
Mean	Maximum
1321	2570



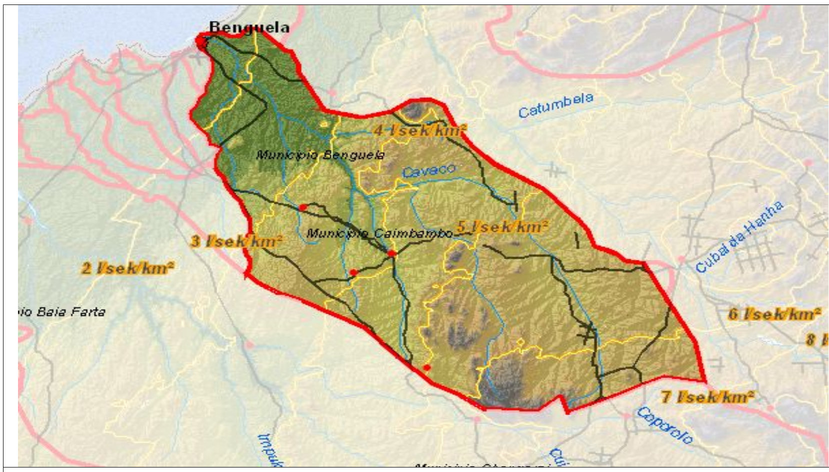
Annual mean discharge m³/s (Q)	
149.1	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*9.0*
Max	17.3
Min	1.8



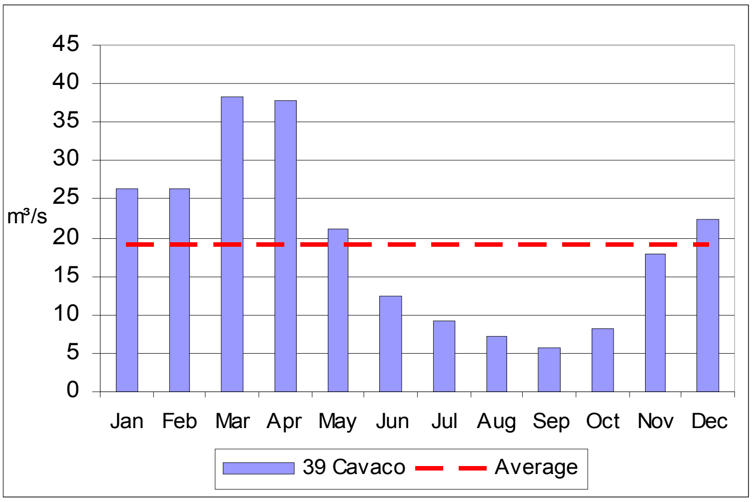
Annual precipitation in mm
1182

Population and Water use				
	2000	2005	2015	2025
Population	657503	721955	961294	1282159
Water use (m³/day)	27659	40553	67212	117574
Water use (m³/s)	0.320	0.469	0.778	1.361

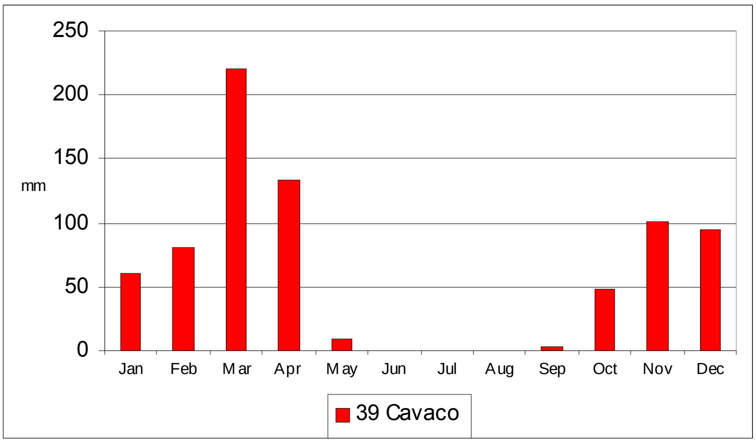
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	213038	213353	214162	215287	Future water deficit
Water use (m³/s)	2.5	2.5	2.5	2.5	NO



6039	
Cavaco	
Area in km²	
4397.8	
Perimeter in km	
313.4	
Elevation (m.a.s.l)	
Mean	Maximum
738	1570



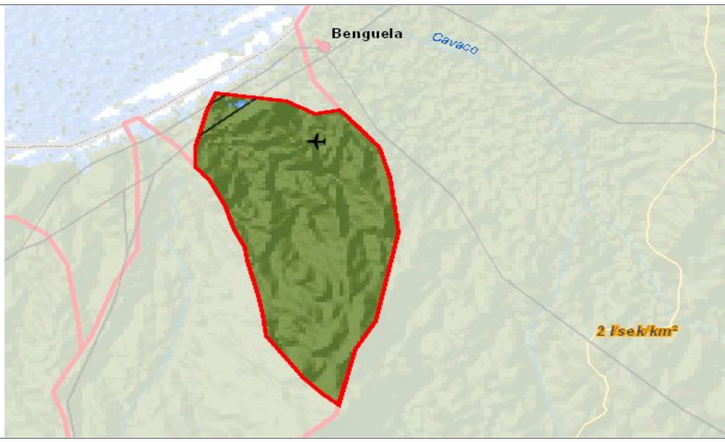
Annual mean discharge m³/s (Q)	
19.44	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.4*
Max	6.8
Min	1.6



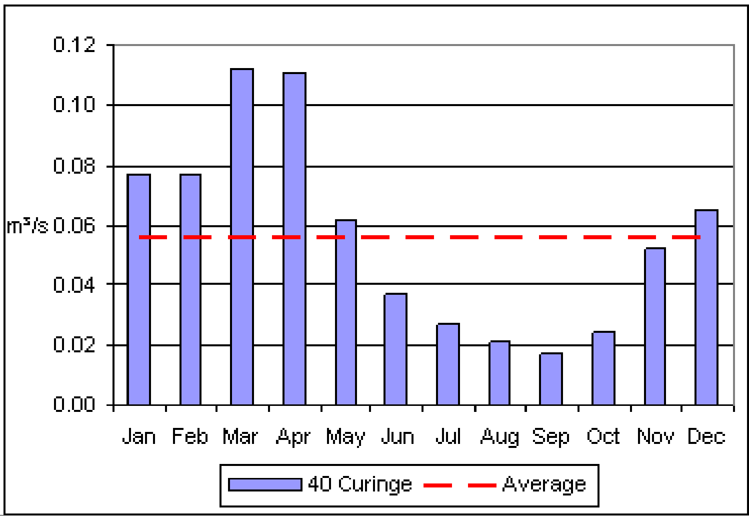
Annual precipitation in mm
751

Population and Water use				
	2000	2005	2015	2025
Population	377915	480809	648468	869021
Water use (m³/day)	17639	35837	56534	102247
Water use (m³/s)	0.204	0.415	0.654	1.183

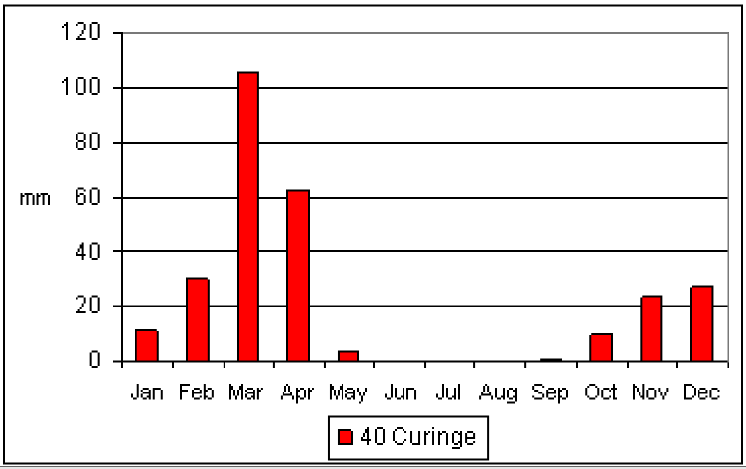
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	430046	431350	434684	439299	Future water deficit
Water use (m³/s)	5.0	5.0	5.0	5.1	YES



6040	
Curinge	
Area in km²	
34.6	
Perimeter in km	
25.4	
Elevation (m.a.s.l)	
Mean	Maximum
80	388



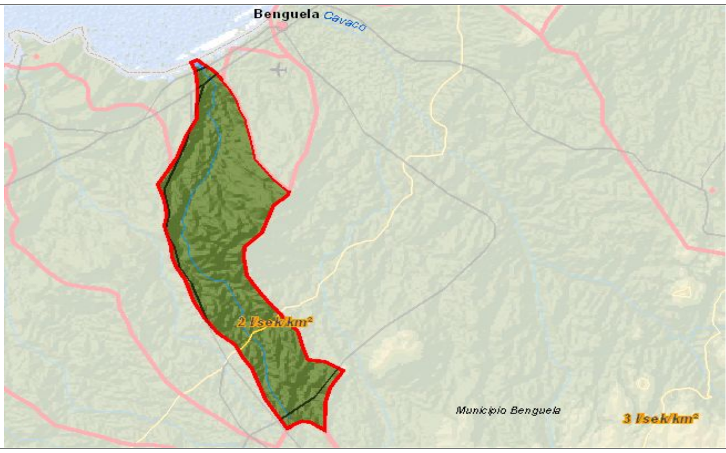
Annual mean discharge m³/s (Q)	
0.06	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.6*
Max	1.9
Min	1.5



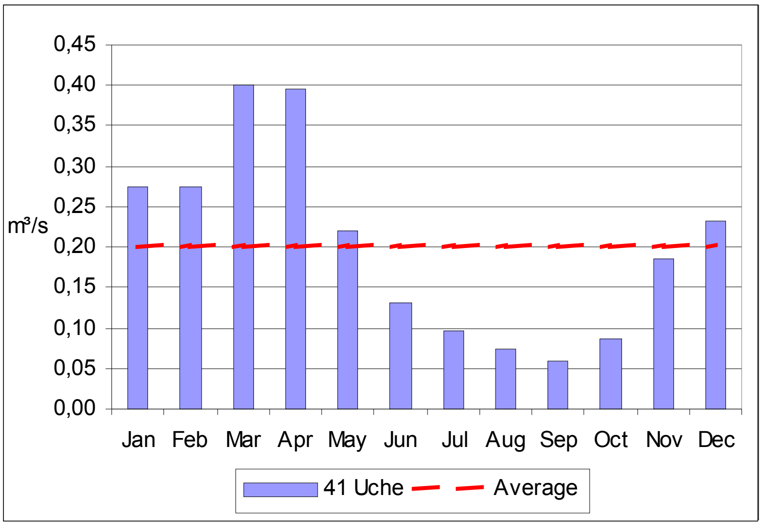
Annual precipitation in mm	
275	

Population and Water use				
	2000	2005	2015	2025
Population	830	950	1270	1709
Water use (m³/day)	12	14	38	51
Water use (m³/s)	0.000	0.000	0.000	0.001

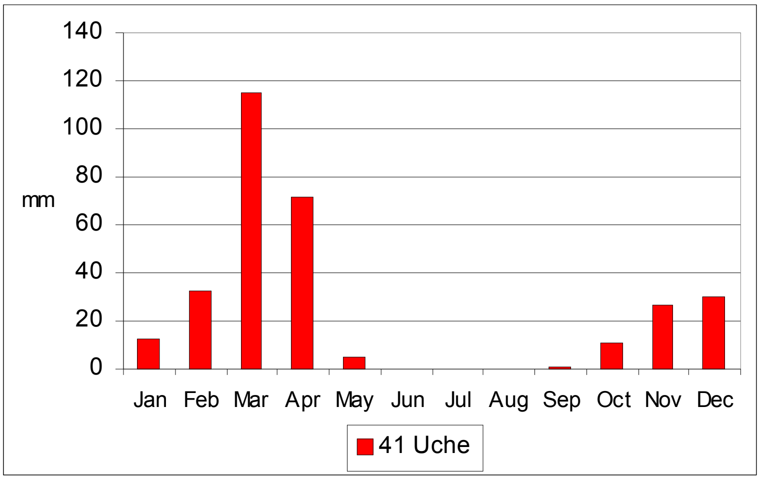
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6041	
Uche	
Area in km²	
110.3	
Perimeter in km	
64.4	
Elevation (m.a.s.l)	
Mean	Maximum
223	484



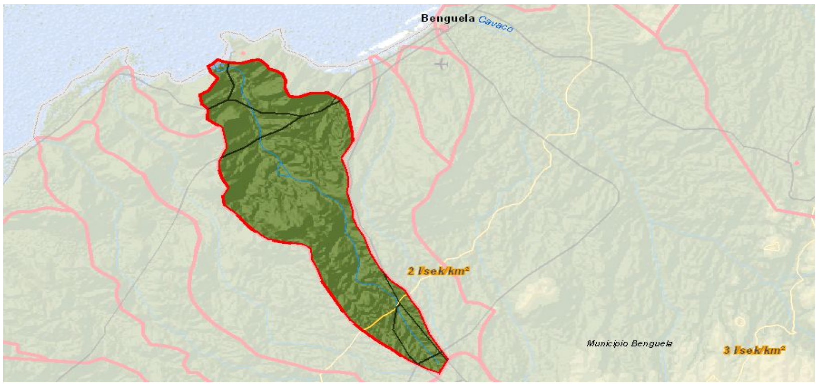
Annual mean discharge m³/s (Q)	
0.20	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.8*
Max	2.3
Min	1.5



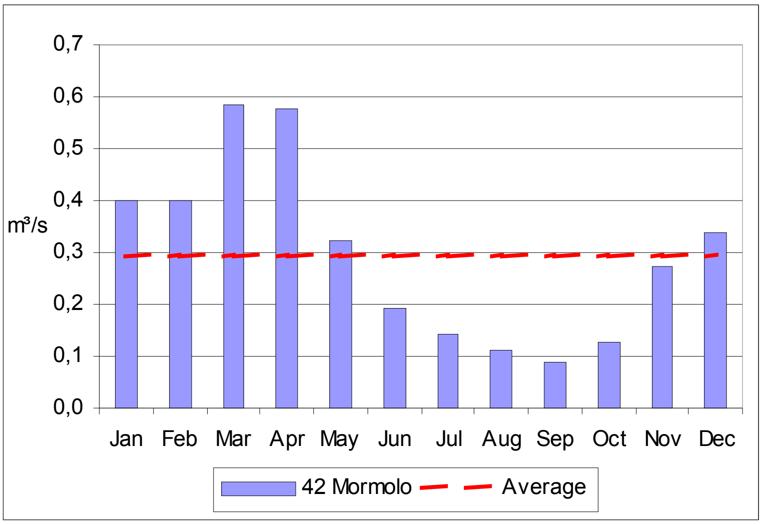
Annual precipitation in mm
305

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

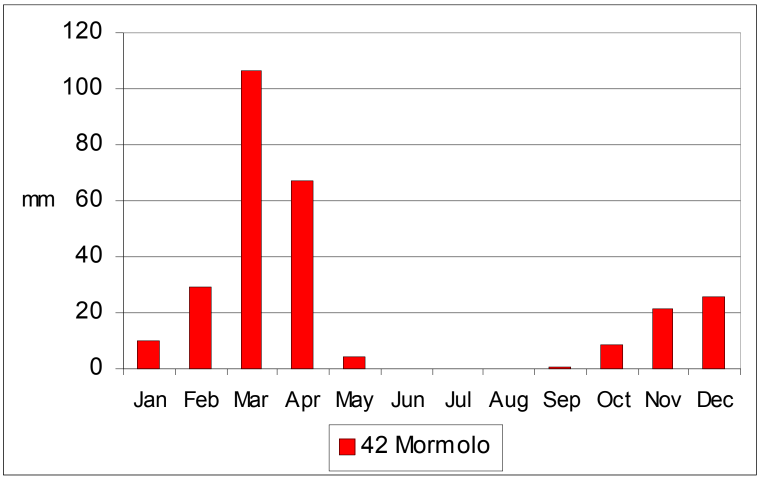
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6042	
Mormolo	
Area in km²	
181.2	
Perimeter in km	
75.5	
Elevation (m.a.s.l)	
Mean	Maximum
158	405



Annual mean discharge m³/s (Q)	
0.30	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.6*
Max	2.2
Min	1.3

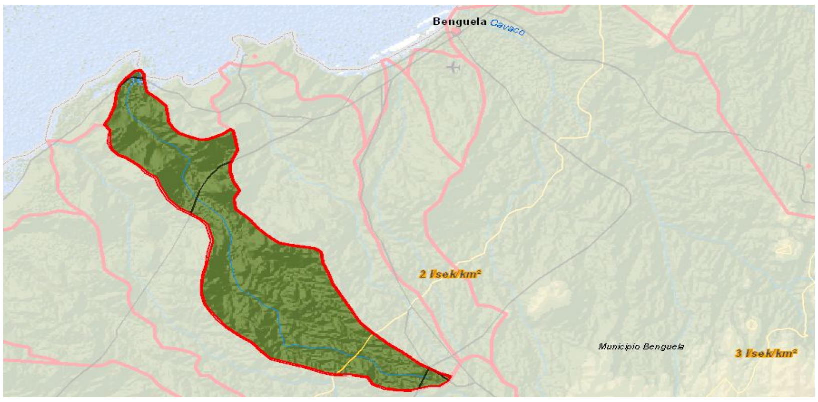


Annual precipitation in mm
273

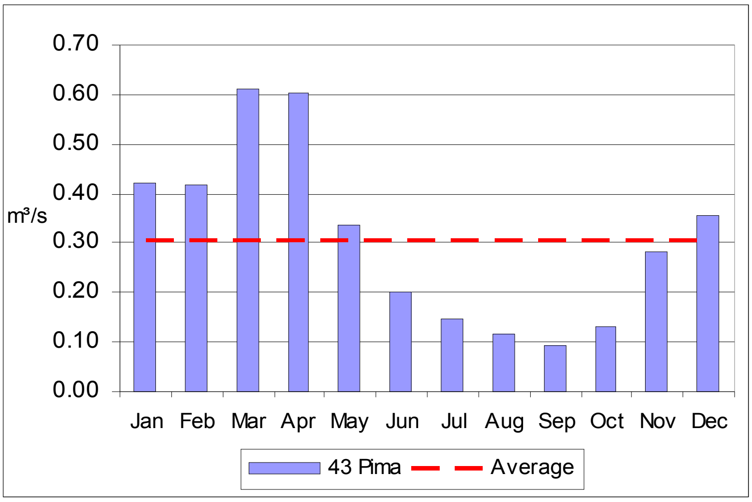
Population and Water use				
	2000	2005	2015	2025
Population	1660	1901	2539	3418
Water use (m³/day)	25	29	76	103
Water use (m³/s)	0.000	0.000	0.001	0.001

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

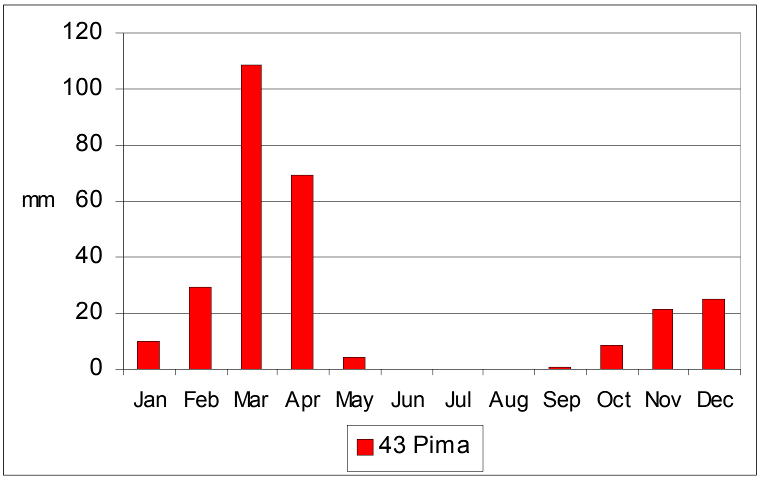
Existing water deficit
NO
Future water deficit
NO



6043	
Pima	
Area in km²	
186.4	
Perimeter in km	
86.4	
Elevation (m.a.s.l)	
Mean	Maximum
210	404



Annual mean discharge m³/s (Q)	
0.31	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.7*
Max	2.2
Min	1.3

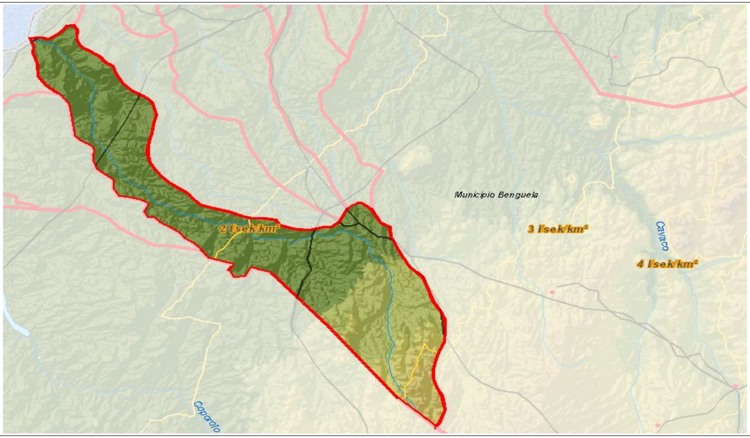


Annual precipitation in mm
277

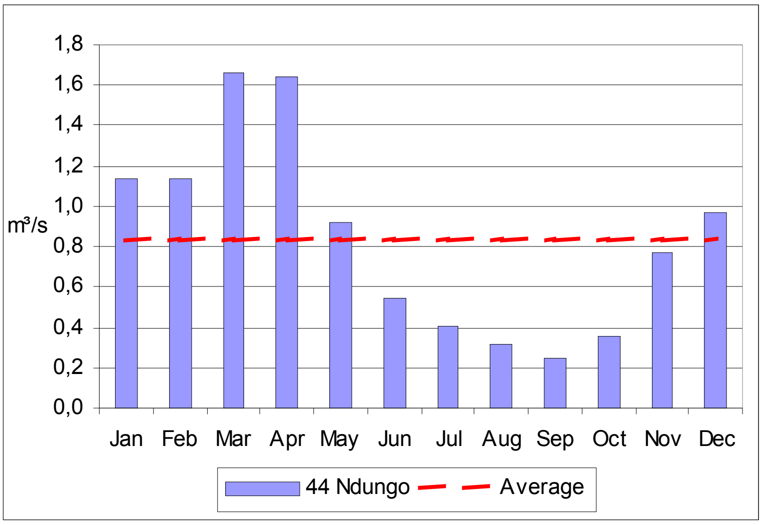
Population and Water use				
	2000	2005	2015	2025
Population	830	950	1270	1709
Water use (m³/day)	12	14	38	51
Water use (m³/s)	0.000	0.000	0.000	0.001

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

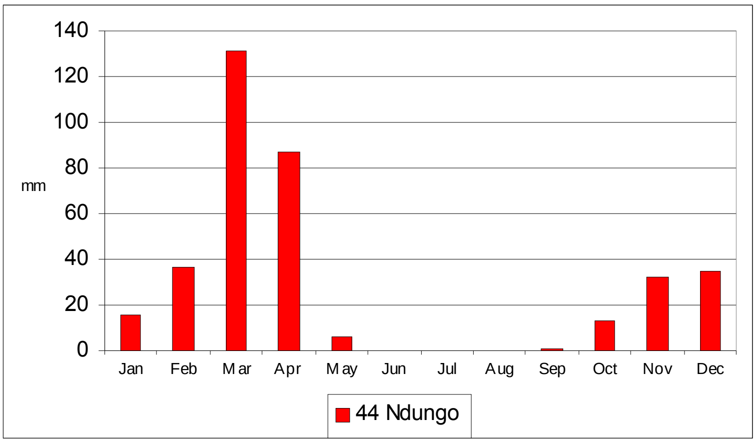
Existing water deficit
NO
Future water deficit
NO



6044	
Ndungo	
Area in km²	
393.8	
Perimeter in km	
141.5	
Elevation (m.a.s.l)	
Mean	Maximum
370	956



Annual mean discharge m³/s (Q)	
0.84	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*2.1*
Max	3.2
Min	1.2

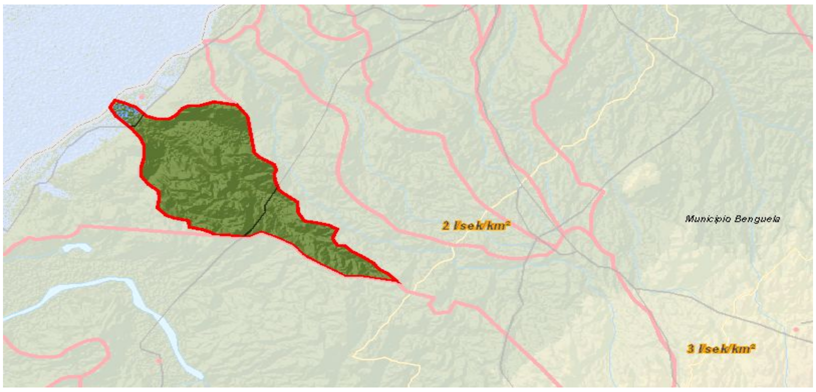


Annual precipitation in mm
358

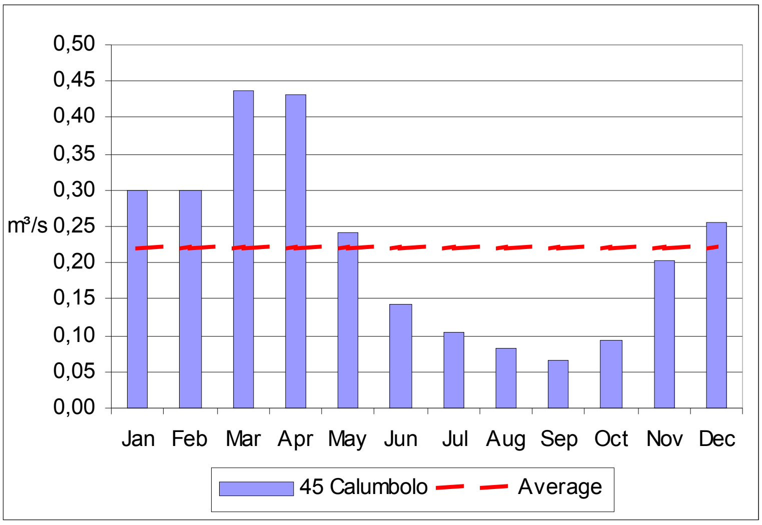
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

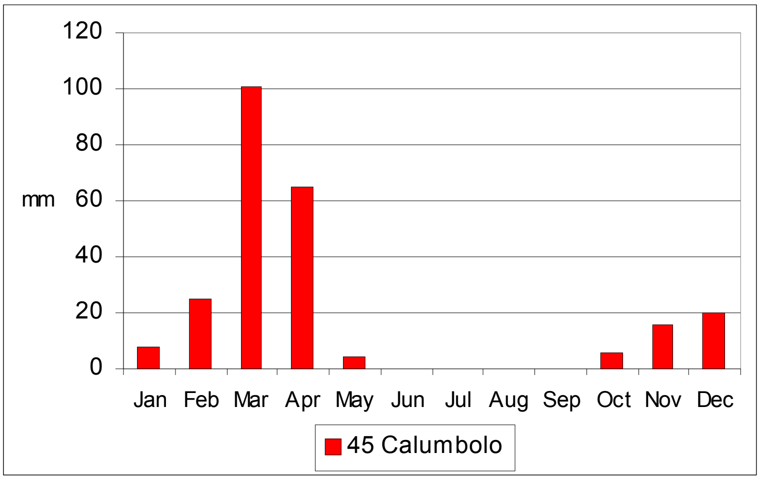
Existing water deficit
NO
Future water deficit
NO



6045	
Calumbolo	
Area in km²	
152.1	
Perimeter in km	
70.9	
Elevation (m.a.s.l)	
Mean	Maximum
158	357



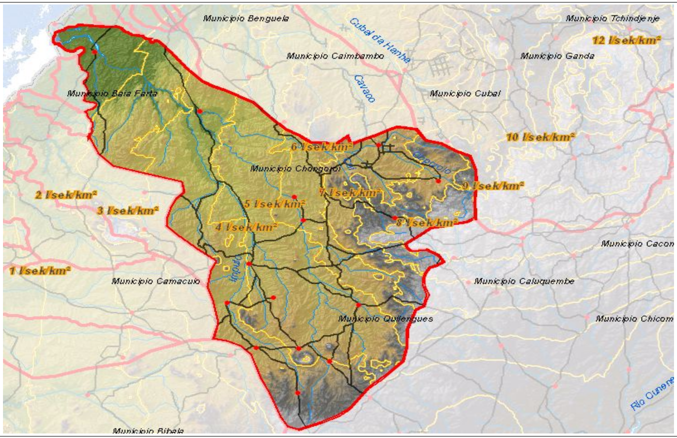
Annual mean discharge m³/s (Q)	
0.22	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.5*
Max	1.9
Min	1.2



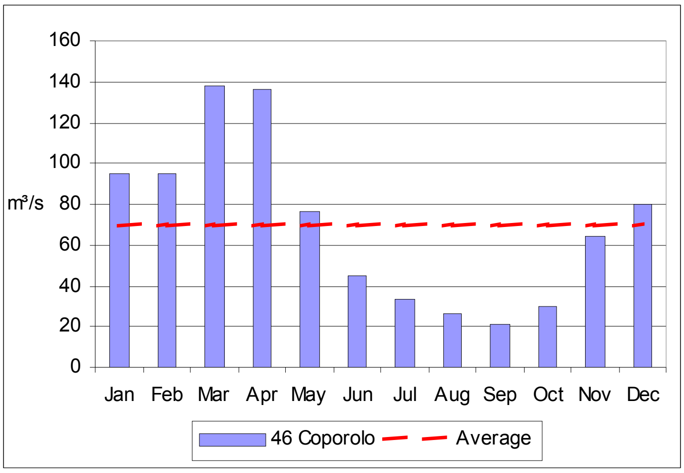
Annual precipitation in mm	
244	

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

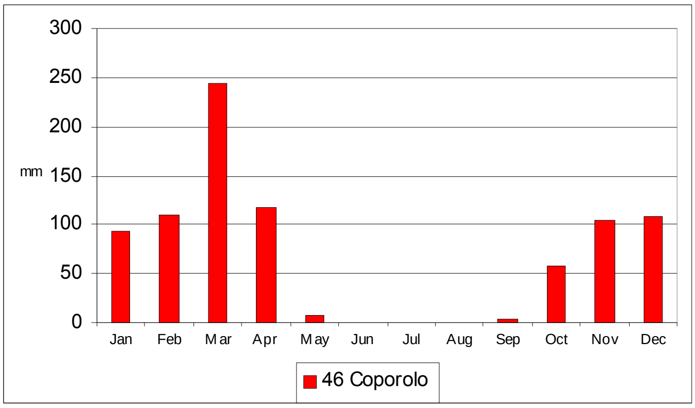
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6046	
Coporolo	
Area in km²	
15239.2	
Perimeter in km	
666.7	
Elevation (m.a.s.l)	
Mean	Maximum
908	2406



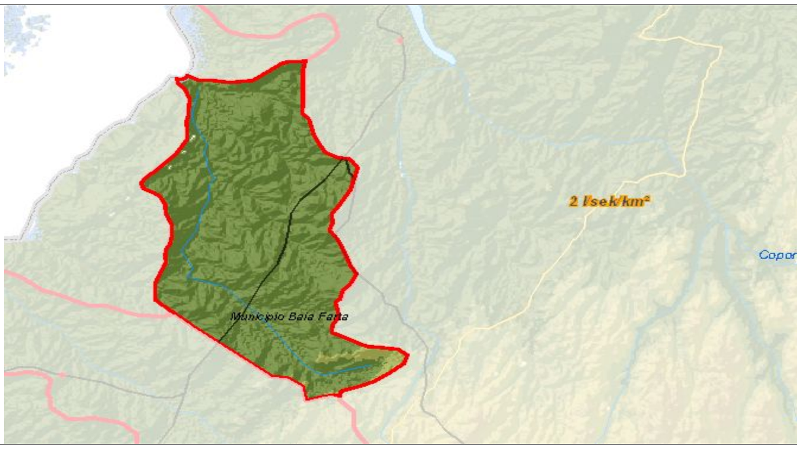
Annual mean discharge m³/s (Q)	
70.0	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*4.6*
Max	9.2
Min	1.1



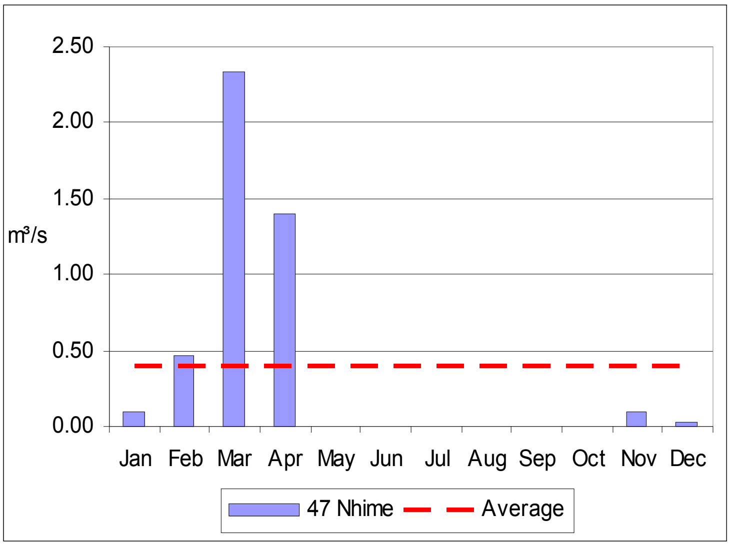
Annual precipitation in mm
846

Population and Water use				
	2000	2005	2015	2025
Population	32439	42728	49812	56258
Water use (m³/day)	538	740	1707	2045
Water use (m³/s)	0.006	0.009	0.020	0.024

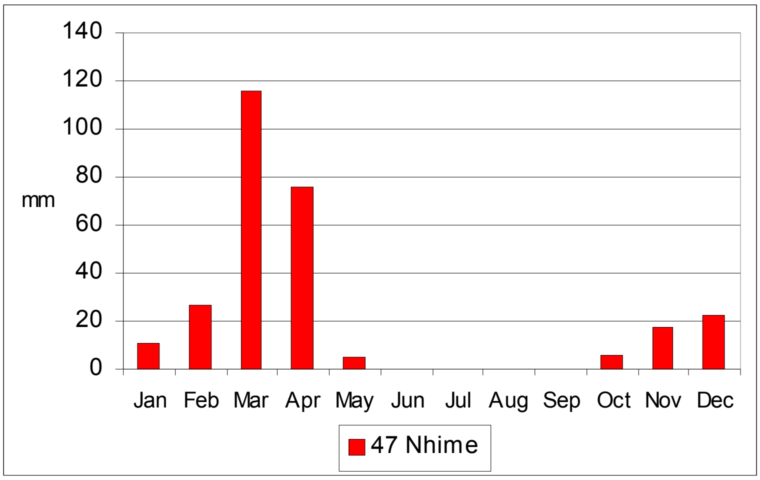
Animal Watering and Irrigation					
	2002	2005	2015	2025	Existing water deficit
					NO
Water use (m³/day)	75324	278284	1851859	1924125	Future water deficit
Water use (m³/s)	0.9	3.2	21.4	22.3	YES



6047	
Nhime	
Area in km²	
269.9	
Perimeter in km	
82.9	
Elevation (m.a.s.l)	
Mean	Maximum
287	551



Annual mean discharge m^3/s (Q)	
0.40	
Annual mean specific discharge (q) $l\ s^{-1}\ km^{-2}$	
Mean	*1.5*
Max	1.9
Min	1.2

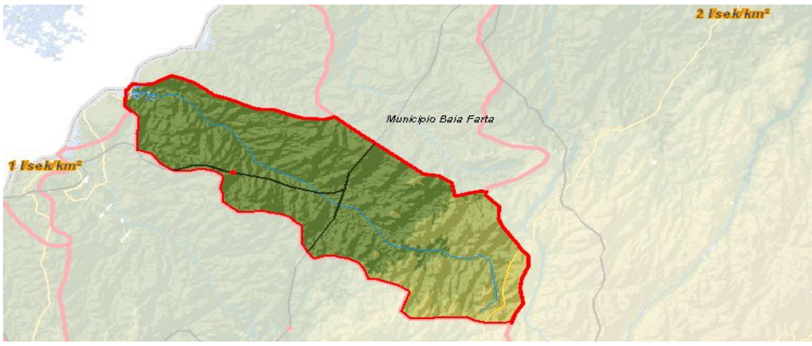


Annual precipitation in mm
280

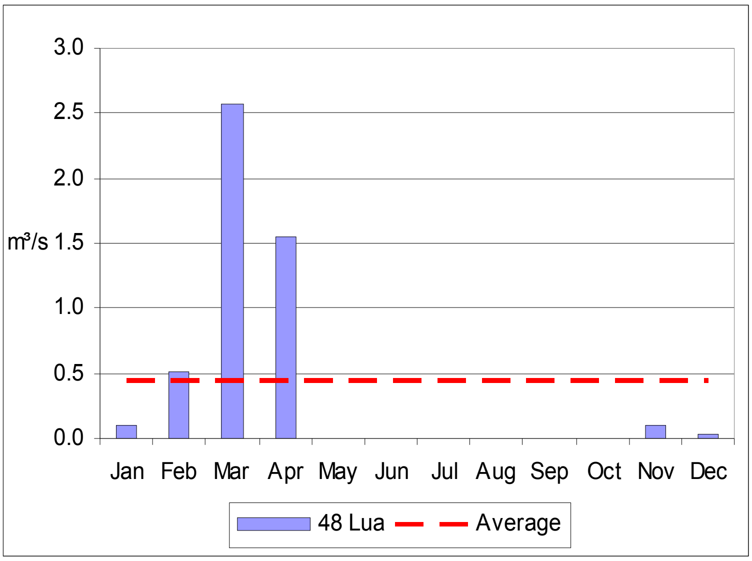
Population and Water use	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

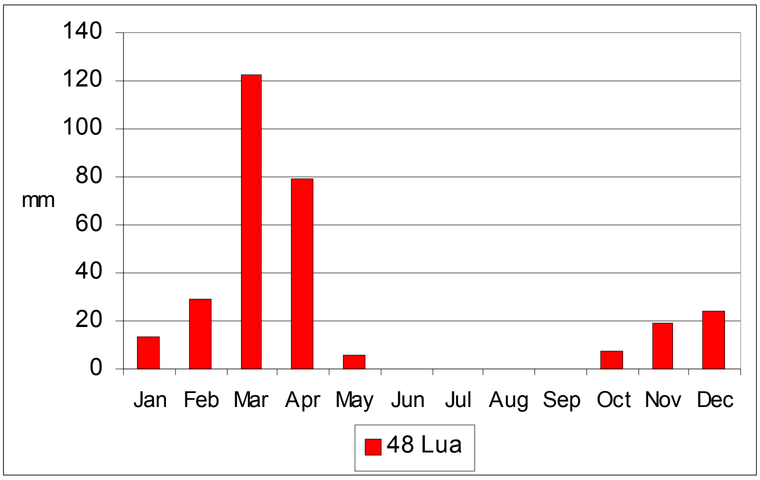
Existing water deficit
NO
Future water deficit
NO



6048	
Lua	
Area in km²	
290.1	
Perimeter in km	
87.5	
Elevation (m.a.s.l)	
Mean	Maximum
361	713



Annual mean discharge m³/s (Q)	
0.4	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.5*
Max	2.1
Min	1.0

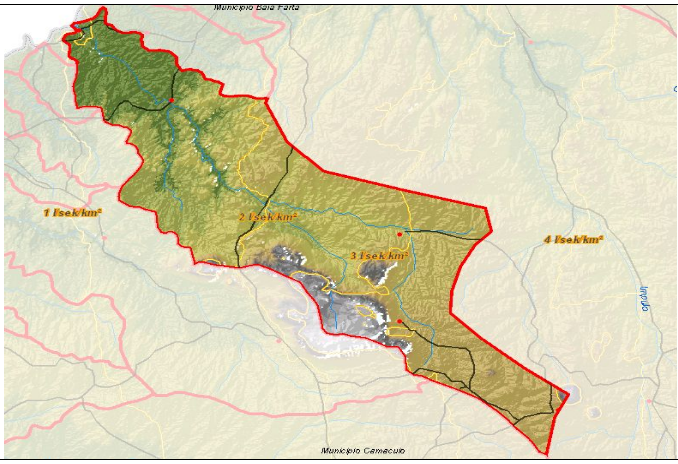


Annual precipitation in mm
300

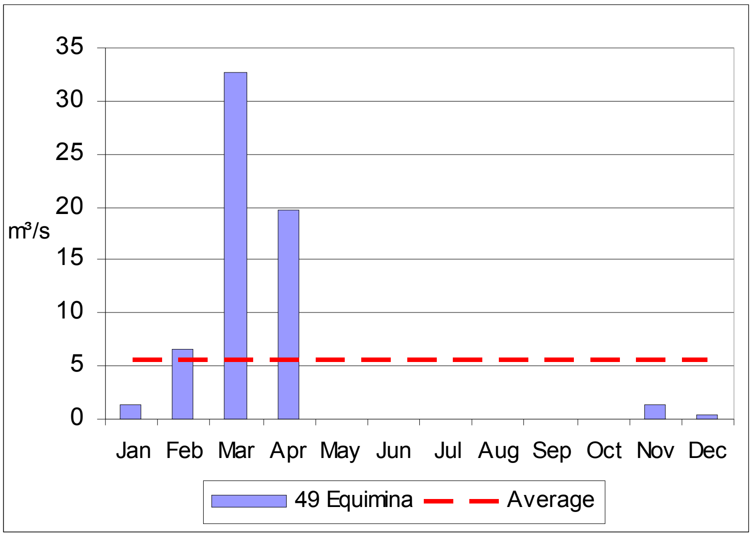
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

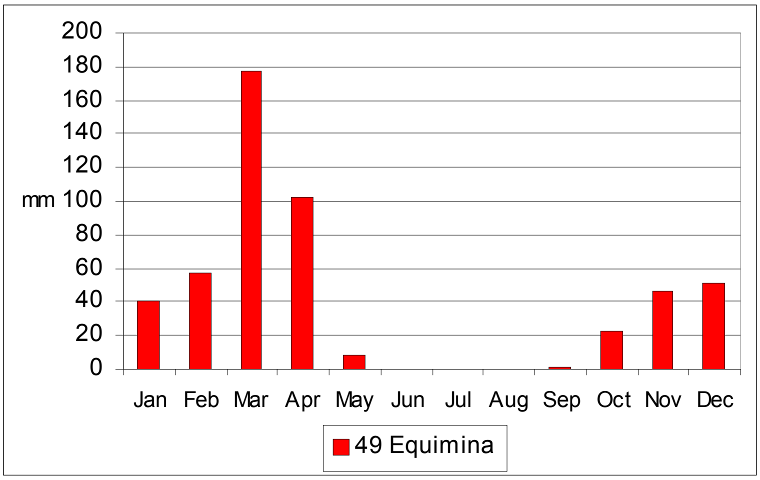
Existing water deficit
NO
Future water deficit
NO



6049	
Equimina	
Area in km²	
2371.3	
Perimeter in km	
308.4	
Elevation (m.a.s.l)	
Mean	Maximum
718	2354



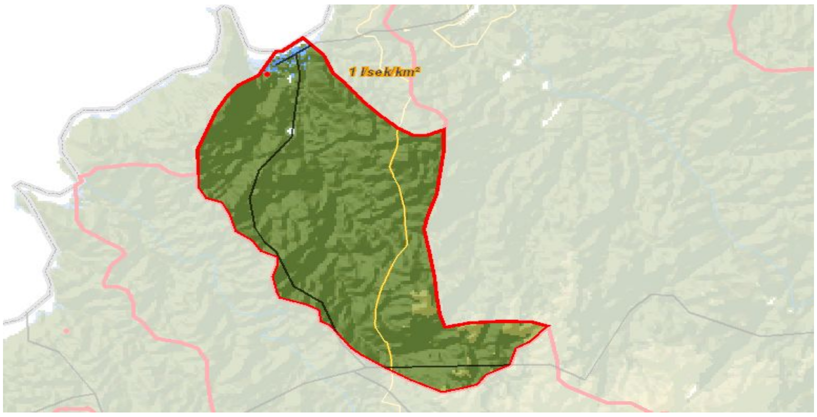
Annual mean discharge m³/s (Q)	
5.6	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*2.4*
Max	4.4
Min	0.9



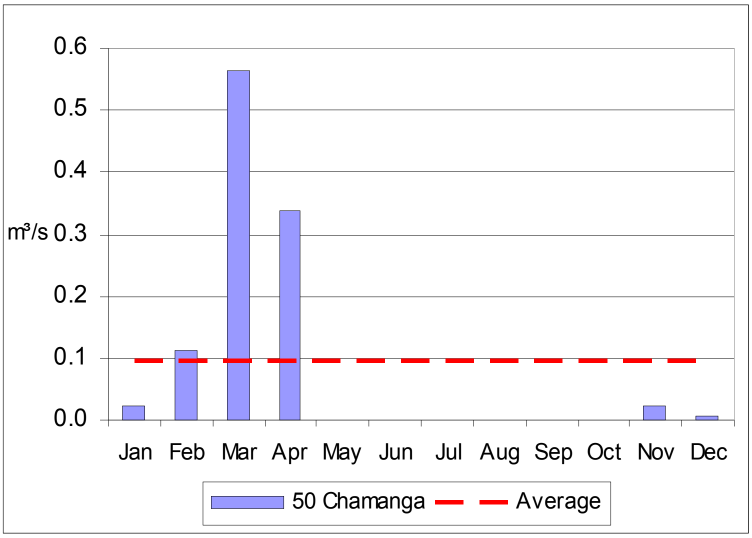
Annual precipitation in mm
506

Population and Water use				
	2000	2005	2015	2025
Population	1660	1901	2539	3418
Water use (m³/day)	25	29	76	103
Water use (m³/s)	0.000	0.000	0.001	0.001

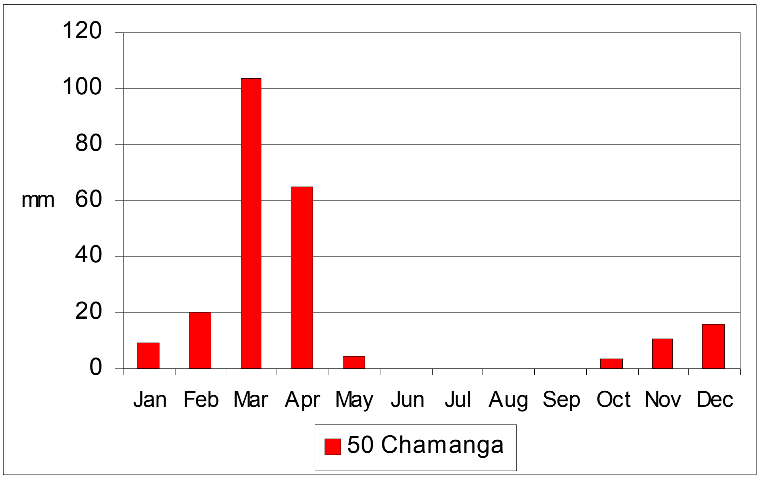
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	YES
Water use (m³/day)	12720	14787	94828	101881	Future water deficit
Water use (m³/s)	0.1	0.2	1.1	1.2	YES



6050	
Chamanga	
Area in km²	
101.6	
Perimeter in km	
50.0	
Elevation (m.a.s.l)	
Mean	Maximum
265	559



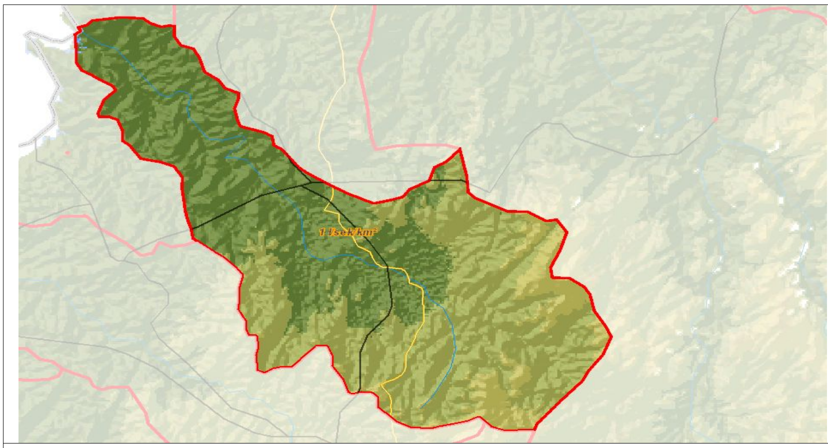
Annual mean discharge m³/s (Q)	
0.10	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*0.9*
Max	1.1
Min	0.8



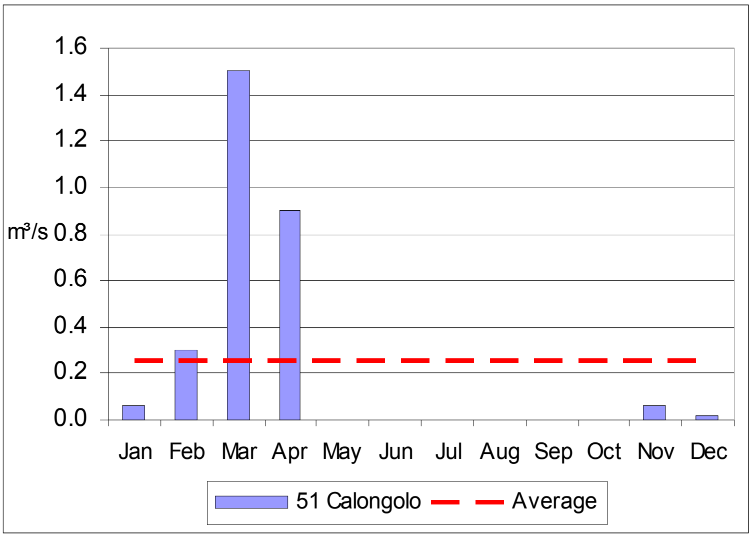
Annual precipitation in mm	
233	

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

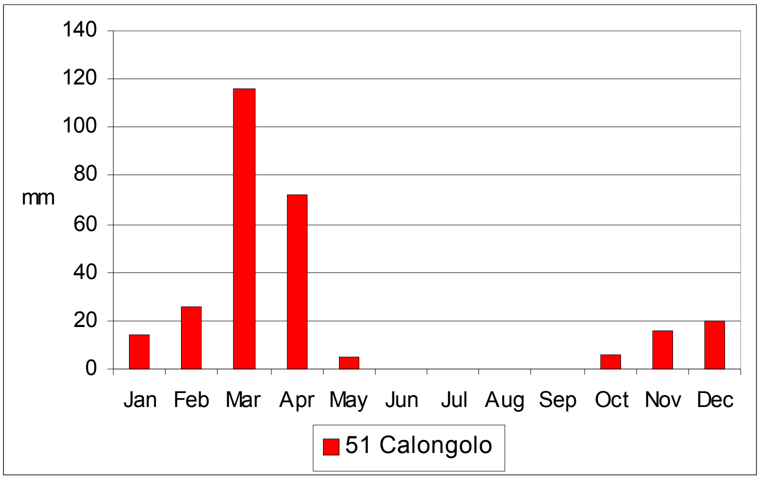
Animal Watering and Irrigation					
	2002	2005	2015	2025	Existing water deficit
					NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6051	
Calongolo	
Area in km²	
255.9	
Perimeter in km	
90.1	
Elevation (m.a.s.l)	
Mean	Maximum
434	661



Annual mean discharge m³/s (Q)	
0.26	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.0*
Max	1.3
Min	0.7

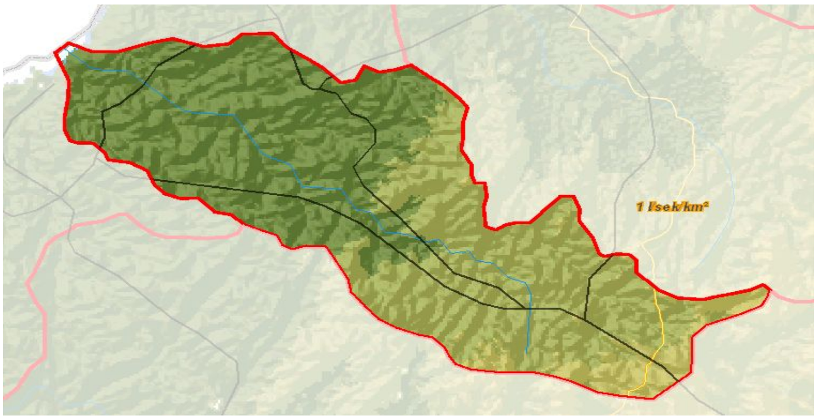


Annual precipitation in mm
275

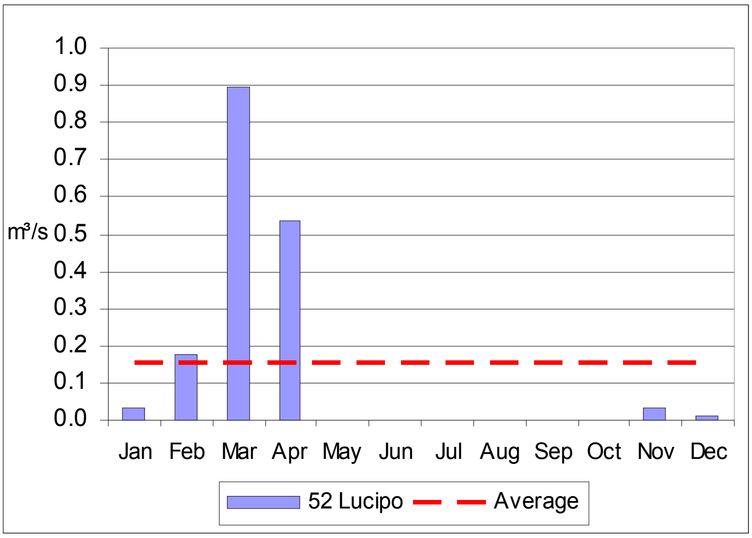
Population and Water use				
	2000	2005	2015	2025
Population	830	950	1270	1709
Water use (m³/day)	12	14	38	51
Water use (m³/s)	0.000	0.000	0.000	0.001

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

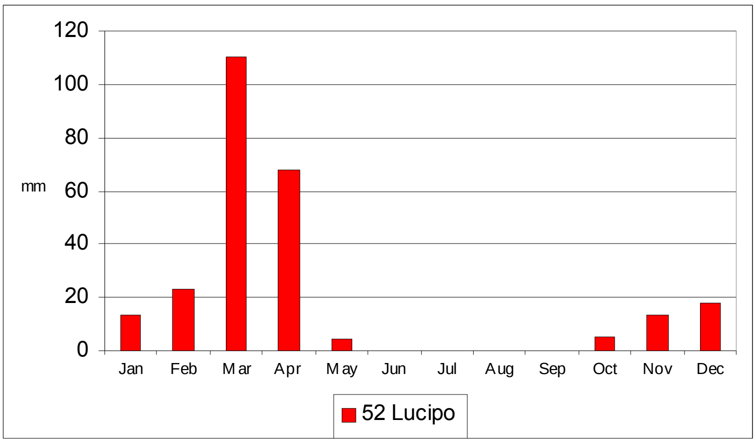
Existing water deficit
YES
Future water deficit
YES



6052	
Lucipo	
Area in km²	
189.7	
Perimeter in km	
77.7	
Elevation (m.a.s.l)	
Mean	Maximum
434	674



Annual mean discharge m³/s (Q)	
0.15	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.8*
Max	1.1
Min	0.6

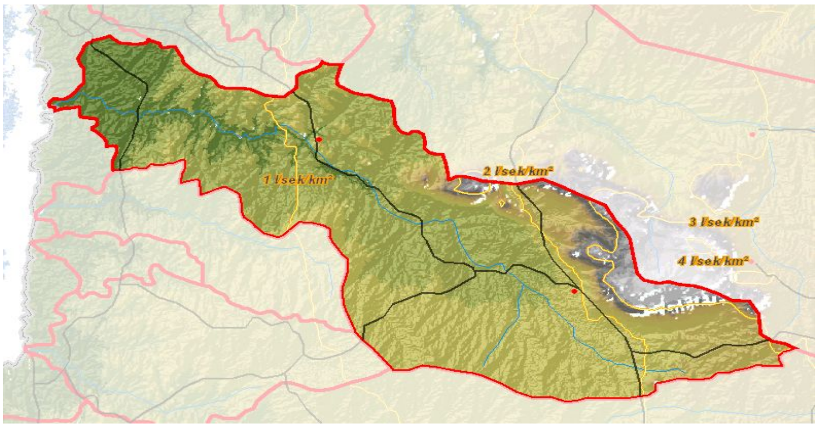


Annual precipitation in mm
256

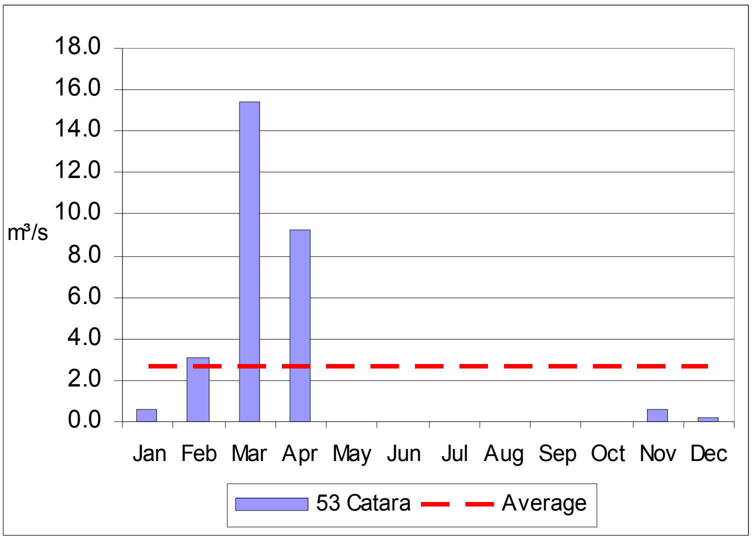
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

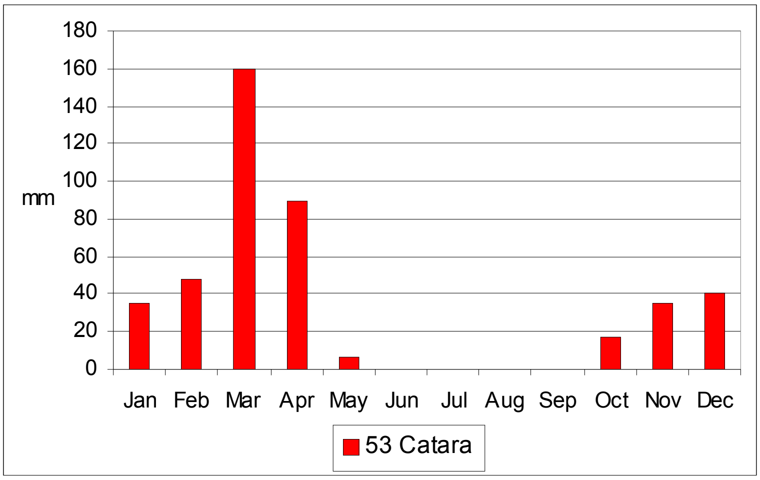
Existing water deficit
NO
Future water deficit
NO



6053	
Catara	
Area in km²	
1732.9	
Perimeter in km	
253.5	
Elevation (m.a.s.l)	
Mean	Maximum
648	2479



Annual mean discharge m³/s (Q)	
2.64	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.5*
Max	3.8
Min	0.5

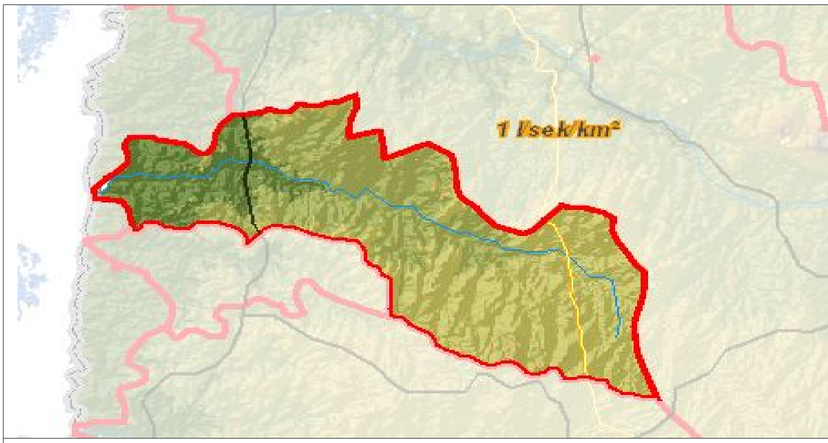


Annual precipitation in mm
433

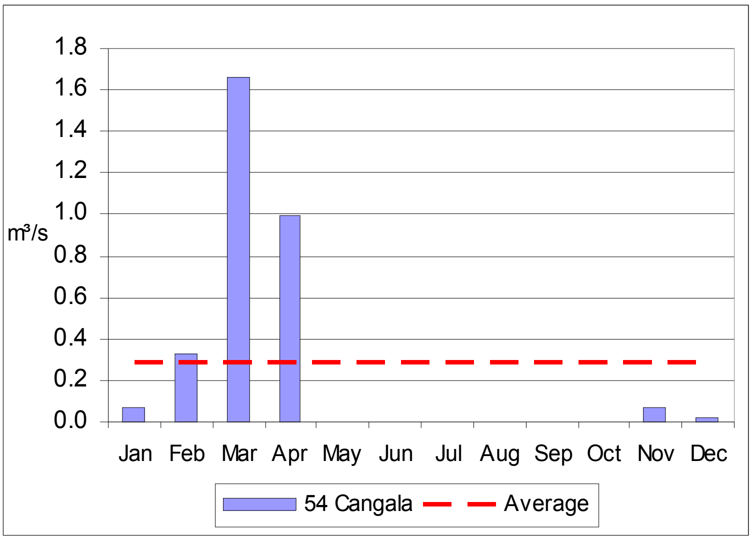
Population and Water use				
	2000	2005	2015	2025
Population	4760	5200	7000	9320
Water use (m³/day)	71	78	210	280
Water use (m³/s)	0.001	0.001	0.002	0.003

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

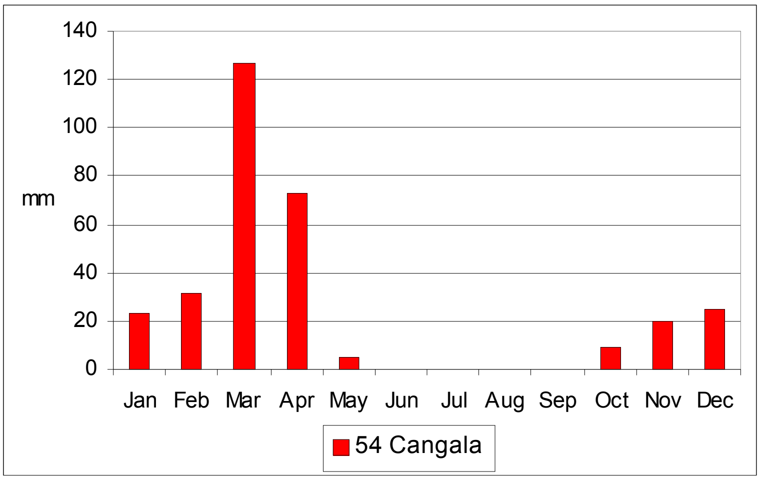
Existing water deficit
YES
Future water deficit
YES



6054	
Cangala	
Area in km²	
362.9	
Perimeter in km	
115.1	
Elevation (m.a.s.l)	
Mean	Maximum
547	827



Annual mean discharge m³/s (Q)	
0.28	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*0.8*
Max	1.1
Min	0.4

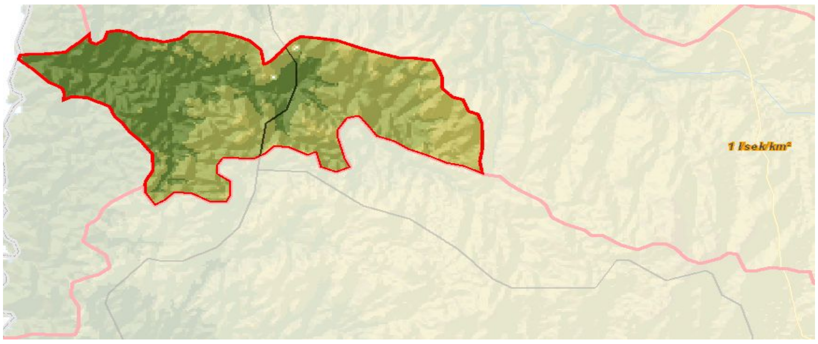


Annual precipitation in mm
312

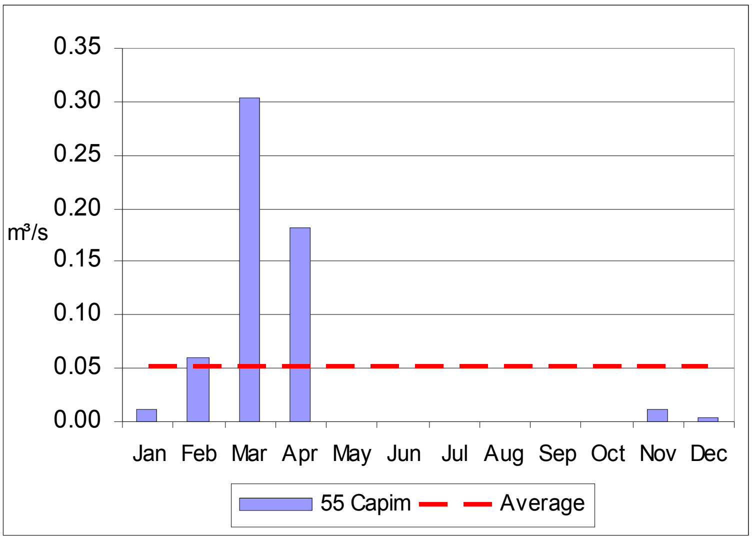
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

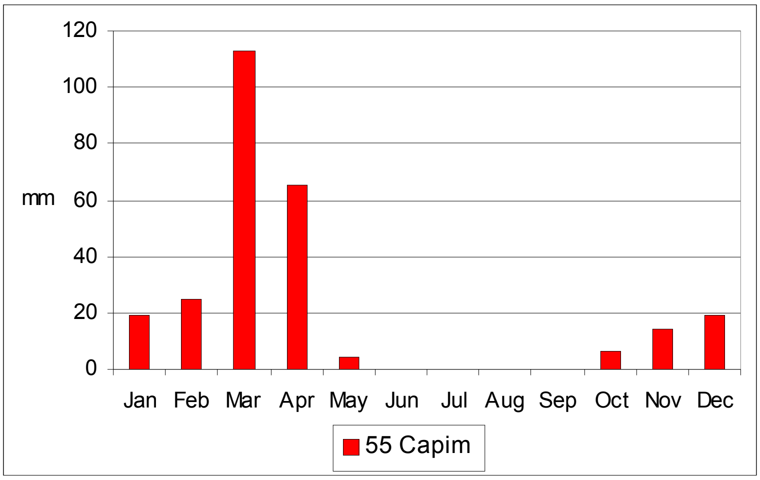
Existing water deficit
NO
Future water deficit
NO



6055	
Capim	
Area in km²	
98.4	
Perimeter in km	
60.9	
Elevation (m.a.s.l)	
Mean	Maximum
470	657
Annual mean discharge m^3/s (Q)	
0.05	
Annual mean specific discharge (q) $l\ s^{-1}\ km^{-2}$	
Mean	*0.5*
Max	0.7
Min	0.4

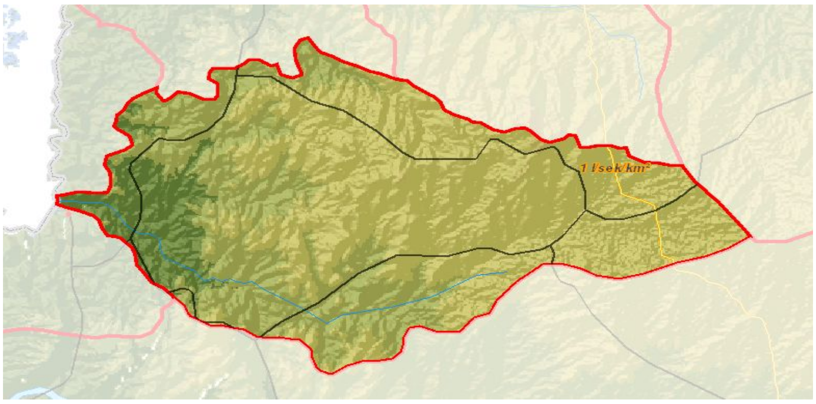


Annual precipitation in mm
266

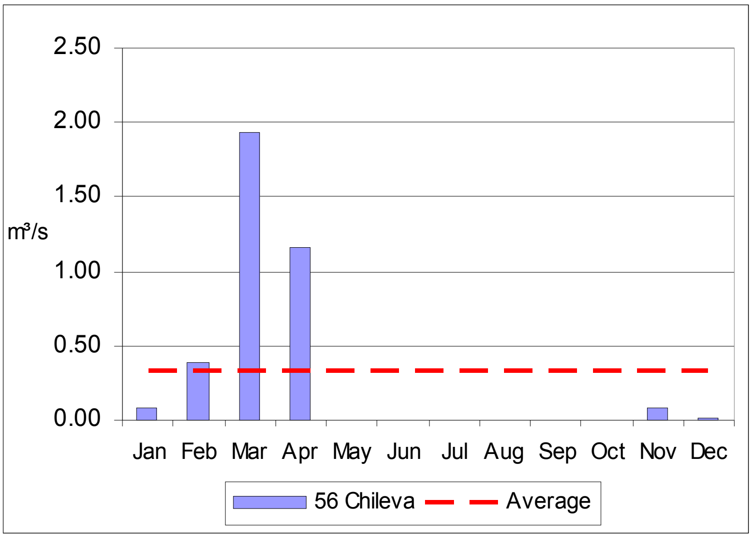


Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m^3/day)				
Water use (m^3/s)				

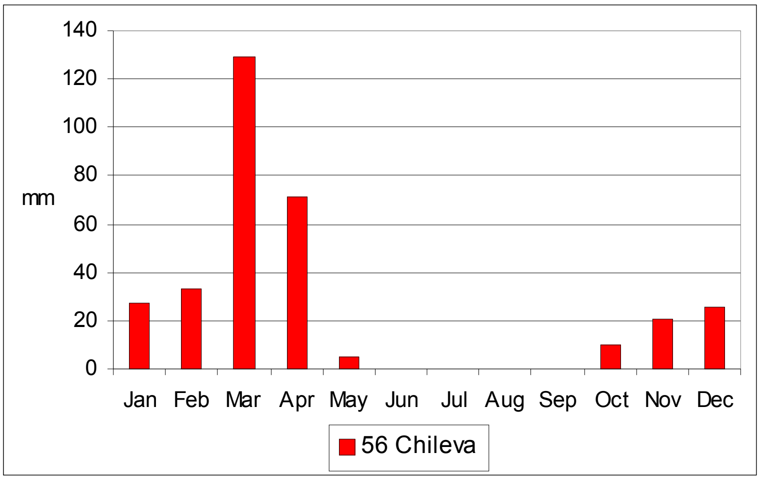
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m^3/day)					Future water deficit
Water use (m^3/s)					NO



6056	
Chileva	
Area in km²	
540.2	
Perimeter in km	
117.6	
Elevation (m.a.s.l)	
Mean	Maximum
578	767



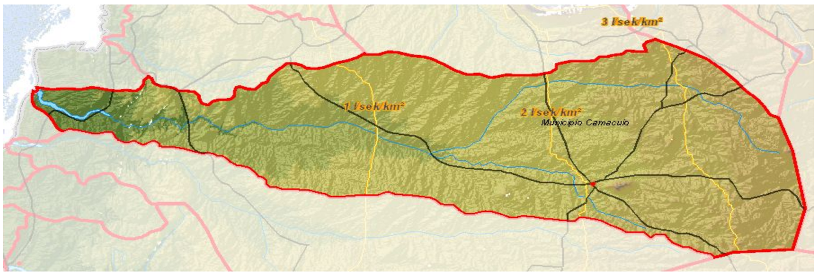
Annual mean discharge m³/s (Q)	
0.33	
Annual mean specific discharge (q) $l\ s^{-1}\ km^{-2}$	
Mean	*0.6*
Max	1.1
Min	0.3



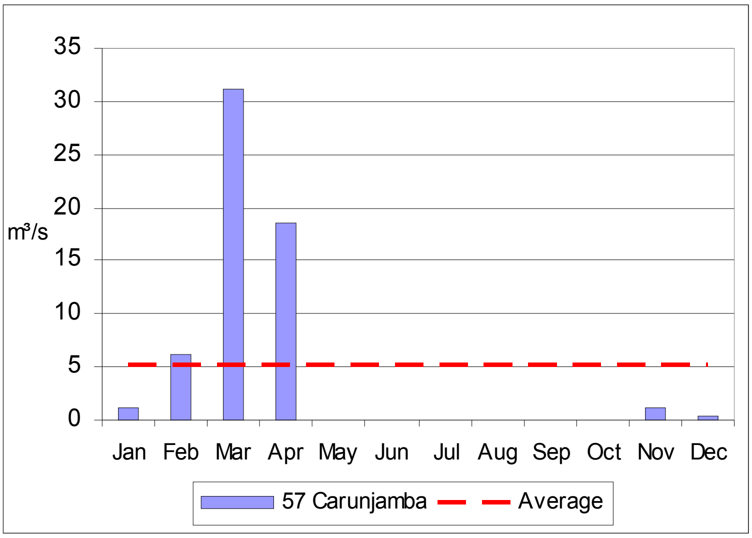
Annual precipitation in mm
322

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

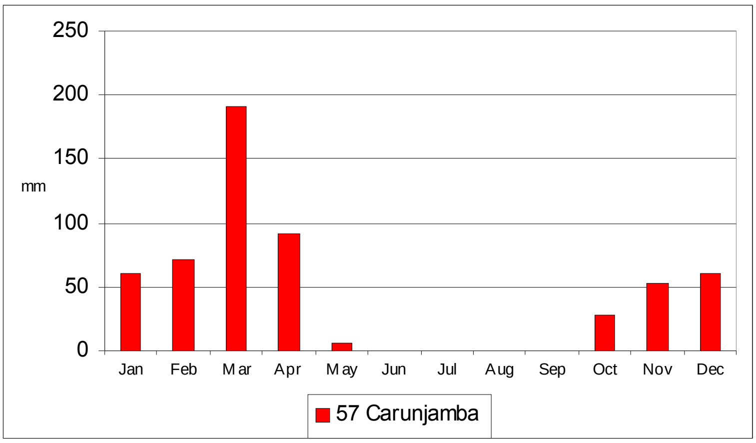
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6057	
Carunjamba	
Area in km²	
2930.6	
Perimeter in km	
304.6	
Elevation (m.a.s.l)	
Mean	Maximum
664	1230



Annual mean discharge m³/s (Q)	
5.32	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.8*
Max	3.8
Min	0.2

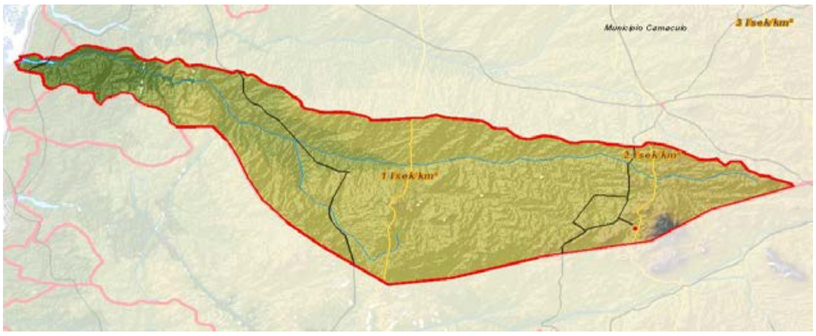


Annual precipitation in mm
560

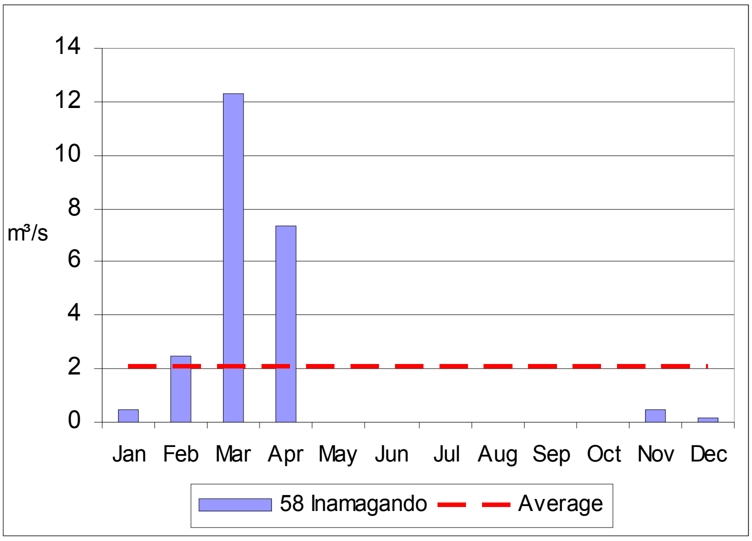
Population and Water use				
	2000	2005	2015	2025
Population	7140	7800	10500	13980
Water use (m³/day)	107	117	315	419
Water use (m³/s)	0.001	0.001	0.004	0.005

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)			27315	72385
Water use (m³/s)	0.0	0.0	0.3	0.8

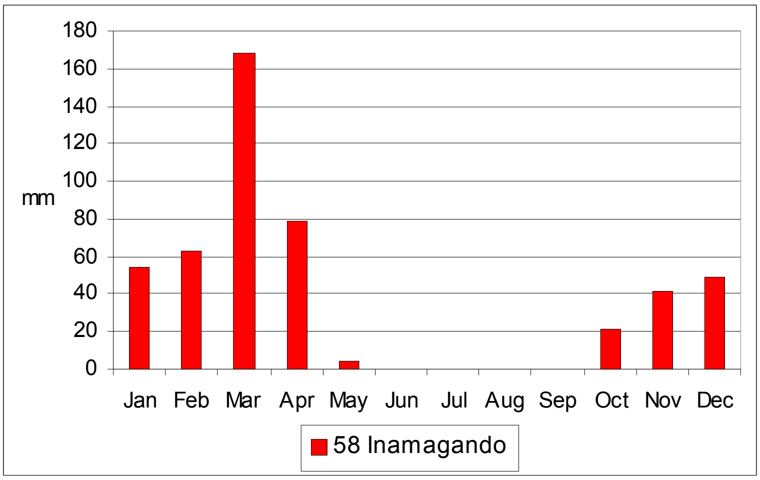
Existing water deficit
YES
Future water deficit
YES



6058	
Inamagando	
Area in km²	
1859.0	
Perimeter in km	
262.9	
Elevation (m.a.s.l)	
Mean	Maximum
623	1477



Annual mean discharge m³/s (Q)	
2.10	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.1*
Max	3.0
Min	0.1

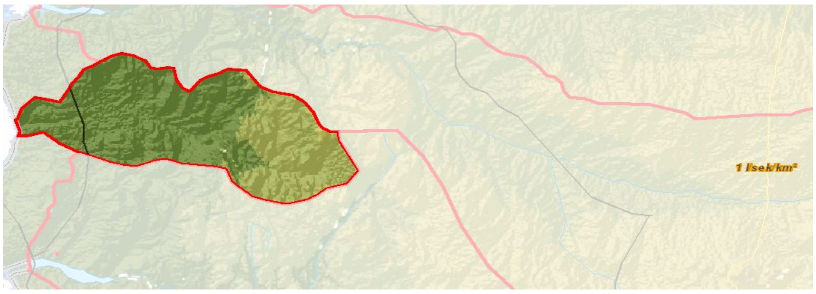


Annual precipitation in mm
479

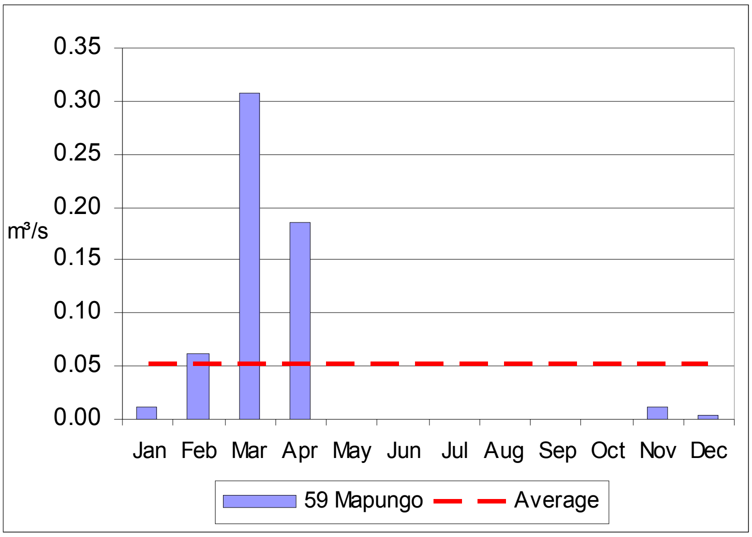
Population and Water use				
	2000	2005	2015	2025
Population	4760	5200	7000	9320
Water use (m³/day)	71	78	210	280
Water use (m³/s)	0.001	0.001	0.002	0.003

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)			13658	27315
Water use (m³/s)	0.0	0.0	0.2	0.3

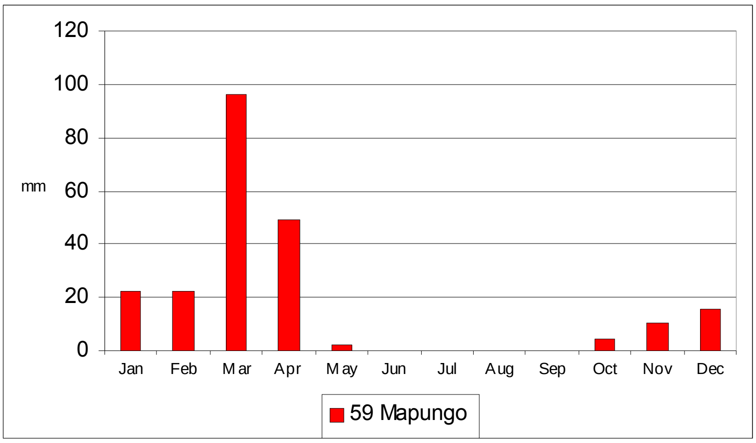
Existing water deficit
YES
Future water deficit
YES



6059	
Mapungo	
Area in km²	
210.2	
Perimeter in km	
70.0	
Elevation (m.a.s.l)	
Mean	Maximum
293	673



Annual mean discharge m³/s (Q)	
0.05	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*0.3*
Max	0.4
Min	0.2

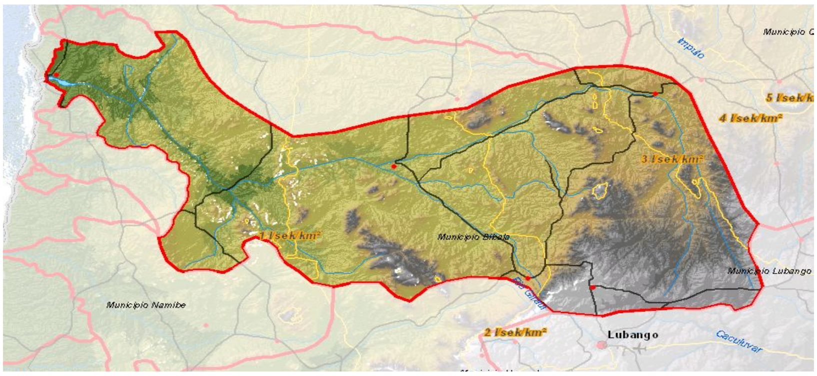


Annual precipitation in mm
222

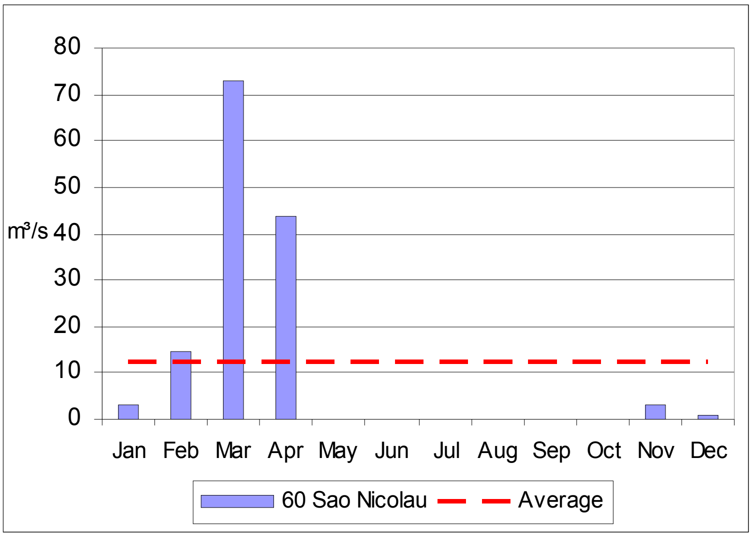
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

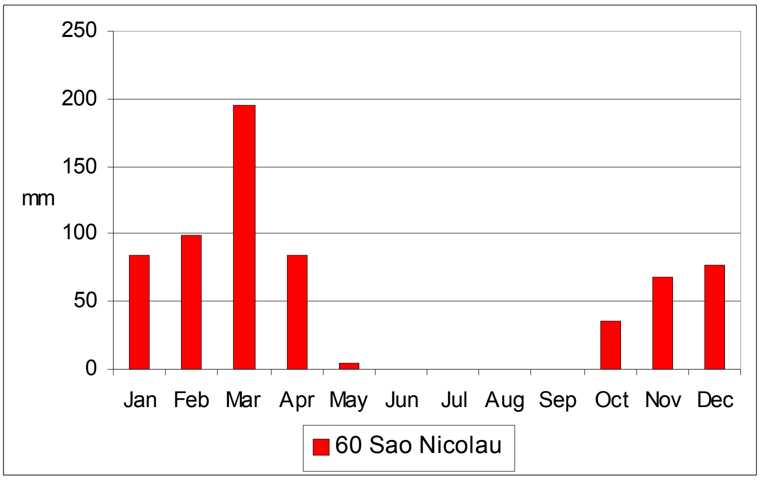
Existing water deficit
NO
Future water deficit
NO



6060	
Bentiaba	
Area in km²	
6934.8	
Perimeter in km	
471.6	
Elevation (m.a.s.l)	
Mean	Maximum
873	2325



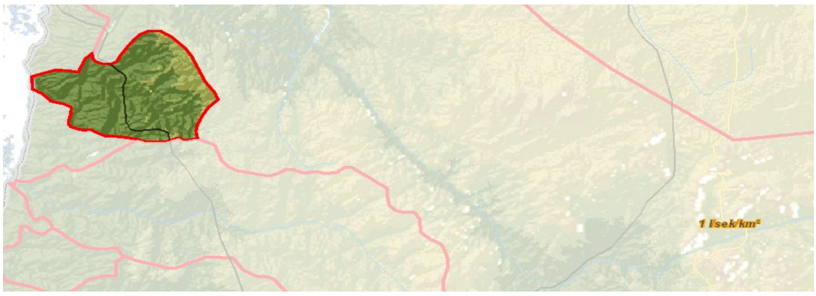
Annual mean discharge m³/s (Q)	
12.44	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.8*
Max	3.7
Min	0.2



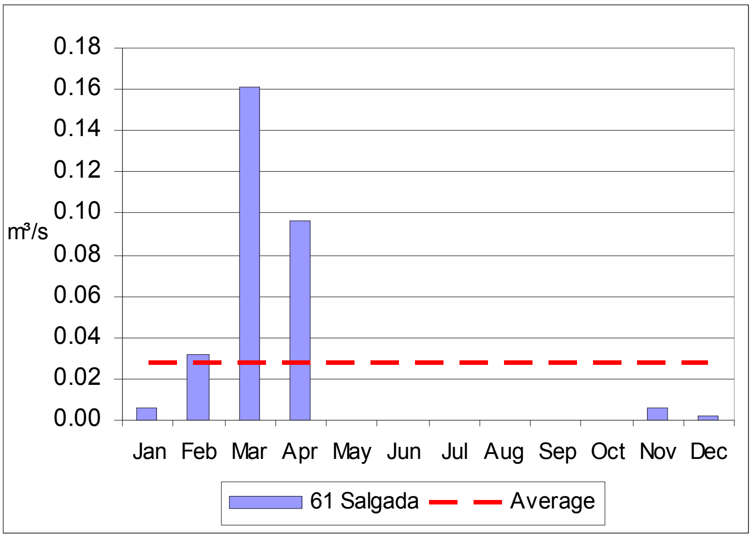
Annual precipitation in mm
648

Population and Water use				
	2000	2005	2015	2025
Population	21420	23400	31500	41940
Water use (m³/day)	321	351	945	1258
Water use (m³/s)	0.004	0.004	0.011	0.015

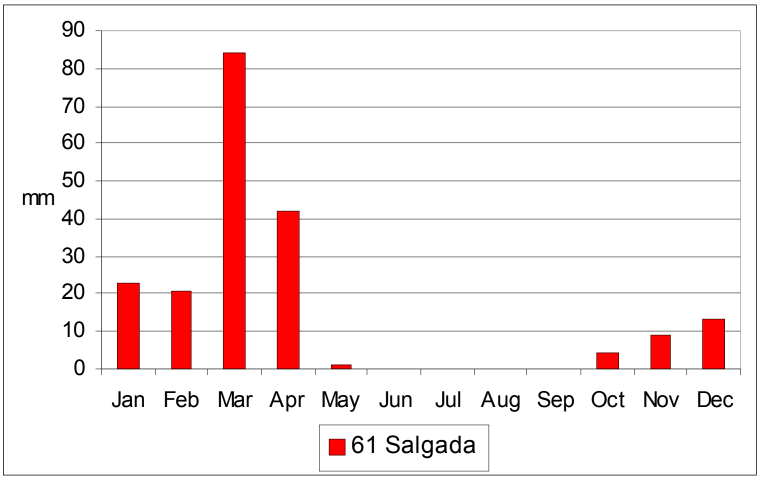
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	YES
Water use (m³/day)	7735	15460	21150	26831	Future water deficit
Water use (m³/s)	0.1	0.2	0.2	0.3	YES



6061	
Salgada	
Area in km²	
100.3	
Perimeter in km	
44.1	
Elevation (m.a.s.l)	
Mean	Maximum
333	514



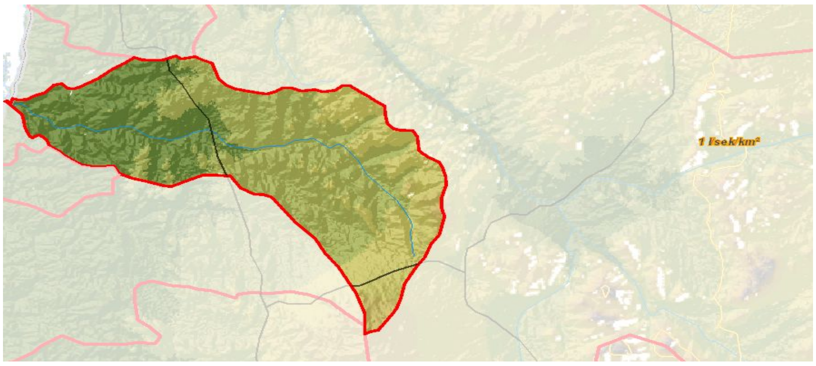
Annual mean discharge m³/s (Q)	
0.03	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.3*
Max	0.3
Min	0.2



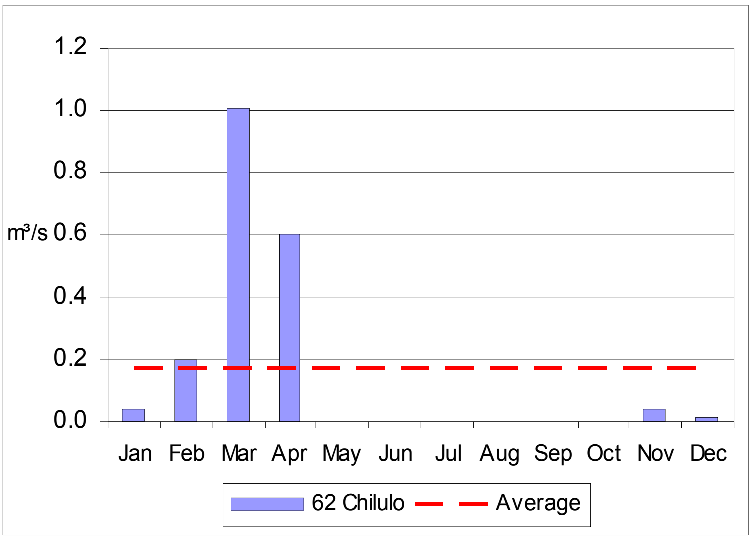
Annual precipitation in mm
199

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

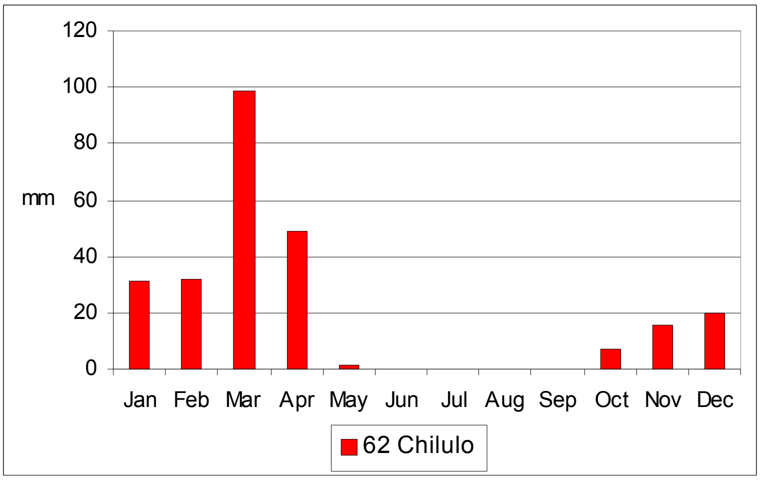
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6062	
Chilulo/Chapén Armado	
Area in km²	
401.1	
Perimeter in km	
104.6	
Elevation (m.a.s.l)	
Mean	Maximum
498	974



Annual mean discharge m³/s (Q)	
0.17	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*0.4*
Max	0.7
Min	0.2

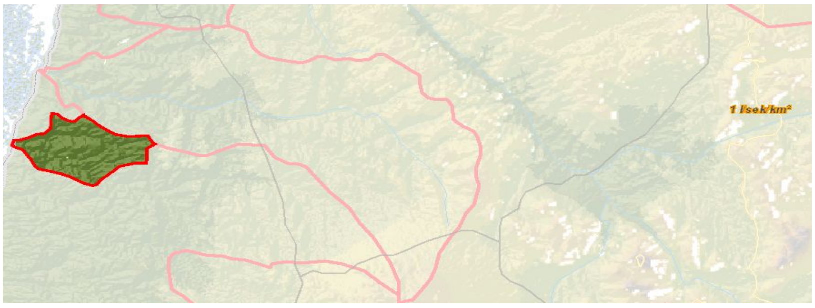


Annual precipitation in mm
255

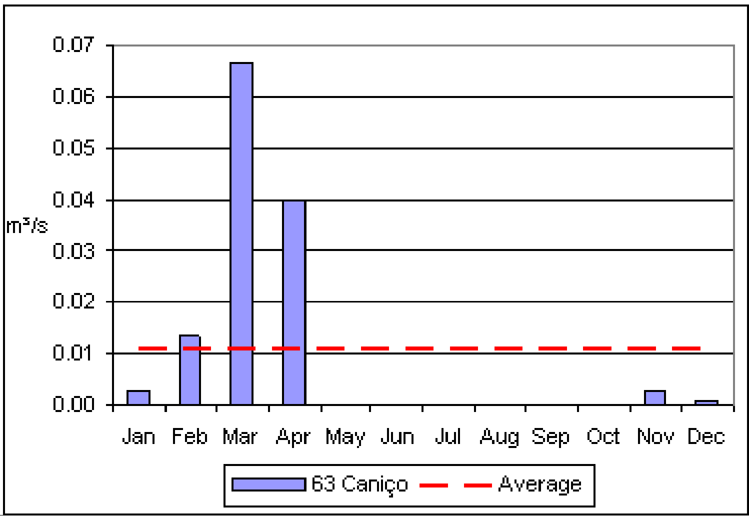
Population and Water use				
	2000	2005	2015	2025
Population	2380	2600	3500	4660
Water use (m³/day)	36	39	105	140
Water use (m³/s)	0.000	0.000	0.001	0.002

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

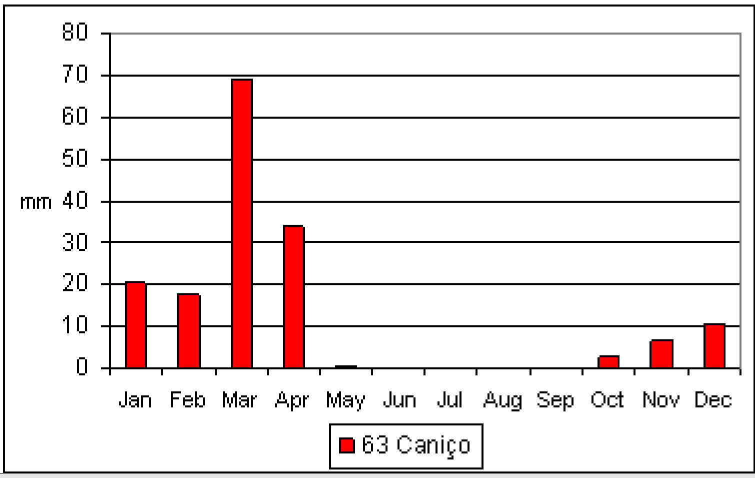
Existing water deficit
YES
Future water deficit
YES



6063	
Caniço	
Area in km²	
43.6	
Perimeter in km	
30.3	
Elevation (m.a.s.l)	
Mean	Maximum
254	455



Annual mean discharge m³/s (Q)	
0.01	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.3*
Max	0.3
Min	0.2

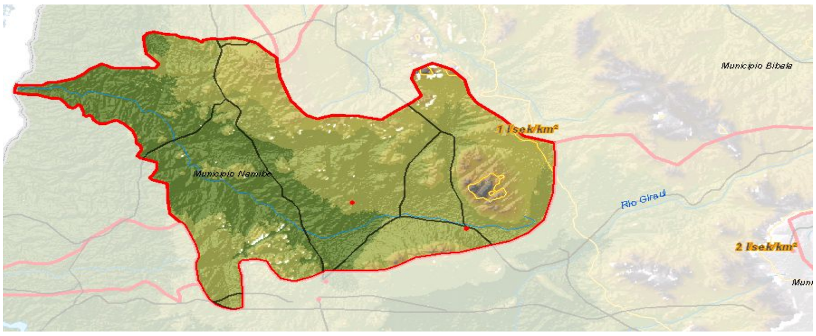


Annual precipitation in mm	
162	

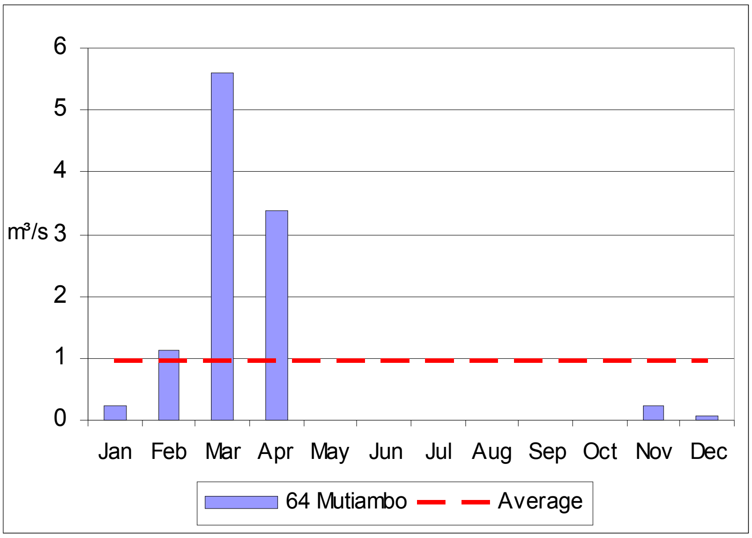
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

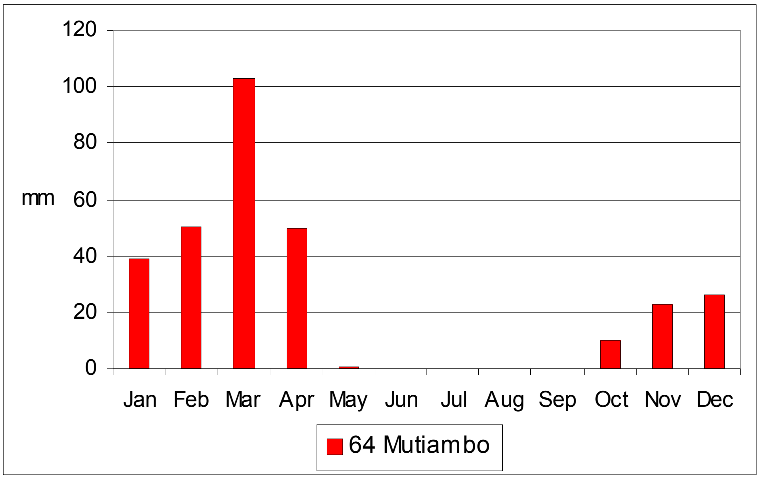
Existing water deficit	
NO	
Future water deficit	
NO	



6064	
Mutiambo	
Area in km²	
1732.1	
Perimeter in km	
233.0	
Elevation (m.a.s.l)	
Mean	Maximum
521	1486



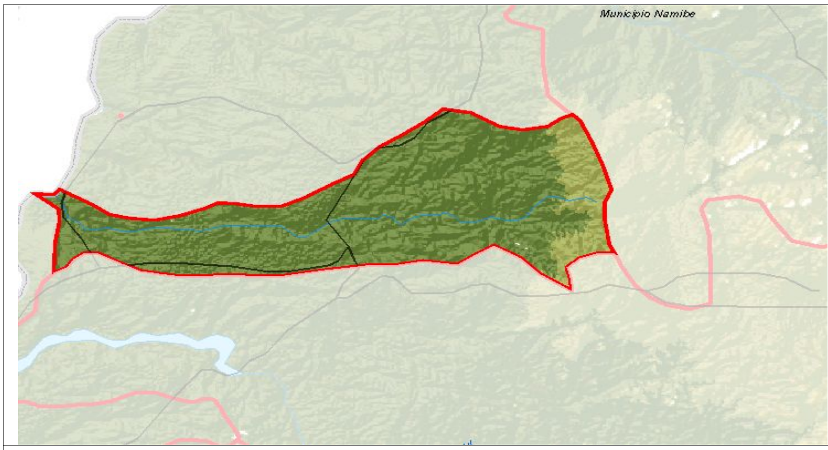
Annual mean discharge m³/s (Q)	
0.96	
Annual mean specific discharge (q) l s^{-1} km^{-2}	
Mean	*0.6*
Max	1.1
Min	0.2



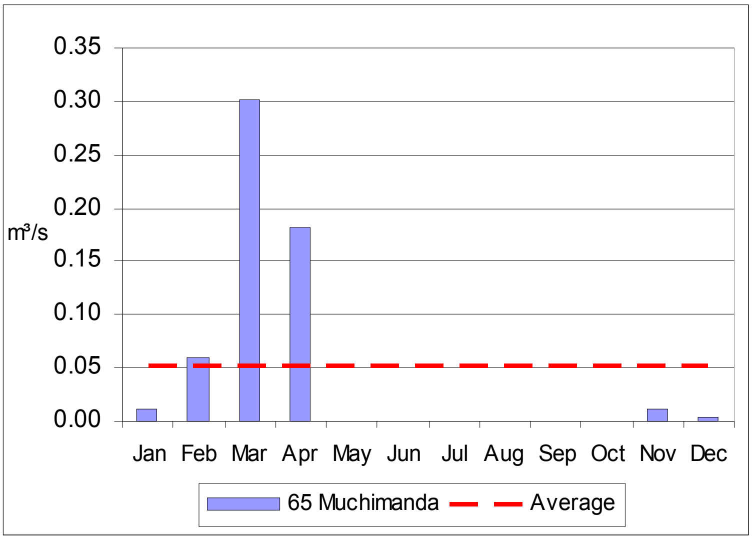
Annual precipitation in mm
303

Population and Water use				
	2000	2005	2015	2025
Population	9520	10400	14000	18640
Water use (m³/day)	143	156	420	559
Water use (m³/s)	0.002	0.002	0.005	0.006

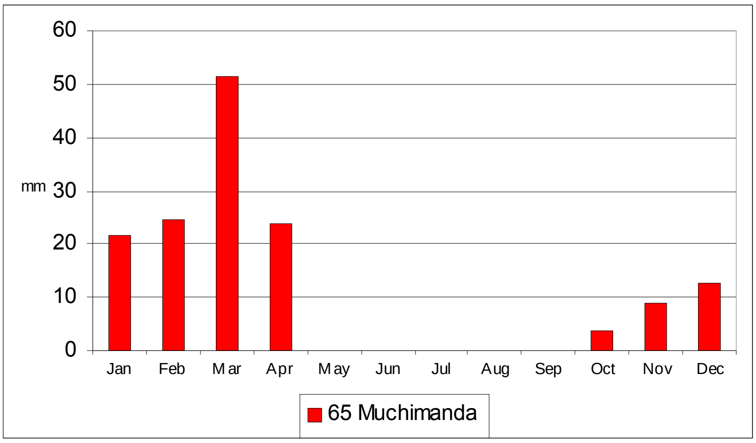
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	YES
Water use (m³/day)					Future water deficit
Water use (m³/s)					YES



6065	
Muchimanda	
Area in km²	
255.0	
Perimeter in km	
95.6	
Elevation (m.a.s.l)	
Mean	Maximum
315	552



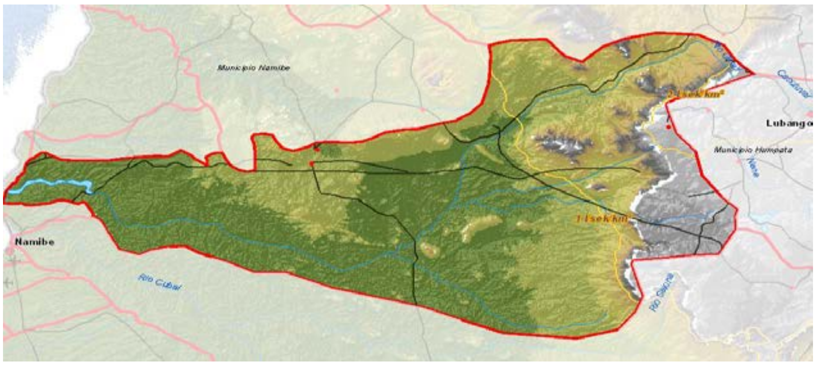
Annual mean discharge m³/s (Q)	
0.05	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.2*
Max	0.3
Min	0.1



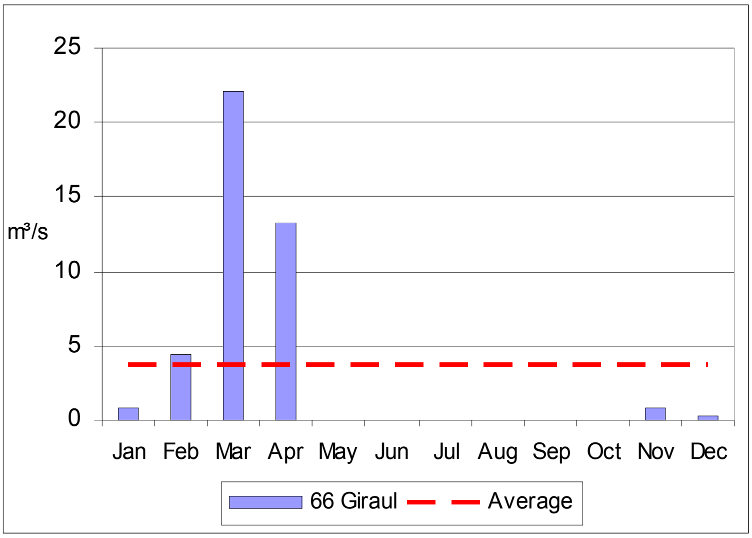
Annual precipitation in mm
147

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

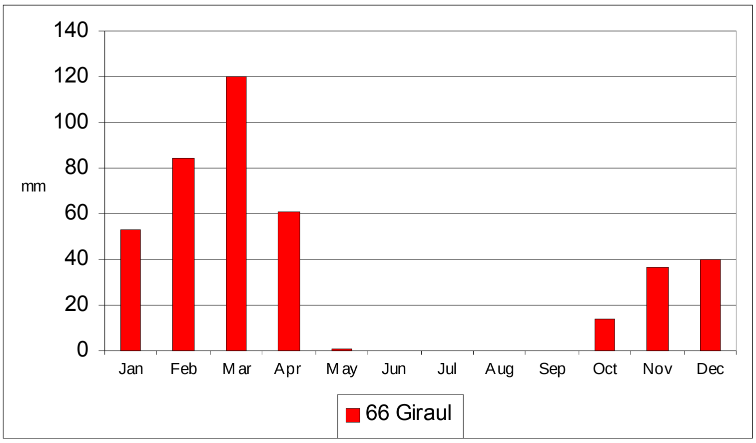
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6066	
Giraul	
Area in km²	
4708.8	
Perimeter in km	
393.4	
Elevation (m.a.s.l)	
Mean	Maximum
615	2322



Annual mean discharge m³/s (Q)	
3.78	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.8*
Max	2.5
Min	0.1

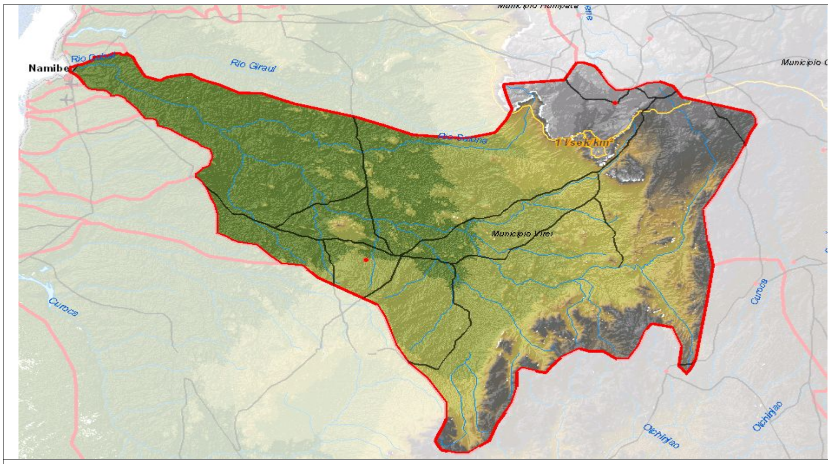


Annual precipitation in mm
409

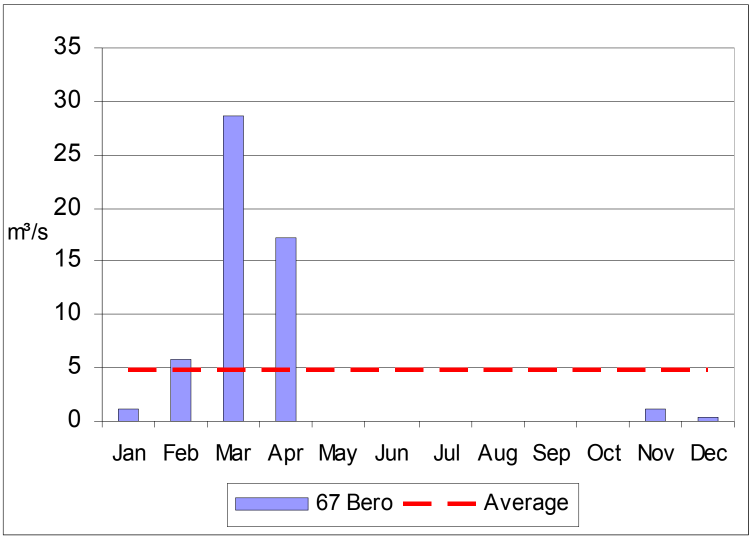
Population and Water use				
	2000	2005	2015	2025
Population	28318	32893	42105	53130
Water use (m³/day)	439	522	1324	1696
Water use (m³/s)	0.005	0.006	0.015	0.020

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	48998	74148	113152	169275
Water use (m³/s)	0.6	0.9	1.3	2.0

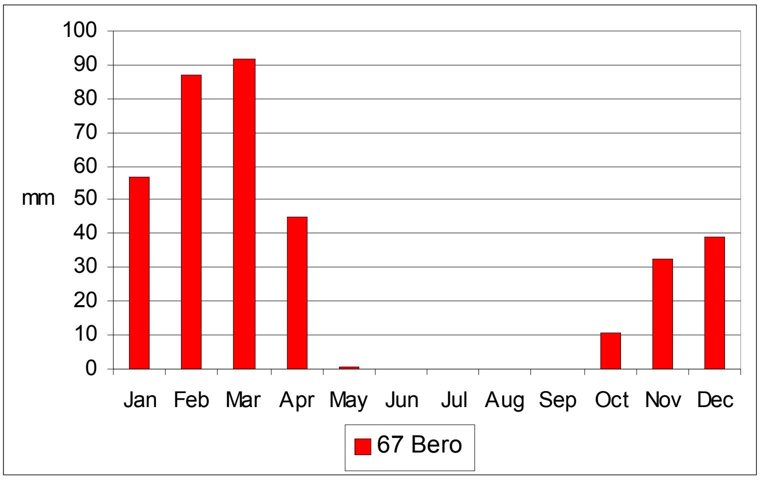
Existing water deficit
YES
Future water deficit
YES



6067	
Bero	
Area in km²	
10476.3	
Perimeter in km	
588.2	
Elevation (m.a.s.l)	
Mean	Maximum
718	2094



Annual mean discharge m³/s (Q)	
4.88	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.5*
Max	1.5
Min	0.1

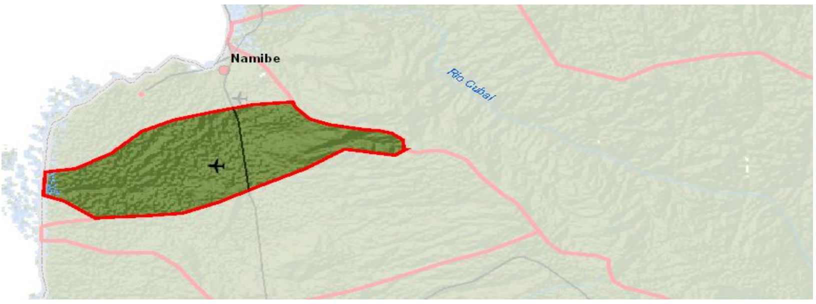


Annual precipitation in mm
364

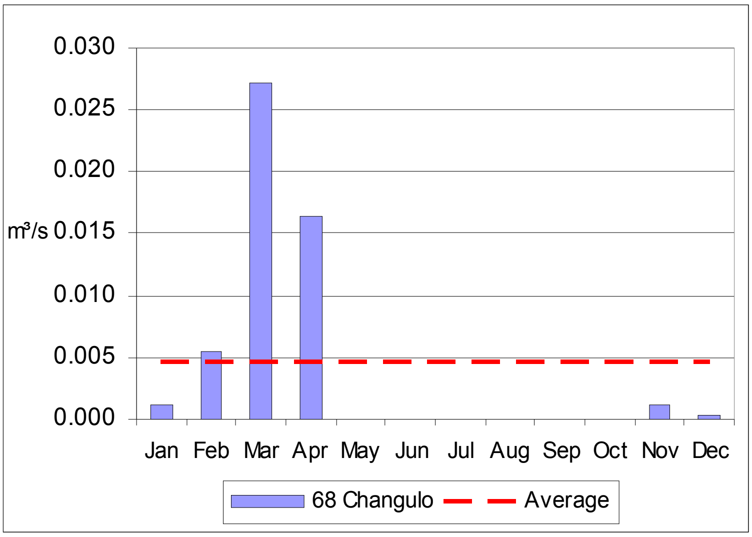
Population and Water use				
	2000	2005	2015	2025
Population	164319	204317	264722	344316
Water use (m³/day)	8711	11442	18296	30692
Water use (m³/s)	0.101	0.132	0.212	0.355

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	181667	347267	517914	690767
Water use (m³/s)	2.1	4.0	6.0	8.0

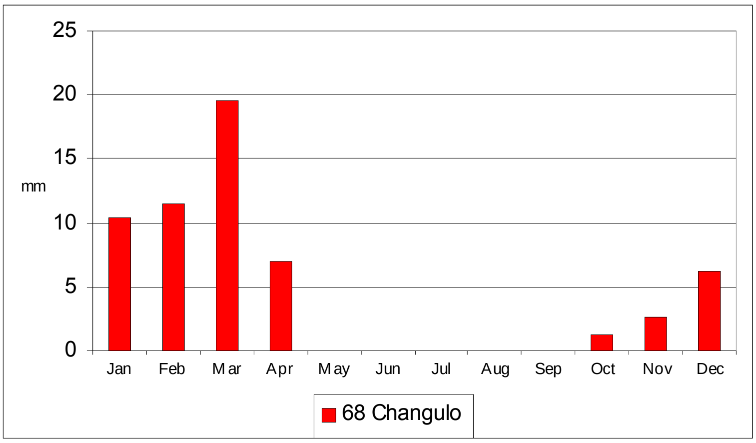
Existing water deficit
YES
Future water deficit
YES



6068	
Changulo	
Area in km²	
95.4	
Perimeter in km	
49.0	
Elevation (m.a.s.l)	
Mean	Maximum
74	267



Annual mean discharge m³/s (Q)	
0.005	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.05*
Max	0.1
Min	0.03

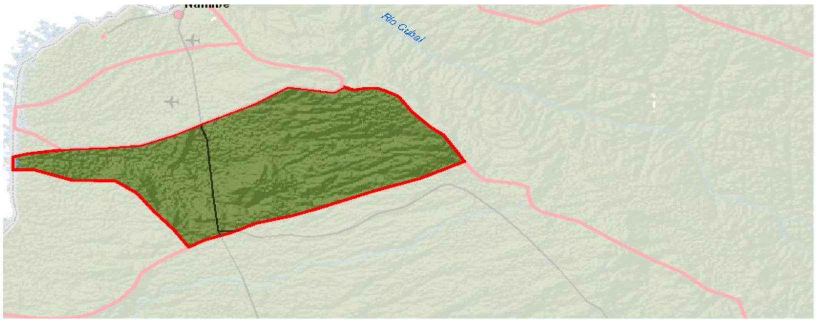


Annual precipitation in mm
59

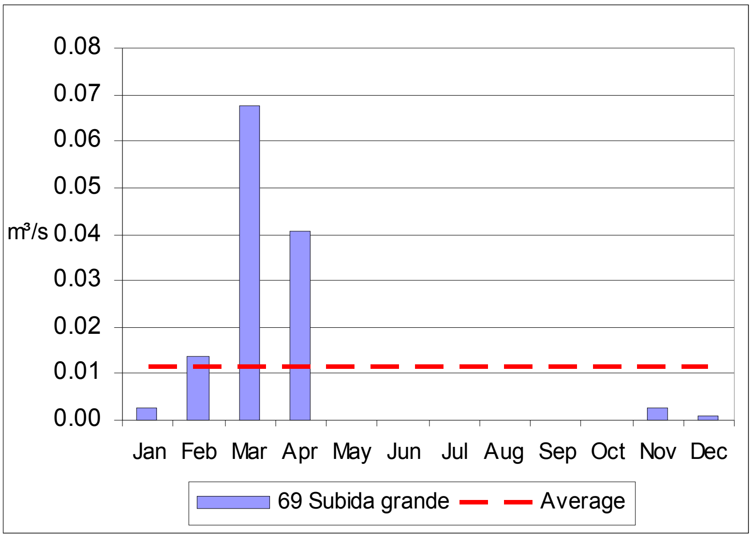
Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

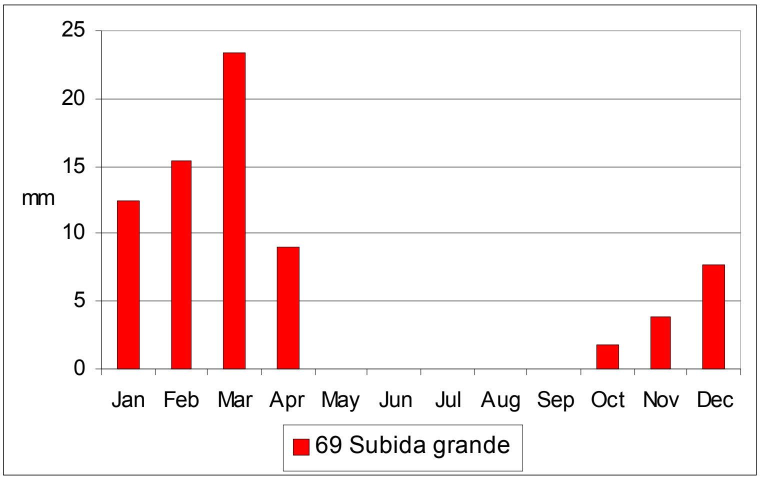
Existing water deficit
NO
Future water deficit
NO



6069	
Subida Grande	
Area in km²	
184.8	
Perimeter in km	
67.8	
Elevation (m.a.s.l)	
Mean	Maximum
177	348



Annual mean discharge m³/s (Q)	
0.01	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.1*
Max	0.1
Min	0.03

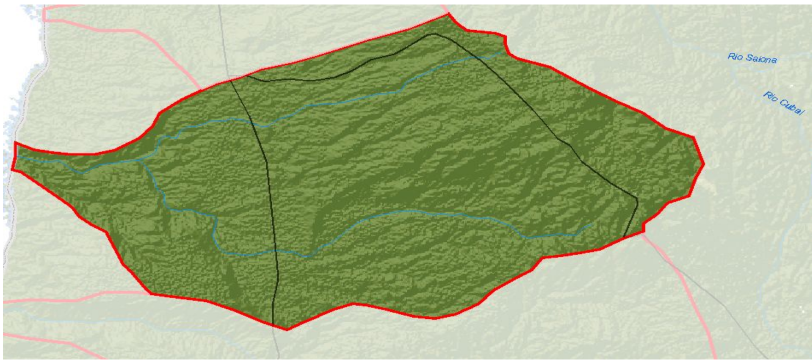


Annual precipitation in mm
74

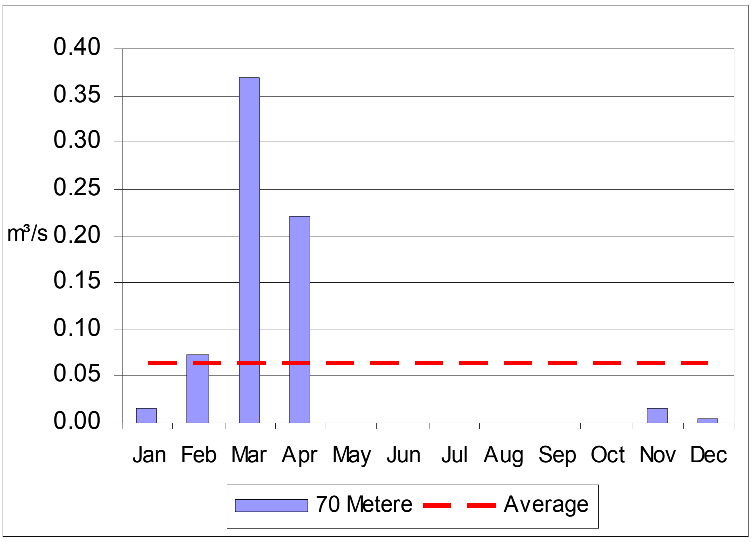
Population and Water use				
	2000	2005	2015	2025
Population	2380	2600	3500	4660
Water use (m³/day)	36	39	105	140
Water use (m³/s)	0.000	0.000	0.001	0.002

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)				
Water use (m³/s)				

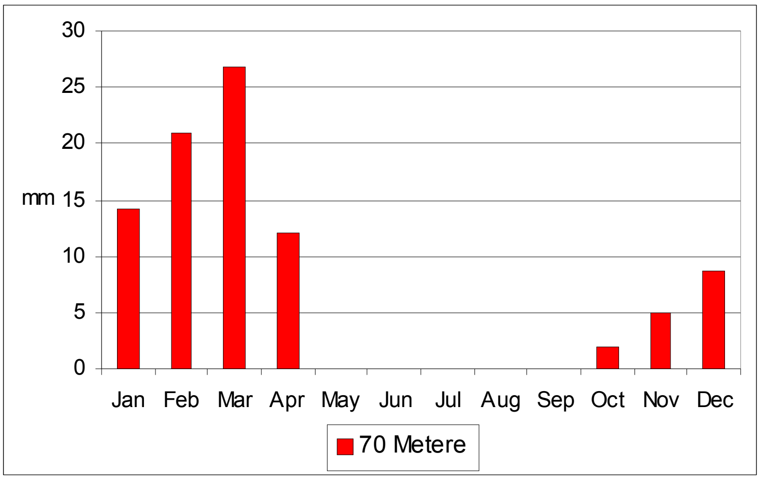
Existing water deficit
YES
Future water deficit
YES



6070	
Metere	
Area in km²	
839.8	
Perimeter in km	
125.2	
Elevation (m.a.s.l)	
Mean	Maximum
251	451



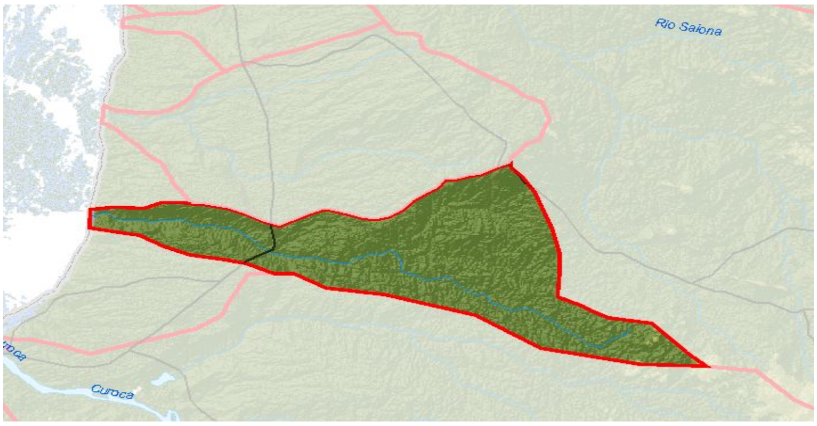
Annual mean discharge m³/s (Q)	
0.06	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.1*
Max	0.2
Min	0.02



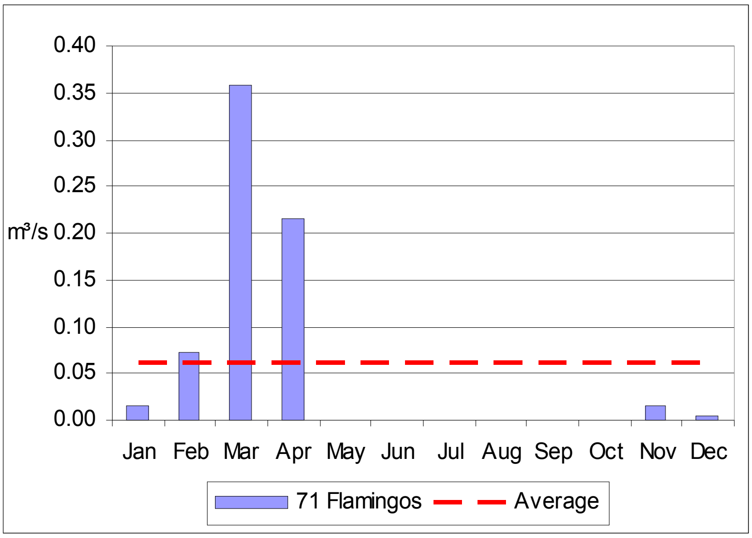
Annual precipitation in mm
89

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

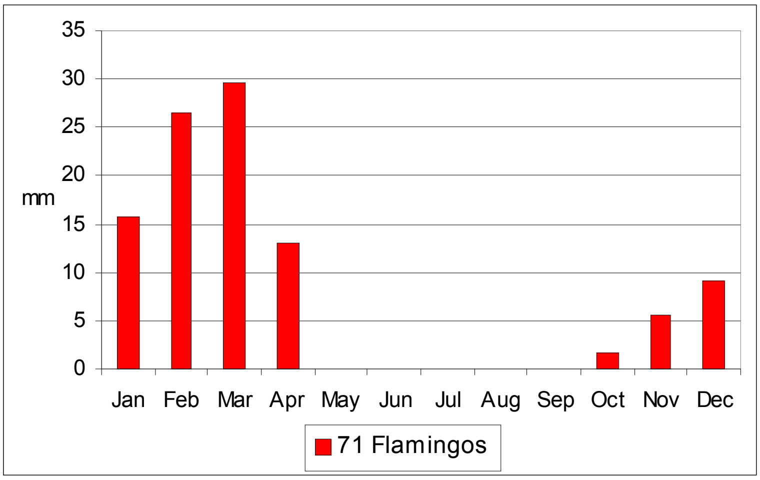
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6071	
Flamingos	
Area in km²	
676.6	
Perimeter in km	
166.7	
Elevation (m.a.s.l)	
Mean	Maximum
261	611



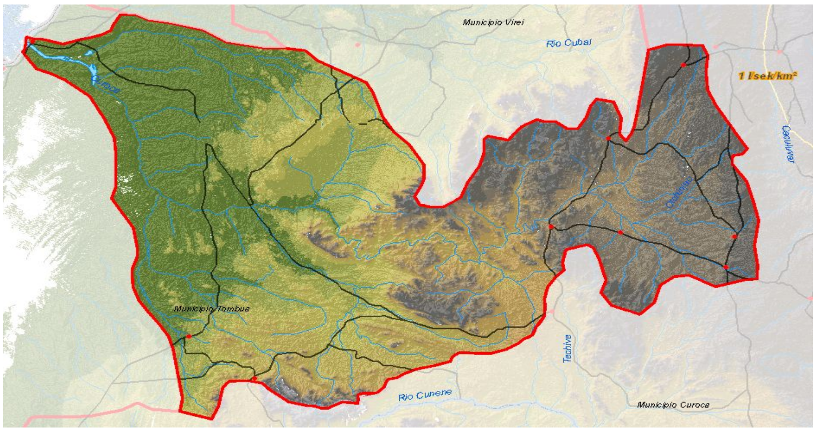
Annual mean discharge m³/s (Q)	
0.06	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.1*
Max	0.2
Min	0.02



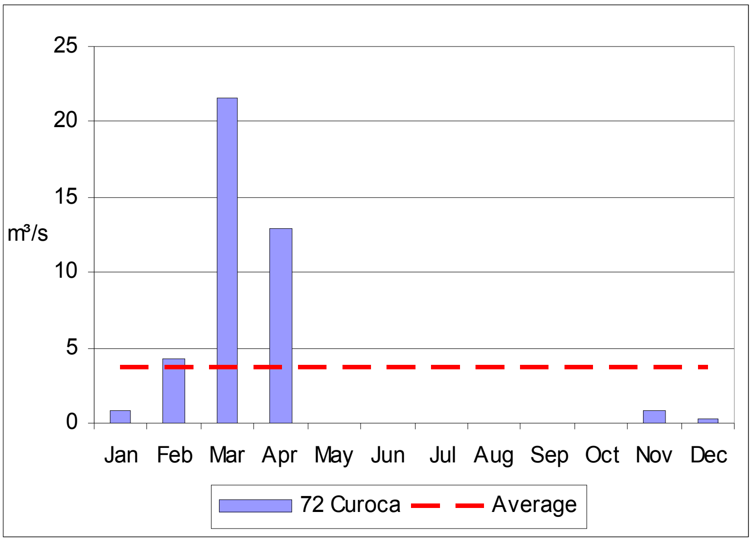
Annual precipitation in mm
102

Population and Water use				
	2000	2005	2015	2025
Population				
Water use (m³/day)				
Water use (m³/s)				

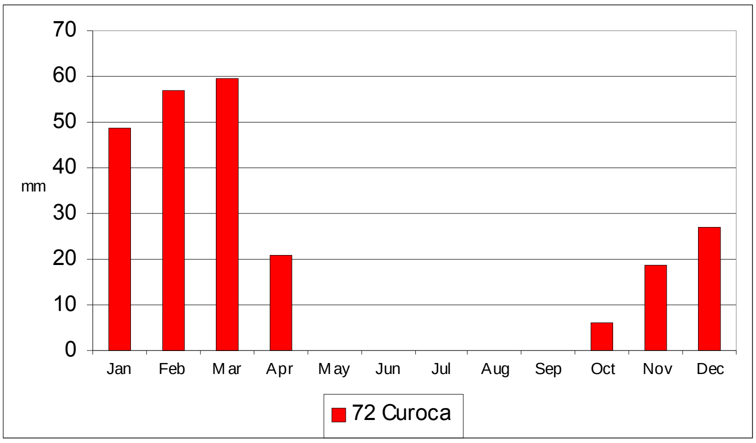
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6072	
Curoca	
Area in km²	
19338.4	
Perimeter in km	
848.9	
Elevation (m.a.s.l)	
Mean	Maximum
762	1864



Annual mean discharge m³/s (Q)	
3.69	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*0.2*
Max	0.9
Min	0.01

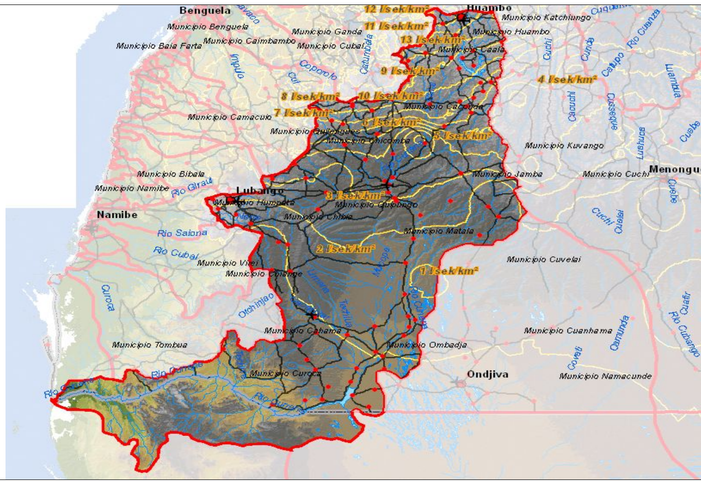


Annual precipitation in mm
238

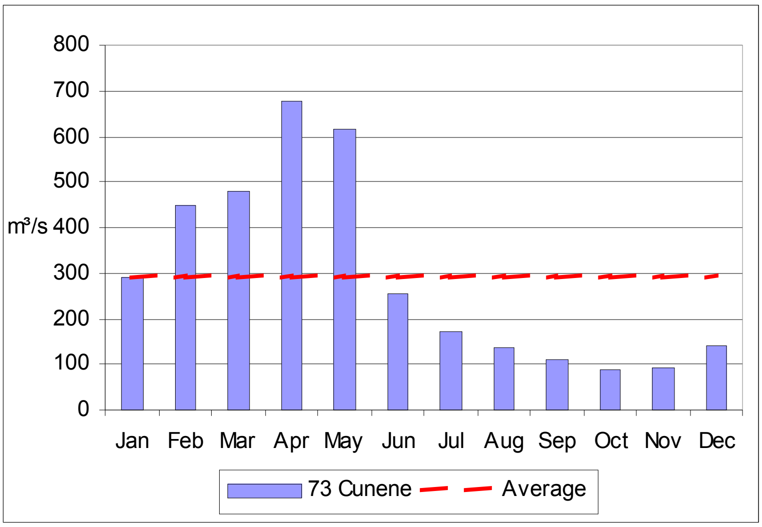
Population and Water use				
	2000	2005	2015	2025
Population	55239	65388	80878	97817
Water use (m³/day)	872	1066	2609	3240
Water use (m³/s)	0.010	0.012	0.030	0.038

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	54686	80689	115033	153997
Water use (m³/s)	0.6	0.9	1.3	1.8

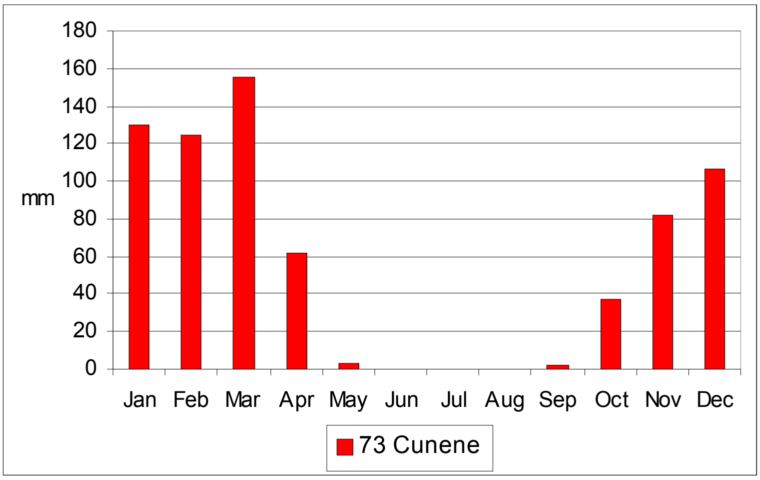
Existing water deficit
YES
Future water deficit
YES



6073	
Cunene	
Area in km²	
113834.7	
Perimeter in km	
2389.7	
Elevation (m.a.s.l)	
Mean	Maximum
1286	2484



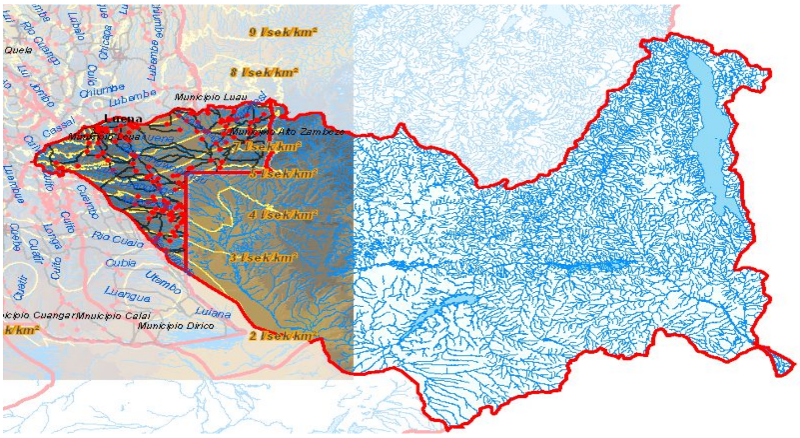
Annual mean discharge m³/s (Q)	
289.5	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*2.5*
Max	13.7
Min	0.01



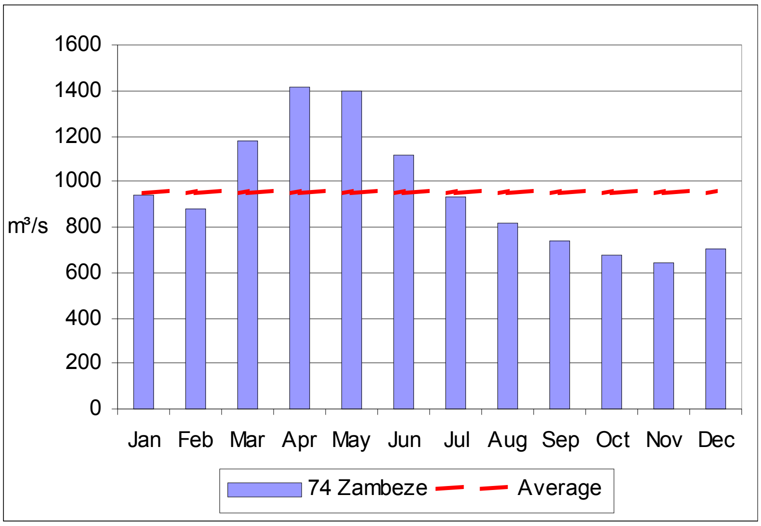
Annual precipitation in mm
704

Population and Water use				
	2000	2005	2015	2025
Population	2501644	3020716	4022883	5346401
Water use (m³/day)	47286	63165	143188	232963
Water use (m³/s)	0.547	0.731	1.657	2.696

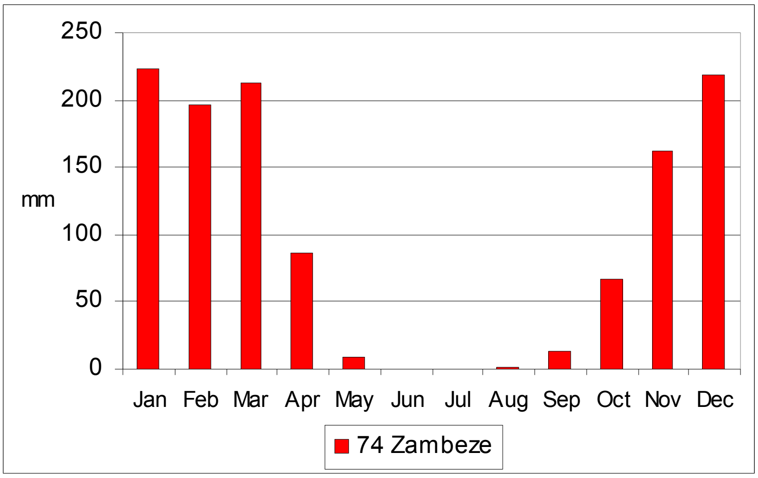
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)	1036862	1183202	11422476	22096162 2	Future water deficit
Water use (m³/s)	12.0	13.7	132.2	249.7	YES



6274	
Zambeze	
Area in km²	
Total:1300565 In Angola: 150003	
Perimeter in km (total)	
7197	
Elevation (m.a.s.l) (Angola)	
Mean	Maximum
1199	1676



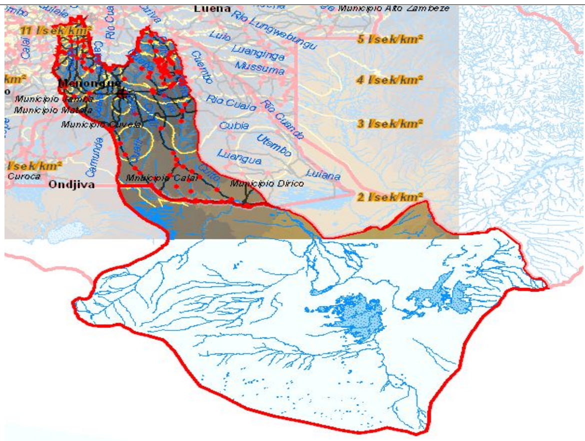
Annual mean discharge m³/s (Q) (Angola)	
937.1	
Annual mean specific discharge (q) l s⁻¹ km⁻² (Angola)	
Mean	*6.2*
Max	11.1
Min	1.3



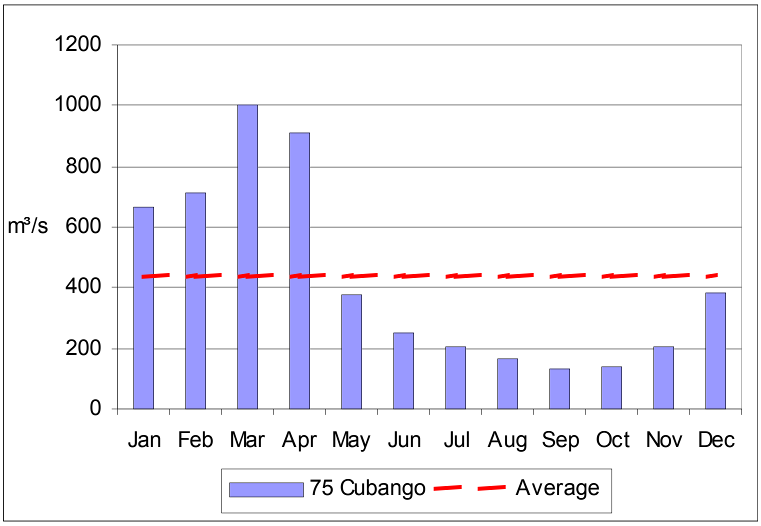
Annual precipitation in mm (Angola)
1191

Population and Water use				
	2000	2005	2015	2025
Population	220412	242963	326373	439089
Water use (m³/day)	5466	6769	14591	22261
Water use (m³/s)	0.063	0.078	0.169	0.258
Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)		15110	30220	60440
Water use (m³/s)	0.0	0.2	0.3	0.7

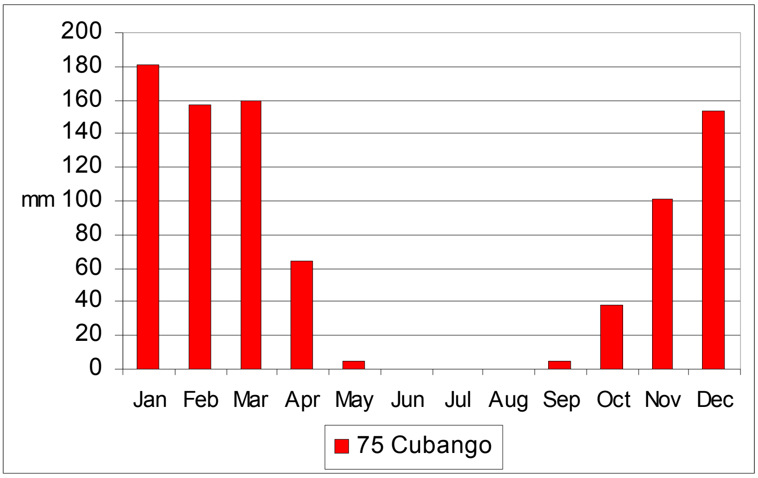
Comments
Elevation, discharge and specific discharge is only calculated for the Angolan part of the catchment
Existing water deficit
NO
Future water deficit
NO



6375	
Cubango	
Area in km²	
Total:749328 In Angola: 153927	
Perimeter in km (total)	
5392	
Elevation (m.a.s.l) (Angola)	
Mean	Maximum
1328	1868



Annual mean discharge m³/s (Q) (Angola)	
429.45	
Annual mean specific discharge (q) l s^{-1} km^{-2} (Angola)	
Mean	*2.8*
Max	*11.4*
Min	1.3



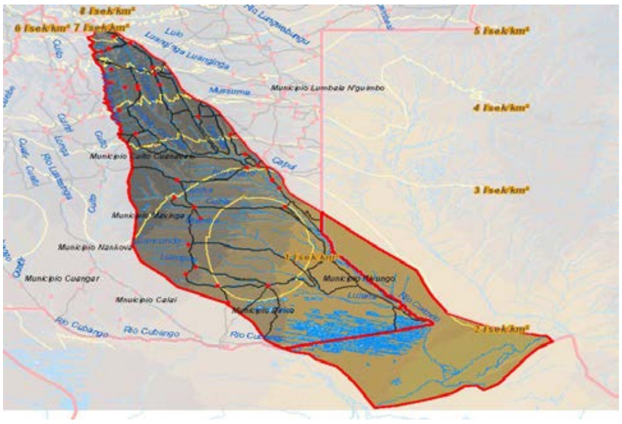
Annual precipitation in mm (Angola)
864

Population and Water use				
	2000	2005	2015	2025
Population	391886	461034	548868	650883
Water use (m³/day)	8220	9257	20991	30349
Water use (m³/s)	0.095	0.107	0.243	0.351

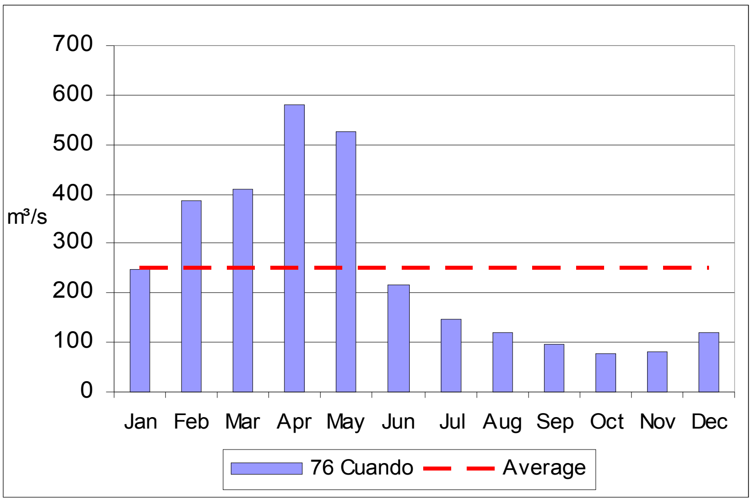
Comments
Elevation, discharge and specific discharge is only calculated for the Angolan part of the catchment

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	169904	170825	248502	328059
Water use (m³/s)	2.0	2.0	2.9	3.8

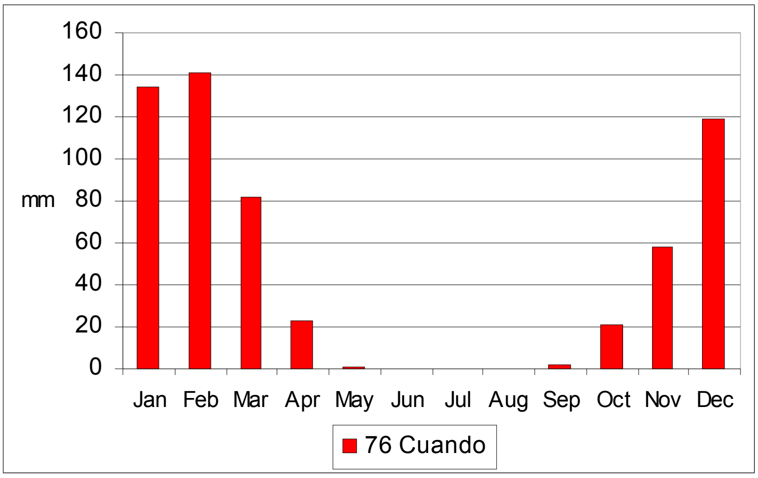
Existing water deficit
NO
Future water deficit
NO



6376	
Cuando	
Area in km²	
Total: 146222 Angola: 104589	
Perimeter in km (Total)	
2083	
Elevation (m.a.s.l)	
Mean	Maximum
982	1539



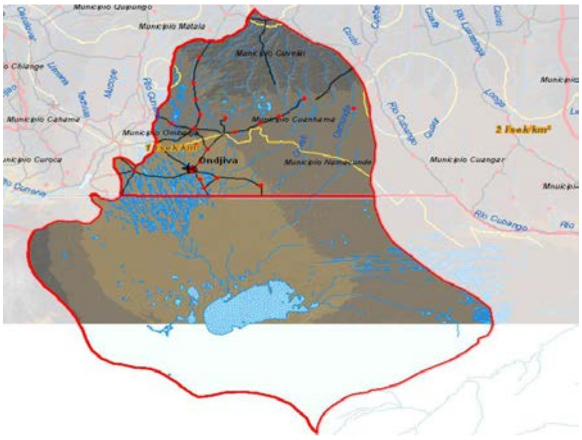
Annual mean discharge m³/s (Q)	
248.47	
Annual mean specific discharge (q) l s⁻¹ km⁻²	
Mean	*1.7*
Max	2.1
Min	1.2



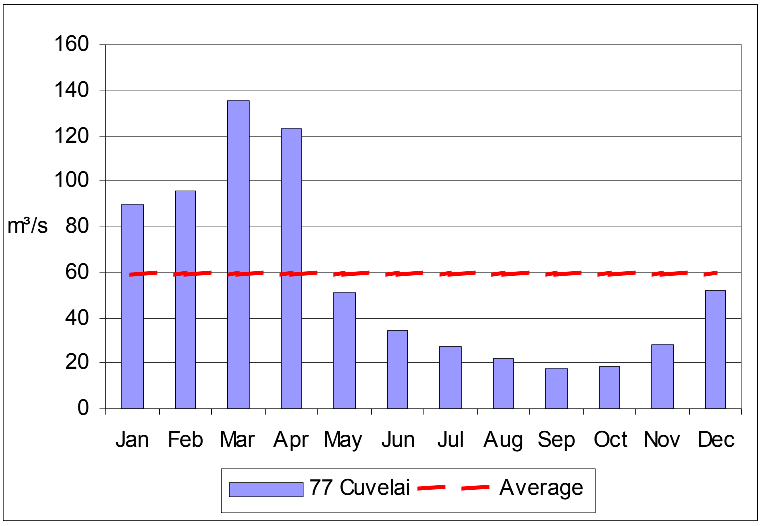
Annual precipitation in mm	
583	

Population and Water use				
	2000	2005	2015	2025
Population	53640	67496	81825	102049
Water use (m³/day)	805	1012	2455	3061
Water use (m³/s)	0.009	0.012	0.028	0.035

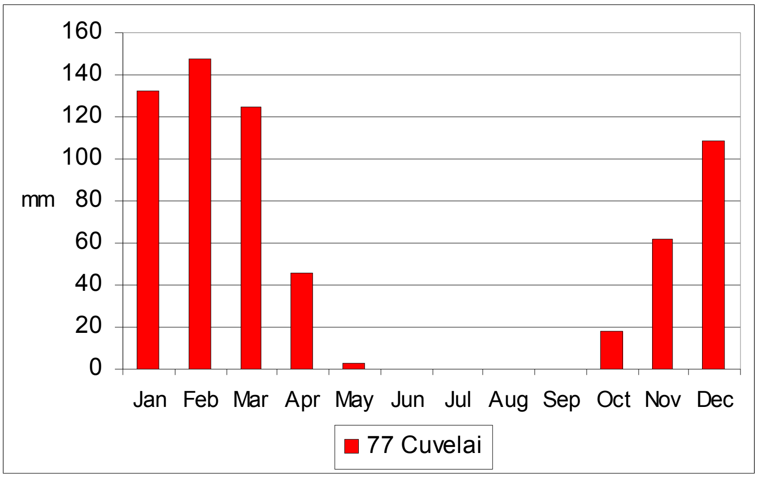
Animal Watering and Irrigation					Existing water deficit
	2002	2005	2015	2025	NO
Water use (m³/day)					Future water deficit
Water use (m³/s)					NO



6377	
Cuvelai	
Area in km²	
Total: 159620 Angola: 52158	
Perimeter in km (Total)	
1821	
Elevation (m.a.s.l) (Angola)	
Mean	Maximum
1191	1477



Annual mean discharge m³/s (Q) (Angola)	
57.96	
Annual mean specific discharge (q) l s^{-1} km^{-2} (Angola)	
Mean	*1.1*
Max	2.2
Min	0.4



Annual precipitation in mm (Angola)
1477

Population and Water use				
	2000	2005	2015	2025
Population	142760	181513	221313	293916
Water use (m³/day)	3296	5298	12359	25660
Water use (m³/s)	0.038	0.061	0.143	0.297

Comments
Elevation, discharge and specific discharge is only calculated for the Angolan part of the catchment

Animal Watering and Irrigation				
	2002	2005	2015	2025
Water use (m³/day)	490954	495036	686470	978053
Water use (m³/s)	5.7	5.7	7.9	11.3

Existing water deficit
NO
Future water deficit
NO

Table 12.1 Division of Hydrological Sub Basins in Angola

1. Division	2. Division	3. Division	Major Basin	Catchment Name
4	40	**1**	S.W.Coast	**Lubinda**
4	40	**2**	S.W.Coast	**Chiloango**
4	40	**3**	S.W.Coast	**Lulondo**
4	40	**4**	S.W.Coast	**Lucula**
4	43	**5**	Zaïre / Congo	**Zaire**
4	60	**6**	S.W.Coast	**Zombo**
4	60	**7**	S.W.Coast	**Luela**
4	60	**8**	S.W.Coast	**Lucolo**
4	60	**9**	S.W.Coast	**Sange**
4	60	**10**	S.W.Coast	**Lucunga**
4	60	**11**	S.W.Coast	**M'Bridge**
4	60	**12**	S.W.Coast	**Sembo**
4	60	**13**	S.W.Coast	**Loge**
4	60	**14**	S.W.Coast	**Uezo**
4	60	**15**	S.W.Coast	**Onzo**
4	60	**16**	S.W.Coast	**Lifune**
4	60	**17**	S.W.Coast	**Dande**
4	60	**18**	S.W.Coast	**Bengo**
4	60	**19**	S.W.Coast	**Cuanza**
4	60	**20**	S.W.Coast	**Perdizes**
4	60	**21**	S.W.Coast	**Sangando**
4	60	**22**	S.W.Coast	**Cabo Ledo**
4	60	**23**	S.W.Coast	**Mengueje**
4	60	**24**	S.W.Coast	**Tanda**
4	60	**25**	S.W.Coast	**Longa**
4	60	**26**	S.W.Coast	**Cutanga**
4	60	**27**	S.W.Coast	**Quiteta**
4	60	**28**	S.W.Coast	**Catata**
4	60	**29**	S.W.Coast	**Tortombo**
4	60	**30**	S.W.Coast	**Queve**
4	60	**31**	S.W.Coast	**N'Gunza**
4	60	**32**	S.W.Coast	**Quicombo**
4	60	**33**	S.W.Coast	**Dui**
4	60	**34**	S.W.Coast	**Evale**
4	60	**35**	S.W.Coast	**Balombo**
4	60	**36**	S.W.Coast	**Cuhula**
4	60	**37**	S.W.Coast	**Cubal Da Hanha**
4	60	**38**	S.W.Coast	**Catumbela**
4	60	**39**	S.W.Coast	**Cavaco**
4	60	**40**	S.W.Coast	**Curinge**
4	60	**41**	S.W.Coast	**Uche**
4	60	**42**	S.W.Coast	**Mormolo**
4	60	**43**	S.W.Coast	**Pima**
4	60	**44**	S.W.Coast	**Ndungo**
4	60	**45**	S.W.Coast	**Calumbolo**
4	60	**46**	S.W.Coast	**Coporolo**
4	60	**47**	S.W.Coast	**Nhime**
4	60	**48**	S.W.Coast	**Lua**
4	60	**49**	S.W.Coast	**Equimina**
4	60	**50**	S.W.Coast	**Chamanga**
4	60	**51**	S.W.Coast	**Calongolo**
4	60	**52**	S.W.Coast	**Lucipo**
4	60	**53**	S.W.Coast	**Catara**
4	60	**54**	S.W.Coast	**Cangala**
4	60	**55**	S.W.Coast	**Capim**
4	60	**56**	S.W.Coast	**Chileva**
4	60	**57**	S.W.Coast	**Carunjamba**
4	60	**58**	S.W.Coast	**Inamagando**
4	60	**59**	S.W.Coast	**Mapungo**
4	60	**60**	S.W.Coast	**Bentiaba**
4	60	**61**	S.W.Coast	**Salgada**
4	60	**62**	S.W.Coast	**Chilulo / Chapéu Armado**
4	60	**63**	S.W.Coast	**Caniço**
4	60	**64**	S.W.Coast	**Mutiambo**
4	60	**65**	S.W.Coast	**Muchimanda**
4	60	**66**	S.W.Coast	**Giraul**
4	60	**67**	S.W.Coast	**Bero**
4	60	**68**	S.W.Coast	**Changulo**
4	60	**69**	S.W.Coast	**Subida Grande**
4	60	**70**	S.W.Coast	**Metere**
4	60	**71**	S.W.Coast	**Flamingos**
4	60	**72**	S.W.Coast	**Curoca**
4	60	**73**	S.W.Coast	**Cunene**
4	62	**74**	Zambezi	**Zambeze**
4	63	**75**	Okavango	**Cubango**
4	63	**76**	Zambezi	**Cuando**
4	63	**77**	Etosha pan	**Cuvelai**

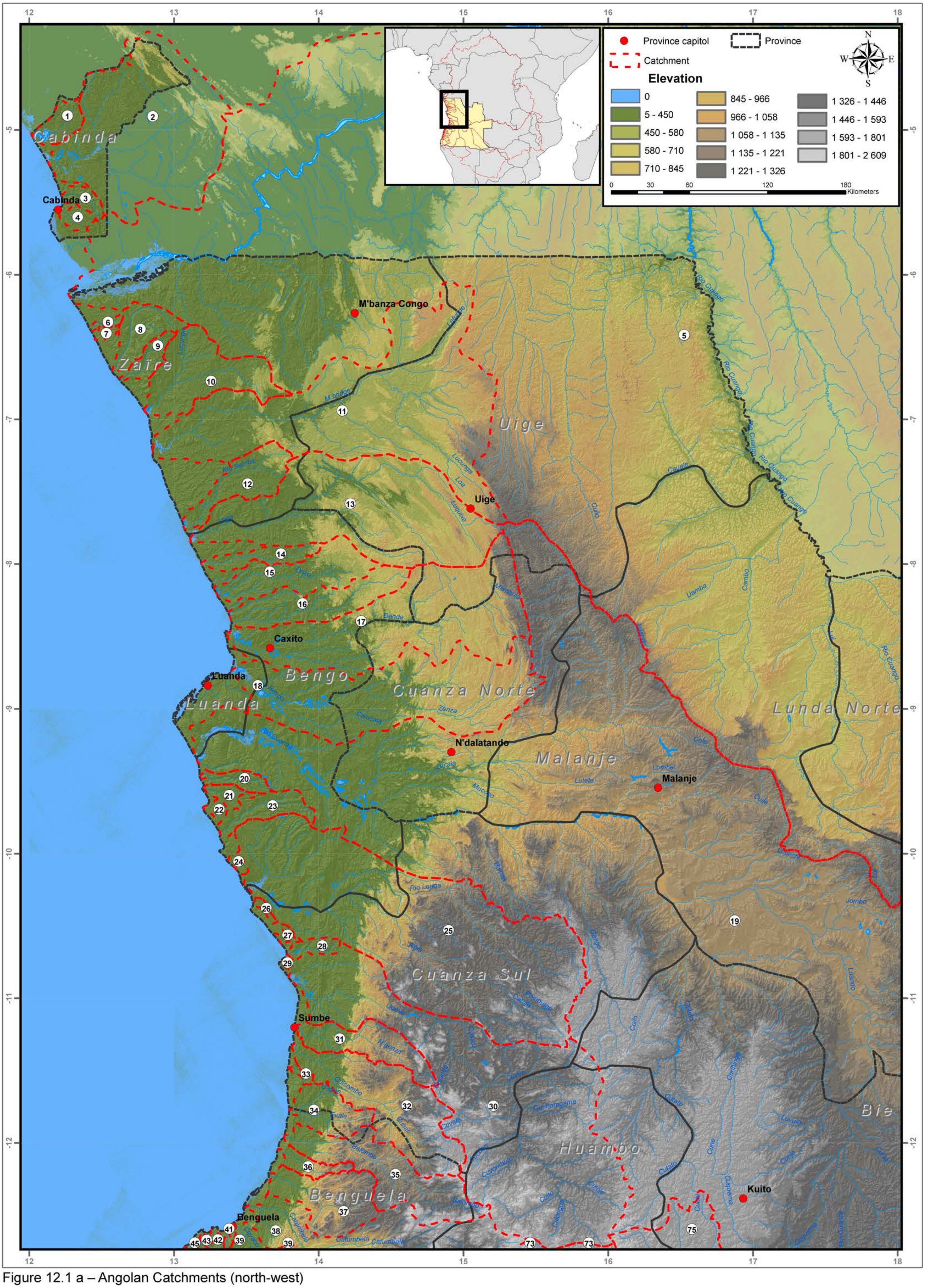


Figure 12.1 a – Angolan Catchments (north-west)

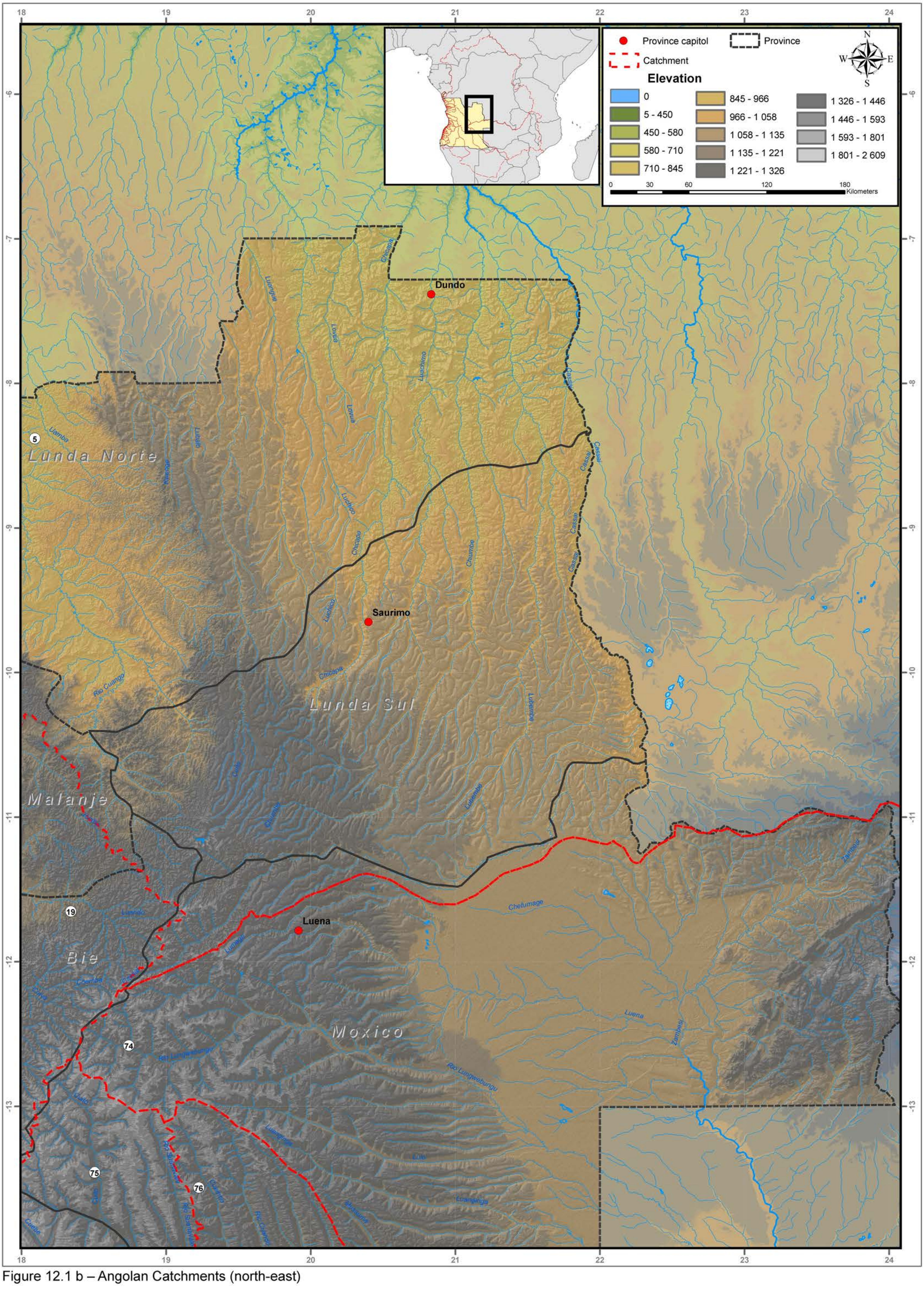


Figure 12.1 b – Angolan Catchments (north-east)

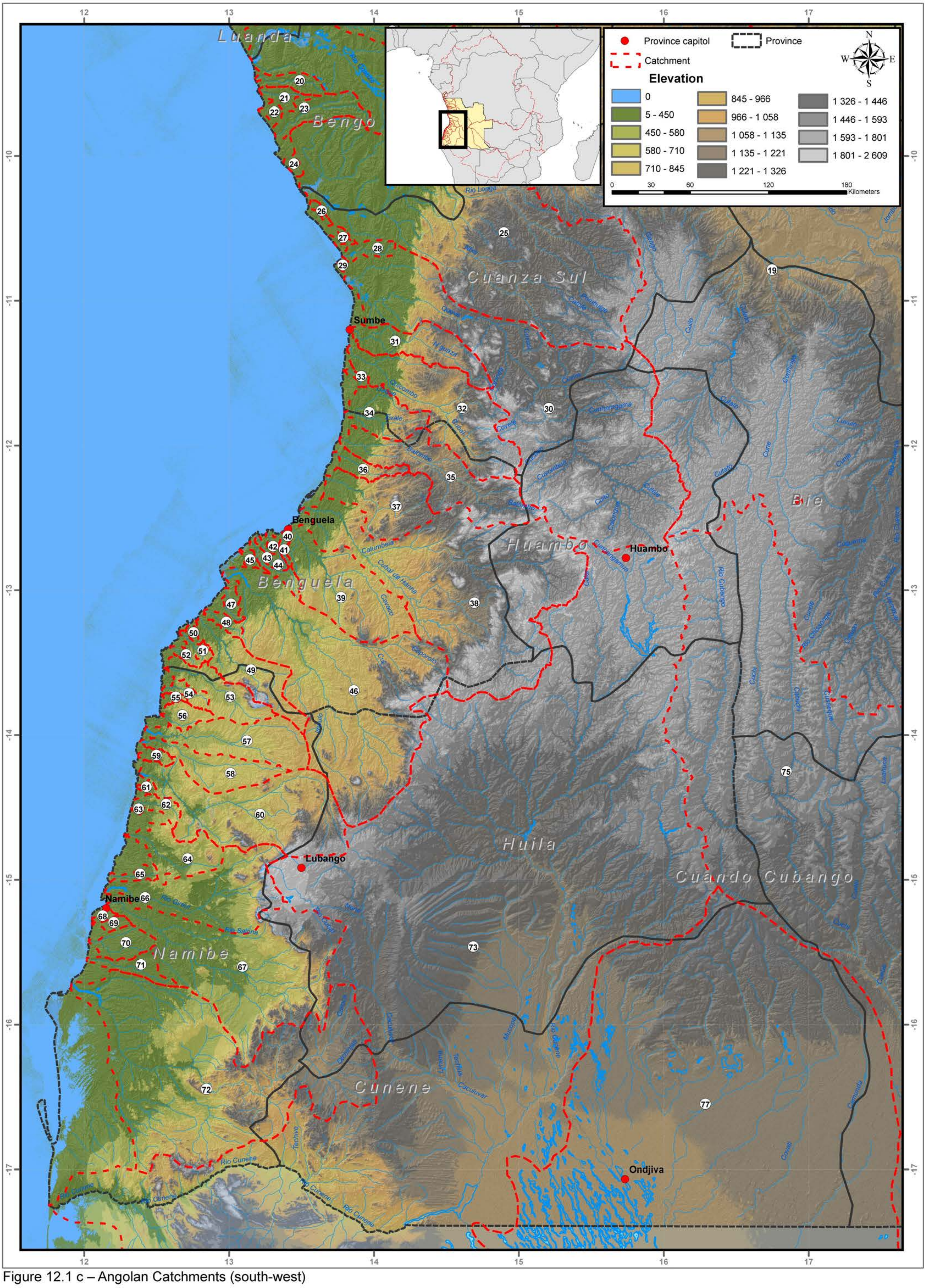


Figure 12.1 c – Angolan Catchments (south-west)

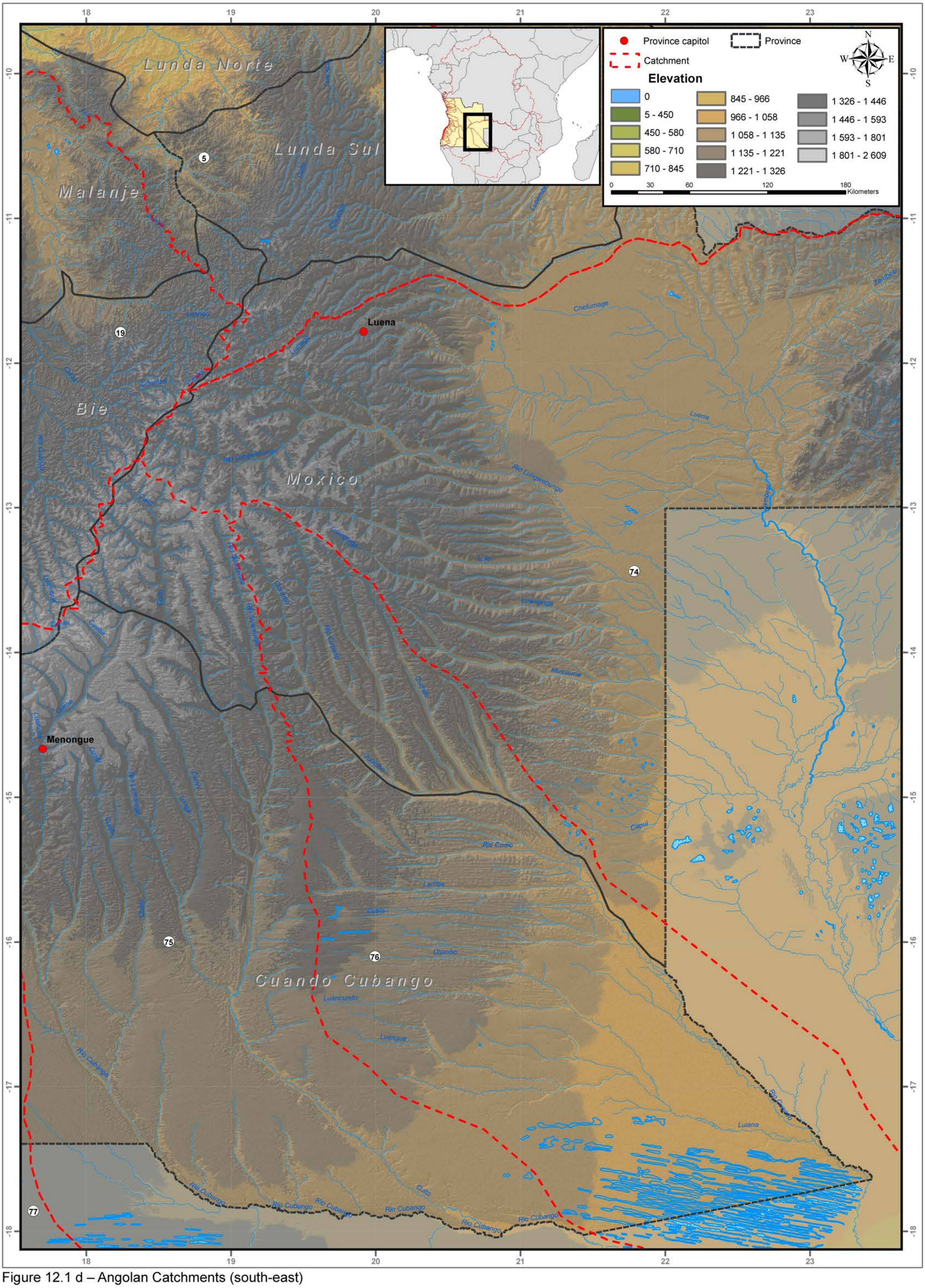


Figure 12.1 d – Angolan Catchments (south-east)

13. RECOMMENDATIONS FOR FUTURE ASSESSMENTS

13.1 Bottlenecks for Further Planning & Management

During the course of the work on the rapid water resources and water use assessment a number of constraints came to light that should, to the extent possible, be alleviated during future updating and development of the assessments.

One major bottleneck to the acquisition of detailed data in water resources and water use from provincial level is the centralised institutional set-up of DNA. An organisation with better links and operative arms at provincial level would be in a better position for data acquisition.

DNA also seems to be comparatively understaffed with respect to the size of its mandate. Well-trained and motivated staff is a prerequisite for an organisation responsible for the water sector in a country the size of Angola. Although this situation has been to a certain extent improved through the implementation of the NAWASMA project, it is vital that this impetus be maintained.

In the following sections we present recommendations designed to help overcome some of the constraints.

13.2 Dissemination of the Rapid Water Resources & Water Use Assessment Results

The rapid water resources and water use assessment has compiled a wealth of information and data which could greatly benefit many of the stakeholders, both, ministerial, institutional and private in the water sector in Angola. It is important that the maximum benefit be reaped from the efforts laid down in the assessment.

One way of disseminating the results of the assessment, and at the same time perhaps enhancing them, would be to present the assessment to key stakeholders in a seminar or workshop. Such a venue would give DNA valuable opportunities to both advertise the results of its work and to gain advice from and extend cooperation with stakeholders in the water sector.

13.3 Maintaining & Developing Water Resources and Water Use Assessment

13.3.1 Water Use Data

Data on present and future water use (both as an input in production and as a recipient of effluents) by industry and mining activities should be made available, and if such data do not exist, a survey be organized to collect such data.

Furthermore, it is recommended that a household expenditure survey along the lines of what the World Bank does in developing member countries be carried out. In such a survey questions about water demand by income and social group should be mapped, their willingness to pay for reliable and safe water supply, and what these same households actually pay for whatever kind of water they get now.

It is also recommended that data is collected to show what people in different settings actually pay for water today so that this can be used as a basis of comparison when they request water from a municipal system.

13.3.2 Population Estimates

As far as the provincial population estimates is concerned, as well as the water use estimates, in the lack of census details, it is recommended that the results of the National Landmine Impact Survey[1] (LIS) currently being carried out by the Survey Action Center (SAC) of USA be retrieved once they are made available. The LIS is due to be completed by the end of 2005 and it is understood that it will include data on settlements, populations, water connections and water use in parts of many provinces of Angola.

Several NGOs have been selected to implement this survey including teams from the Development Workshop Angola (DW-A), HALO Trust (HALO), INAD, InterSOS (SOS), Mines Advisory Group (MAG), Norwegian People's Aid (NPA), Santa Barbara Foundation (SBF), Cranfield Mine Action (CMA), and GeoSpatial International (GSI). A SAC coordination centre in Luanda is overseeing the field operations. The SAC team is working with the National Inter-Sectoral Commission for Demining and Humanitarian Assistance (CNIDAH), which is the national authority for mine action within Angola. HALO is operating in the Benguela, Bie, Cuando Cubango, and Huambo provinces. INAD (Instituto Nacional de Desminagem - the National Demining Institute) is operating in the Cabinda and Lunda Norte provinces. NPA is operating in the Bengo, Cuanza Norte, Cuanza Sul, Luanda, Lunda Sul, Malanje, Uige, and Zaire provinces. MAG and SBF are operating in the provinces of Moxico and Cunene, respectively. SOS is operating in the Huila and Namibe provinces. DW-A is conducting a Community Mine Action Planning Pilot Project in Huambo. CMA and GSI are heading up a strategic planning group.

Data obtained from this survey could be useful in the updating of the assessment until the results of a future census become available.

13.3.3 Suggestions for Further Evaluation of Groundwater Potential of Angola

During this study we have experienced that there exists data on groundwater wells and groundwater use both in official institutions, NGOs, and in private companies. Some information gathered during meetings in Lubango resulted, for example, in the following information:

- HYDROMINAS has a lot of data, probably both in old archives and in a computerised database which is understood to be in an initial stage of development. Several private companies are now working in the groundwater business. Two of them are collaborating with HYDROMINAS in data gathering. HYDROMINAS runs three drilling rigs and uses a computerised program to register well data. They also register hydro-chemical data.

- DPA - Lubango (Direcção Provincial de Água) has information on the existing 700 boreholes in the municipalities of Huila province. According to information from HYDROMINAS DPA - Lubango also have three drilling rigs.

- UNICEF focuses on groundwater in the provinces of Benguela, Huila, Namibe, and Cunene. Since 1989 UNICEF ran a water supply programme for the southern region of Angola. UNICEF is now abandoning the rural water supply component and is concentrating on water supply for primary schools.

- UNICEF informed that DPA - Cunene has good information on water wells in their province. AICF, a French NGO, worked on water and sanitation and handed over all the information to DPA - Cunene.

[1] http://www.sac-na.org/surveys_angola.html

To draw further conclusions on Angola's groundwater potential it is important to collect all information on wells, water yields and water qualities in a common and easy accessible register. The register should be open for any institution or company working on groundwater supply in Angola.

To create such a register there standardised forms should be prepared and issued to drilling companies and well owners for registering of data. The forms should include data on the depth of wells, rock types, water yields at different levels, pumping tests, water quality, and practical information on the well structures. For example, in most European countries the well drillers are instructed by law to submit such information to a central register. This is a question of legislation.

Based on such a register, conclusions on the groundwater potential of different rock units and provinces could be drawn. Water supply programmes could then be better planned, and the resources spent on well drilling could be used more efficiently.

In the southwestern part of the country there is obviously a lot of knowledge on the hydrogeology. In other parts of the country the experience from well drillings is considerably less. Some effort should be placed on evaluating the groundwater potential from alluvial sediments in the northern parts of the country. Some of these aquifers probably have the possibility to supply a lot of people with clean water. Practical research programmes including the drilling of wells are quite expensive, and we do not believe that such programmes should be prioritised in hardrock areas. Working on registers of existing data would be much more efficient.

13.3.4 Hydrological Network

The constructed runoff map is based on observations made in the period 1964-1974. As part of the NAWASMA project, some of the hydrometric stations of the network are been rehabilitated[2] and observations from these stations may in a few years be used as control of the accuracy of the maps.

The runoff map is mostly based on values from the central areas of Angola. Measurements in Cabinda in the north, in the northeast in the Congo basin and along the Namibe coast are more or less nonexistent, and values from these areas are more prone to error. Hydrological measurements should be made in these areas to control the estimates.

Institutional cooperation between the neighbouring countries should be extended to ease the sharing of hydrometric data on the shared rivers.

13.3.5 Sediment Transport

No network for measurements of sediment transport is in existence today, and some form of routine for collecting such data should be organized.

Perhaps one option could be that ENE (the National Enterprise for Electricity) responsible for most of the Angolan hydropower plants, GAMEK (the entity responsible for the construction of Capanda dam), GABHIC, Gabinete para Administração da Bacia Hidrográfica do Cunene

[2] The following hydrometric stations were rehabilitated under the NAWASMA project: Porto-Quipiri (Bengo province), Cabiri (Bengo province), Bom Jesus (Bengo province), Cachoeiras da Binga (Kuanza Sul province), Quicombo (Kuanza Sul province), Xângongo (Cunene provine) and Biópio (Benguela province). In addition two SADC-HYCOS stations, namely Cambambe and Luena have or are being developed.

(the Cunene River Basin Authority) and HIDROCHICAPA, the entity responsible for the construction of Chicapa hydropower plant in Chicapa – Lunda Norte province were given the responsibility of sediment transport measurements.

13.3.6 Geographical Information Systems (GIS)

Personnel at DNA (Direcção Nacional de Águas) and other government institutions related to water affairs should be encouraged to broaden their knowledge of the use of Geographical Information Systems (GIS). Courses should be attended and workshops held. Institutional cooperation should be extended to ease the sharing of geographical (and other) data.

13.3.7 Agriculture and Irrigation

MINADER, the Ministry of Agriculture and Rural Development, should make an effort to collect information on the irrigation sub-sector in the provinces of Cabinda, Cuando Cubango, Uíge, Bié, Lunda Norte, Lunda Sul and Moxico.

MINEA (the Ministry of Water and Energy) and MINADER (the Ministry of Agriculture and Rural Development) should make an effort to make more information available on the Angolan side of the Cuvelai River Basin under the Programme on the Shared Resources of Cuvelai River Basin.

Most of the planned area for irrigated agriculture was defined during the colonial period. It is important that the government of Angola, through MINADER, validates those areas for irrigated agriculture.

As far as the consumptive use of water is concerned, DNA (MINEA) and the DNHAER, the National Directorate of Agricultural Hydraulics and Rural Engineering (MINADER), should extend their collaboration.

As DNA (MINEA) has now done through the NAWASMA project and through this rapid water resources and water use study, DNHAER (MINADER) should make an effort to create its own database on the irrigation sub-sector. Such a database should be built on updated information of all existing irrigation schemes.

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APPENDICES

APPENDIX A: SEDIMENT YIELDS DATABASE FOR AFRICAN RIVERS

APPENDIX B: EXISTING & POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

APPENDIX C: GEODATA DOCUMENTATION AND DESCRIPTION

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APPENDIX A

SEDIMENT YIELDS DATABASE FOR AFRICAN RIVERS

The following data has been extracted from the World River Sediment Yields Database of the FAO Water Resources Development and Management Service, available via the Internet.

River	Location	Country	Catchment Area (km²)	Monitoring started	Monitoring ended	Rainfall (mm/y)	Runoff (mm/y)	Sedim. yield (t/km²/y)
Allalah	Sidi Akacha	Algeria	295	1972	1979	599	120	6654.00
Assif Tala	R N 25	Algeria	300	1972	1979	782	256	806.00
Bouroumi	Tarzoult	Algeria	215	1972	1979	652	146	3345.00
Bousellah	Magraoua	Algeria	2350	1972	1979	398	17	99.00
Chelief	Mouth	Algeria	22274					152.00
Cheliff		Algeria	22000					140.00
Chiffa	Amont des Gorges	Algeria	316	1972	1979	871	367	2461.00
Chouly	Chouly R N 7	Algeria	170	1972	1979	542	103	75.00
Deurdeur	Sidi Mokrebi	Algeria	500	1972	1979	564	85	223.00
Djer	El Aferoun	Algeria	395	1972	1979	582	131	1729.00
Djer		Algeria	390				130	1700.00
Ebda	Arib Ebda	Algeria	270	1972	1979	757	338	2493.00
El Abiod	Mchouneche	Algeria	1050	1972	1979	299	17	401.00
El Arab	Khanga S Nadat	Algeria	2085	1972	1979	640	16	539.00
El Harrach	Hammam Melouane	Algeria	387	1972	1979	829	332	1630.00
El Harrach		Algeria	390				330	1600.00
Gueiss	F El Gueiss	Algeria	144	1972	1979	459	20	196.00
Hachem	Bordj Ghobeni	Algeria	215	1972	1979	631	236	1542.00
Haddad	S A Djillali	Algeria	470	1972	1979	305	17	103.00
Hamman	Zit Emba	Algeria	485	1972	1979	595	74	197.00
Isser	Reachi	Algeria	1935	1972	1979	486	59	116.00
Isser		Algeria	3595					2610.00
Isser	Lakhdaria	Algeria	31615	1972	1979	466	106	1712.00
Isser		Algeria	3600				110	1700.00
Kebir Est	Ain El Assel	Algeria	680	1972	1979	864	288	903.00
Kebir Ouest	Ain Charchar	Algeria	1130	1972	1979	602	90	92.00
Ksob	Medjez	Algeria	1330	1972	1979	334	21	333.00
Mddjerdah		Algeria	21000					620.00
Melah	Bouchegoue	Algeria	550	1972	1979	558	153	716.00
Reboa	Reboa	Algeria	296	1972	1979	384	21	594.00
Ressoul	Ain Berda	Algeria	103	1972	1979	620	97	214.00
Rhiou	Ammi Moussa	Algeria	1890	1972	1979	375	56	1822.00
Rouina	Rouina Mines	Algeria	865	1972	1979	437	68	1151.00
Sly	Ouled B.Aek	Algeria	1225	1972	1979	458	122	2037.00
Soubellah	Sidi Quadah	Algeria	176	1972	1979	322	21	36.00
Tleta	Ghazaouet	Algeria	100	1972	1979	472	74	297.00
Mbam		Cameroon	42300					85.00
Sanaga		Cameroon	130000				500	20.00
Sanaga		Cameroon	77000					28.00
Tsanaga		Cameroo	1535					210.00

The following data has been extracted from the World River Sediment Yields Database of the FAO Water Resources Development and Management Service, available via the Internet.

River	Location	Country	Catchment Area (km²)	Monitoring started	Monitoring ended	Rainfall (mm/y)	Runoff (mm/y)	Sedim. yield (t/km²/y)
		n						
Bangoran		Central African Republic	2590					4.40
Fafa		Central African Republic	6750					3.10
Gribingui		Central African Republic	5680					5.00
Ouham		Central African Republic	44700					9.40
Bahr Sar		Chad	79600					8.40
Chari		Chad	600000					3.90
Chari		Chad	193000					0.90
Logone		Chad	85000					14.90
Nile	Cairo	Egypt	3000000	1958	1964		30	40.00
Nile	delta	Egypt	2977235			200	30	39.00
Mesanu ?	Mesanu Basin, (Tigrai ?)	Ethiopia	150					1680.00
Awash	Melka Kentare	Ethopia	4440					845.00
Awash	Melka Gorge	Ethopia	7823					868.00
Awash	Dubti	Ethopia	62732					622.00
Awash	Hertale	Ethopia	32744					228.00
Awash	Kolka	Ethopia	10115	1959	1973		187	1468.00
Awash	Metehara	Ethopia	14355					205.00
Awash	Awash Station	Ethopia	17405					287.00
Jawaha		Ethopia	565					3480.00
Kesem	Awora Melka	Ethopia	3130					1140.00
Mbam		Ghana	42000					85.00
Tano		Ghana	16000					22.00
Volta		Ghana	400000				91	48.00
S. Pedro		Ivory Coast	3300					22.00
Ehania	above Thika	Kenya	517					79.00
Ewaso Ngiro	above Archer's	Kenya	15300					780.00
Nzoia	above Broderick Falls	Kenya	8500					25.00
Perkerra		Kenya	1310					19520.00
Sagana	above Sagawa	Kenya	2650					17.00
Sagana	above Kiganjo	Kenya	501					4.10
Sirimon	above Isiolo-Nanyuki Road	Kenya	62					4.30
Tana	Masinga	Kenya	7335	1981	1983		353	6330.00
Tana		Kenya	32000				135	1000.00
Tana	between Grand Falls and Garissa	Kenya	15200				12	780.00

The following data has been extracted from the World River Sediment Yields Database of the FAO Water Resources Development and Management Service, available via the Internet.

River	Location	Country	Catchment Area (km²)	Monitoring started	Monitoring ended	Rainfall (mm/y)	Runoff (mm/y)	Sedim. yield (t/km²/y)
Tana	Kamburu	Kenya	9520	1974	1981		358	410.00
Tana	above Kamburu Dam 4DE3	Kenya	9520					318.70
Tana	between Kindaruma and ?	Kenya	7700				12	1550.00
Tana	Kamburu	Kenya	9520	1981	1983		358	337.00
Tana	Kindaruma	Kenya	10000	1968	1981		356	238.00
Tana	Grand Falls	Kenya	17580	1948	1958	1250	261	692.00
Thiba	above Machanga	Kenya	1970					80.00
Bokong	Bokong	Lesotho	403	1978	1982			3.00
Caledon	Mohlokagala	Lesotho	5600	1976	1982			930.00
Caledon	Mashili	Lesotho	1560	1976	1982			730.00
Caledon		Lesotho	945					1979.00
Hlotse	Ha Setene	Lesotho	728	1978	1982			790.00
Hololo	Khukhune	Lesotho	212	1978	1982			80.00
Khobelu	Tlokoeng	Lesotho	852	1978	1982			14.00
Little Caledon	Masianokeng	Lesotho	945	1971	1976	873	103	1979.00
Malibamatso	Paray	Lesotho	3240	1976	1982			60.00
Malibamatso	Ha Lejone	Lesotho	1157	1976	1982			9.00
Maphutseng	Maphutsaneng	Lesotho	323	1978	1982			500.00
Matsoku	Seshote	Lesotho	662	1978	1982			7.00
N Phuthiatsana	Kolonyama	Lesotho	905	1978	1982			740.00
N Phuthiatsana	Mapoteng	Lesotho	386	1976	1982			2050.00
S Phuthiatsana	Masianokeng	Lesotho	945	1976	1982			1382.00
Senqu	Seaka	Lesotho	19875	1976	1982			210.00
Senqu	Koma - Koma	Lesotho	7950	1976	1982			70.00
Senqu	Mokhotlong	Lesotho	1660	1976	1982			30.00
Senqu	White Hill	Lesotho	10900	1976	1982			140.00
Beritsoka	Barrage	Madagascar	575	1970	1971	1202	300	3130.00
Morondava	Tslandava	Madagascar	4255	1970	1971	1262	462	1586.00
Morondava		Madagascar	4200				430	1600.00
Sakamaly	Migodo	Madagascar	799	1970	1971	1181	355	2440.00
Faleme		Mali	15000					40.00
Senegal		Mali	157400					14.60
Aoudour		Morocco	1039	1969		1179	490	3850.00
B Regreg	S Mohamed b Abdellah	Morocco	9800	1974	1986	530	85	338.00
B Regreg		Morocco	9800	1983		500	91	370.00
Beih	El Kansera	Morocco	4540	1935	1986	550	82	325.00
Beih		Morocco	4540	1983		570	87	440.00

The following data has been extracted from the World River Sediment Yields Database of the FAO Water Resources Development and Management Service, available via the Internet.

River	Location	Country	Catchment Area (km²)	Monitoring started	Monitoring ended	Rainfall (mm/y)	Runoff (mm/y)	Sedim. yield (t/km²/y)
Bou Sellem		Morocco	2300				20	100.00
Draa	Mansour Eddahbi	Morocco	15000	1972	1986	190	27	410.00
El Abid	Bin El Quidane	Morocco	6400	1953	1986	620	176	675.00
El Abid	Bin el ouidane	Morocco	6400	1983		650	190	740.00
Er Rbia	Imfout	Morocco	30000	1983		300		160.00
Er Rbia	Al Massira	Morocco	28500	1979	1986	400	104	415.00
Fraa	Mansour Eddahbi	Morocco	15000	1983		180	26	450.00
Inaouene	Idris I	Morocco	3680	1972	1986	800	157	707.00
Inaouene		Morocco	3680	1983		780	161	780.00
Inaouene		Morocco	3324	1969		831	167	1110.00
Issen	Abdelmoumen	Morocco	1300	1981	1986	500	67	200.00
Loukos	El Makhazine	Morocco	1820	1979	1986	1130	455	1299.00
Loukos		Morocco	1820	1983		1130	417	1420.00
M'Jara		Morocco	5190					2910.00
Massa		Morocco	3784	1983		300	32	420.00
Massa	Youssef b Tachfine	Morocco	3784	1973	1986	300	32	378.00
Mellah		Morocco	1800	1983		420	88	560.00
Mharhar	Ibn Battouta	Morocco	178	1977	1986		365	3650.00
Moulouya		Morocco	51000				30	130.00
Moulouya	Mohamed V	Morocco	49920	1983		314	19	420.00
Moulouya	Mohammed V	Morocco	49920	1976	1986	310	15	383.00
N' Fis	Lalla Takerkoust	Morocco	1707	1935	1986	560	97	1100.00
N'Fis	Lalla Takerkoust	Morocco	1707	1983			101	420.00
Nakhla	Nakhla	Morocco	107	1961	1986	900	636	1576.00
Nekor	M B Abdelkrim	Morocco	780	1981	1986	340	103	4620.00
Nekor	M B Abdelkrim	Morocco	780	1983		340	119	5900.00
Querrha	M'Jara	Morocco	6183	1969		1065	441	3500.00
Querrha	Ourtzarh	Morocco	4398	1969		1074	459	3340.00
Querrha	B Ouender	Morocco	1756	1969		966	326	3590.00
Sebou		Morocco	40000				130	930.00
Sebou	Azib Soltane	Morocco	16276	1969		684	136	650.00
Sebou	Pont Sebou	Morocco	12985	1969		730	152	750.00
Sebou	Pont de M'dez	Morocco	3474	1969		667	73	320.00
Sebou	A Timedrine	Morocco	4429	1969		655	156	590.00
Sous		Morocco	16000				200	260.00
Tessaout	Moulay Youssef	Morocco	1441	1970	1986	650	268	1291.00
Tessaout	Moulay Youssef	Morocco	1441	1983		650	237	1400.00
Unknown	Hassan Ter	Morocco	1670	1987	1990			617.00
Unknown	Oued Mellah	Morocco	1800	1931				127.70
Ziz	Hassan Eddakhil	Morocco	4400	1971	1986	170	33	511.00
Ziz	Hassan Eddakhil	Morocco	4400	1983		170	37	570.00
Limpopo		Mozambi	410000				13	80.00

The following data has been extracted from the World River Sediment Yields Database of the FAO Water Resources Development and Management Service, available via the Internet.

River	Location	Country	Catchment Area (km²)	Monitoring started	Monitoring ended	Rainfall (mm/y)	Runoff (mm/y)	Sedim. yield (t/km²/y)
		que						
Limpopo	Beitbridge	Mozambique	196000					17.30
Zambesi		Mozambique	1400000				390	35.00
Bunsuru	Zurmi	Nigeria	6826	1962	1965	742	60	161.00
Bunsuru		Nigeria	5900					438.00
Gagare	Kaura Namoda	Nigeria	6172	1962	1965	909	83	225.00
Niger		Nigeria	1200000				160	33.00
Niger	Baro	Nigeria	1113227			1000	172	5.00
Rima	Argungu	Nigeria	43490	1964	1965		38	7.00
Rima	Rima Bridge	Nigeria	21590	1963	1965			16.00
Rima	Sabon Birni	Nigeria	19832	1962	1965		48	100.00
Sokoto	Sokoto	Nigeria	12851	1962	1965		60	212.00
Sokoto	Gusau	Nigeria	2653	1962	1965	1024	134	257.00
Sokoto	Bakolori	Nigeria	4344	1965		966	151	426.00
Watari		Nigeria	1450					483.00
Zamfara	Kalgo	Nigeria	16678	1962	1965		85	38.00
Zamfara	Anka	Nigeria	4126	1962	1965		147	344.00
Senegal		Senegal	270000				48	8.00
Orange		South Africa	890000				100	100.00
Orange	Bethulie	South Africa	6362	1929	1969			890.00
Atbara	Khashm el Girba	Sudan	20000	1964	1976		545	3422.00
Blue Nile	Roseires	Sudan	90000	1966	1976		555	957.00
Ikowa ?	Ikowa	Tanzania	640	1957	1969			292.00
Ikowa ?	Ikowa	Tanzania	640	1957	1960			543.00
Ikowa ?	Ikowa	Tanzania	640	1960	1963			290.00
Ikowa ?	Ikowa	Tanzania	640	1963	1969			167.00
Ikowa ?	Ikowa	Tanzania	640					287.00
Ikowa ?	Ikowa	Tanzania	640	1957	1969	573		192.00
Morogoro		Tanzania	19					390.00
Rufiji		Tanzania	180000				50	95.00
Rufiji	Stiegler's Gorge	Tanzania	156600	1954	1970	1050		106.00
Medjerda	Mouth	Tunisia	20927					708.00
Zaire	Mouth	Zaire	4012795			1750	312	18.00
Zaire		Zaire	3800000				340	11.00
Gwai		Zimbabwe	14500					56.00
Hunyani		Zimbabwe	1510					16.00
Umsweswe		Zimbabwe	1990					34.00

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO ALTO KUANZA

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Tassongue	298	Gango	2	91	1.1	3	14	
Quipeio	2691	Gango	16	46	6	15	70.1	
Banza-Tamba	2943	Gango	18	140	19	40	227	
Muanga-Tumbo	3687	Gango	18	65	9.3	20	109.4	
Lunga	6123	Gango	23	30	5.5	10	64	
Embala-Andulo	2909	Cutato	14	70	6.9	15	80	
Salamanca	2880	Luvulu	17	25	2.5	5	30	
Cutato	7033	Cutato	39	19	4.1	10	47.2	
Cambungo	9811	Cutato	39	110	34	60	400	
Cunhinga	1058	Cunhinga	_	_	_	_	_	
Chivava	865	Cune	13	75	7.2	15	80	
Cundende	1010	Coquema	2	50	0.7	1	8	
Chimbemba	894	Cuito	2	17	0.3	1	3.7	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO ALTO KUANZA (continuação)

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Coemba	2210	Coemba	11	68	6.2	15	72.2	
Salamba	4013	Luando	16	111	15	20	174.4	
Quissol	2835	Cuije	15	22	1.8	3	14	
Cativa	23066	Kuanza	70	22	8.4	15	96	
Dando	35537	Kuanza	135	34	37	70	428.8	
Quissande	92767	Kuanza	387	30	61	120	536	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO MÉDIO KUANZA

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço previsão
Capanda	109022	Kuanza	400	90	115	450	1080	em construção
N'Hangue	112536	Kuanza	500	90	150	450	1300	
Lauca *	112617	Kuanza	500	135	540	2120	4700	
Caculo-Cabaça * *	112663	Kuanza	500	215	850	1560	7500	
Zenzo-I	113218	Kuanza	500	80	310	450	2700	
Zenza-II	113239	Kuanza	500	20	80	120	700	
Tumulo do caçador	113503	Kuanza	500	80	310	450	2700	
Luime	115122	Kuanza	500	43	170	330	1500	
Cambambe * * *	115524	Kuanza	500	114	470	580	4100	1962-73

***** (produção em trés centrais)

****** (produção em duas centrais)

******* (produção em duas centrais, uma já em exploração)

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO LUCALA

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço previsão
Duque	7300	Lucala	17	112	15	30	130	
Carianga	14500	Lucala	70	220	117	240	1025	
Bembeze	15600	Lucala	65	218	113	250	990	
Cangala Gala	18200	Lucala	70	63	34	105	300	
Cabondo	18500	Lucala	69	69	36	60	315	
Mungongo	18700	Lucala	69	78	43	60	375	
Cababanga	19900	Lucala	69	49	27	45	235	
Tabanga	20200	Lucala	70	60	31	105	270	
Caango	20400	Lucala	70	105	58	160	510	
Quituto		Lucala	22	105	16	16	95	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO CATUMBELA

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
1- (Chicuma) *	2117	Catumbela	46	144	53	53	458	
2B *	2725	Catumbela	48	63	24	24	209	
3- (Cuvera)	3408	Catumbela	48	65	25	25	215	
19	3116	Cuivo	58	30	14	14	120	
4	3448	Catumbela	31	20	5	5	42	
5	7242	Cuivo	100	65	51	51	449	
5A	8080	Catumbela	220	40	70	70	605	
6	8304	Catumbela	210	60	100	100	870	
7	8262	Catumbela	125	30	30	30	259	
24 *	418	Cubal	7.5	6.5	6.5	6.5	56	
25	456	Cubal	8	95	6	6	52.5	
26	520	Cubal	10	25	2	2	17.2	
27	557	Cubal	9	70	5	5	43.5	
28	569	Cubal	5	150	6	6	51.8	

* (Aproveitamento com albufeira de Regulação)

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO CATUMBELA (CONTIUAÇÃO)

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
29	823	Cubal	19	80	12	12	105	
20	3663	Cubal	98	90	70	70	609	
21	3974	Cubal	55	30	13	13	114	
22	4479	Cubal	60	50	24	24	207.3	
22A	4598	Cubal	62.5	20	10	10	86.4	
22B	4710	Cubal	60	20	10	10	83	
8- (Lomaun)	8297	Catumbel	125	25	25	25	216	1964
9	8399	Catumbela	80	188	120	120	1040	
12	9278	Catumbela	136	55	60	60	517	
13 *****	10032	Catumbela	120	94	90	90	779	
14 *****	15344	Catumbela	274	183	400	400	3456	
15A	15494	Catumbela		170	_	_	_	
11	_	_	66	_	60+30	60+30	_	
111	_	_	59	_	80	80	_	

* (Aproveitamento com albufeira de Regulação)

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO CATUMBELA (continuação)

Aprovetamento	Área da ^Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
2º			125		200	200		
16	15907	Catumbela	275	50	110	110		
17 -(Biópio)	15919	Catumbela	157	30	34	34		1957
18A	16016	Catumbela	285	60	135	135		
18B	16207	Catumbela	179	35	50	50		

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO CUNENE (Aproveitamento Angolano)

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Regularizado (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Gove	4811	Cunene	46	36	13.2	25	114.4	
Jamba-Ia-Oma	8637	Cunene	78	40	25	50	215.6	
Chivondua	8681	Cunene	78	30	18.7	15	162	
Jamba-Ia-Mina	12336	Cunene	98	79	62	130	535	
Matala	28037	Cunene	103	20	16.4	45.5	142	1959
Matunto	41048	Cunene	118	30	28.3	50	72	
Chissola	837	Calai	6.6	82	4.3	6.5	37	
Caringo	1209	Cuando	12	36	3.4	5	30	
Gunge	1333	Cuando	13.2	50	5.3	4	34	
Lucunde	1403	Cuando	14	58	6.5	6.5	56	
Cabundi	829	Catapi	7.7	58	3.6	14.5	31	
Catembulo	_	_	_	_	_	_	_	_
Rega	4510	Cului	148	25	2.9	5	25	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO CUNENE (Aproveitamentos Internacionais)

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Calueque	_	Cunene	144	11	12.6	20	110	
Jacavale	_	Cunene	138	28	30.9	60	267	
Luandege	_	Cunene	138	143	157.8	195	1364	
Ruacaná	89600	Cunene	138	134	148	300	1278	
Ondorusu	_	Cunene	138	45	38.6	70	334	
Zebra	_	Cunene	138	29	32	60	276	
Epupa- II	_	Cunene	138	113	125	325	1078	
Epupa- I	_	Cunene	138	41	45	120	391	
Baynes	_	Cunene	138	125	138	260	1192	
Mariem	_	Cunene	138	140	155	300	1335	
Hartman	_	Cunene	138	67	74	140	639	
Hombolo	_	Cunene	138	93	103	195	887	
Mcha	_	Cunene	138	41	45.2	90	391	

*** (Considerando que somente 50% da Produção, ao longo da Fronteira, pertence à República de Angola)**

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO QUEVE

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Máximo (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Caivole	9336	Queve	98	55	35	70	275	
Cafula	19040	Queve	164	230	270	540	2115	
Dtiundumbo	19420	Queve	164	100	118	235	927	
Dala	19450	Queve	164	205	255	510	1998	
Benga	19650	Queve	164	335	400	815	3132	
Capunda	20170	Queve	164	150	190	380	1494	
Balalunga	20660	Queve	164	110	138	275	1080	
Cachoeiras da Binga	20760	Queve	164	80	98	195	765	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO CUBANGO

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Mèdio (m3/s)	Queda Bruta Média (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Cavango	2452	Cubango	27.6	16		7	12.8	
Chazenga	6508	Cubango	58.6	17		15	29	
Mangonga	7065	Cubango	61.4	30		26	53.4	
Mumba	12495	Cubango	92	30		40	79	
Muculungungo	38148	Cubango	179	20		54	103.8	
Mucundi	50024	Cubango	203	25		74	142.2	
M'bambi *****	_	_	_	_	_	_	_	
Calemba	3381	Cubango	27.2	13		53	10.23	
Cutato	3683	Cubango	29.6	80		32.5	68.6	
Malobras	8774	Cubango	55.5	58		48	92.66	

*** (Internacional)**

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO N'GUNZA, QUICOMBO, EVALE e BALOMBO

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Regular (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Chiongo	1131	N'gunza	9.7	105	7.4	15	59	
Ganja	1179	N'gunza	10	145	11	20	87	
Calixa	1678	N'gunza	11	410	35.6	90	284	
Cumbe	3726	Quicombo	35	500	137	295	1093	
Gangaue	4069	Quicombo	51	65	24.5	49	185	
Cavonde	3198	Balombo	28	55	10.1	25	81	
Sungo	3700	Balombo	41	695	232	352	550	
Camama	53-3700	Evale-Balombo	41	460	151	240	1149	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

BACIA DO LONGA

Aprovetamento	Área da Bacia Hidrográfica (Km2)	Rio	Caudal Regular (m3/s)	Queda Bruta (m)	Potência garantida (MW)	Potência à instalar (MW)	Energia Garantida GWh	Ano de Entrada em Serviço (previsão)
Quissuca	6304	Longa	27	210	43	110	336	
Cuteca	6549	Longa	27	345	73	185	572	
Cacula	8670	Longa	77	180	108	170	922	
Lundo	3080	N'Hia	29	50	17	17	95	
Cassongo	4402	N'Hia	29	190	45	110	471	
Lungo	4533	Zó	40	85	27	50	212	
Murimbo	830-4543	Luau	46	240	77	170	704	
Quissonhe	1133-4953	Luau	77	305	185	395	1579	

APPENDIX B - EXISTING AND POTENTIAL HYDROELECTRIC PLANT IN ANGOLA

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APPENDIX C

GEODATA DOCUMENTATION AND DESCRIPTION

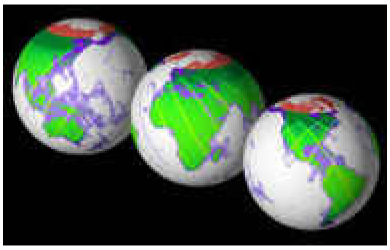
1 INTRODUCTION

This chapter describes data collected and utilized in the current study. It describes the source of data, collection method, and file and attribute information contained within the data. The data is gathered from sources in Angola and from many other parts of the world.

The data came either in the form of vector information as in lines, points or polygons like in ESRI Shapefiles (*.shp) or ArcInfo Exportformat (*.e00), in gridded information as in images or rasters.

1.1 Terrain models

1.1.1 SRTM



The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Imagery and Mapping Agency (NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry.

The SRTM instrument consisted of the Spaceborne Imaging Radar-C (SIR-C) hardware set modified with a Space Station-derived mast and additional antennae to form an interferometer with a 60 m long baseline. A description of the SRTM mission, can be found in Farr and Kobrick (2000).

Synthetic aperture radars are side-looking instruments and acquire data along continuous swaths. The SRTM swaths extended from about 30 degrees off-nadir to about 58 degrees off-nadir from an altitude of 233 km, and thus were about 225 km wide. During the data flight the instrument was operated at all times the orbiter was over land and about 1000 individual swaths were acquired over the ten days of mapping operations. The lengths of the acquired swaths range from a few hundred to several thousand kilometres. Each individual data acquisition is referred to as a "data take."

SRTM was the primary payload on the STS-99 mission of the Space Shuttle Endeavour, which launched February 11, 2000 and flew for 11 days. Following several hours for instrument deployment, activation and checkout, systematic interferometric data was collected for 222.4 consecutive hours. The instrument operated virtually flawlessly and imaged 99.96% of the targeted landmass at least one time, 94.59% at least twice and about 50% at least three or more times. The goal was to image each terrain segment at least twice from different angles (on ascending, or north-going, and descending orbit passes) to fill in areas shadowed from the radar beam by terrain.

This 'targeted landmass' consisted of all land between 56 degrees south and 60 degrees north latitude, which comprises almost exactly 80% of the total landmass.

1.1.1.1 Data Set Characteristics

SRTM data was processed in a systematic fashion using the SRTM Ground Data Processing System (GDPS) supercomputer system at the Jet Propulsion Laboratory in Pasadena, California, USA. Data was mosaiced into approximately 15,000 one degree by one degree cells and formatted according to the Digital Terrain Elevation Data (DTED) specification for delivery to NIMA. Data were processed on a continent-by-continent basis. NIMA applied several post-processing steps to these data including editing, spike and well removal, water body levelling and coastline definition. Following these "finishing" steps data was returned to NASA for distribution to the scientific and civil user communities, as well as the public.

1.1.1.2 Organization of Data

SRTM data are delivered in individual rasterized cells, or tiles, each covering one degree by one degree in latitude and longitude. Sample spacing for individual data points outside of US territory is 3 arc-seconds, referred to as SRTM-3. Since one arc-second at the equator corresponds to roughly 30 meters in horizontal extent, the sets are sometimes referred to as "90 meter" data.

1.1.1.3 Elevation Mosaics

Each SRTM data tile contains a mosaic of elevations generated by averaging all data takes that fall within that tile. Since the primary error source in synthetic aperture radar data is speckle, which has the characteristics of random noise, combining data through averaging reduces the error by the square root of the number of data takes used. In the case of SRTM the number of data takes could range from a minimum of one up to as many as ten.

1.1.1.4 Data Formats

The names of individual data tiles refer to the longitude and latitude of the lower-left (southwest) corner of the tile (this follows the DTED convention as opposed to the GTOPO30 standard).

SRTM-3 data are sampled at three arc-seconds and contain 1201 lines and 1201 samples with similar overlapping rows and columns. This organization also follows the DTED convention. Unlike DTED, however, 3 arc-second data are generated in each case by 3x3 averaging of the 1 arc-second data - thus 9 samples are combined in each 3 arc-second data point. Since the primary error source in the elevation data has the characteristics of random noise this reduces that error by roughly a factor of three.

This sampling scheme is sometimes called a "geographic projection", but of course it is not actually a projection in the mapping sense. It does not possess any of the characteristics usually present in true map projections, for example it is not conformal, so that if it is displayed as an image geographic features will be distorted. However it is quite easy to handle mathematically, can be easily imported into most image processing and GIS software packages, and multiple cells can be assembled easily into a larger mosaic.

1.1.1.5 DEM File (.HGT)

The DEM is provided as 16-bit signed integer data in a simple binary raster. There are no header or trailer bytes embedded in the file. The data are stored in row major order (all the data for row 1, followed by all the data for row 2, etc.).

All elevations are in metres referenced to the WGS84 geoid. Note that this is from data processed by the "PI Processor", which uses the WGS84 ellipsoid.

Byte order is Motorola ("big-endian") standard with the most significant byte first. Since they are signed integers elevations can range from -32767 to 32767 meters, encompassing the range of elevation to be found on Earth.

In these preliminary data there will commonly be data voids from a number of causes such as shadowing, phase unwrapping anomalies, or other radar-specific causes. Voids are flagged with the value -32768.

1.1.1.6 Data Encoding Notes

Because the DEM data are stored in a 16-bit binary format, users must be aware of how the bytes are addressed on their computers. The DEM data are provided in Motorola or IEEE byte order, which stores the most significant byte first ("big endian"). Systems such as Sun SPARC and Silicon Graphics workstations use the Motorola byte order. The Intel byte order, which stores the least significant byte first ("little endian"), is used on DEC Alpha systems and most PCs. Users with systems that address bytes in the Intel byte order may have to "swap bytes" of the DEM data unless their application software performs the conversion during ingest.

1.1.1.7 SRTM Caveats

As with all digital geospatial data sets, users of SRTM must be aware of certain characteristics of the data set (resolution, accuracy, method of production and any resulting artefacts, etc.) in order to better judge its suitability for a specific application. A characteristic of SRTM that renders it unsuitable for one application may have no relevance as a limiting factor for its use in a different application.

In particular, data produced by the PI processor should be considered as "research grade" data suitable for scientific investigations and development and testing of various civil applications. No editing has been performed on the data, and the elevation data in particular contain numerous voids and other spurious points such as anomalously high (spike) or low (well) values. Water bodies will generally not be well defined, in fact since water surfaces generally produce very low radar backscatter they will appear quite "noisy" or rough in the elevations data. Similarly, coastlines will not be well defined.

1.1.1.8 Africa Data Release

NASA has released the SRTM data set for the African continent, plus the Arabian Peninsula, the Persian Gulf area, and the island of Madagascar. This data set represents almost a quarter of the data collected during the mission, and follows similar releases for North and South America and Eurasia.
As with the other SRTM data for regions outside the United States the Africa set is sampled at 3 arc-seconds, which is 1/1200th of a degree of latitude and longitude, or about 90 metres (295 feet).

Because of persistent cloud cover or inhospitable terrain Africa has been one of the most poorly mapped regions of the planet. Thus the SRTM data reveal, mostly for the first time, an enormous diversity of landforms including the deserts and mountains of the north, the tropical forests and rift valley of central Africa, and the plateaus and coastal plains of the south.

1.1.1.9 Conversion from DEM files to ESRI Grid

For conversion an avenue script for ArcView 3.2 was used. Grid Machine 6.44, made by Johannes Weigel, imports and exports various data formats among these *.hgt (SRTM data). Each tile was then merged (Union) into one raster file covering Angola. The area covered, stretches from10 degrees to 26 degrees longitude and -3 degrees to -19 degrees latitude, covering and area approximately 1780 x 1780 km, or 3,168,400 km^2.

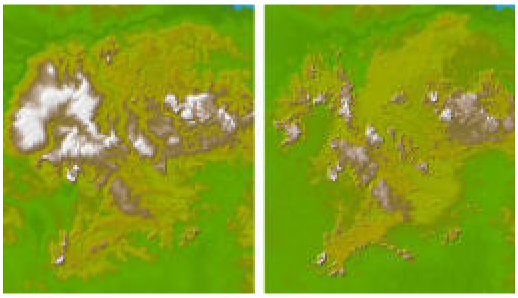
The file is named ***S04-S19***.

1.1.1.10 References

T.G.Farr, M.Kobrick, 2000, Shuttle Radar Topography Mission produces a wealth of data, American Geophysical Union Eos, v. 81, p.583-585.

1.1.2 WORLDCLIM – Altitude

This altitude dataset is a compilation and interpolation of the SRTM 1 arc-second data into a 30 arc-seconds (1 km) dataset. SRTM data was used to update the older USGS GTOPO30 global DEM, by averaging to 30 arc-sec resolution and replacing GTOPO30 heixels between the latitudes of 60° North and 56° South.



Figur 1 *Difference between old and new GTOPO30 Global dataset.*

1.2 DCW – Digital Chart of the World

The Digital Chart of the World contains data for the world at a scale of 1:1,000,000. There are various thematic layers including: political/oceans, populated places, roads, railroads, utilities, drainage, hypsography (elevation), land cover, ocean features, aeronautical, cultural landmarks, transportation structure, and vegetation.

1.2.1 Data Sources

The U.S. Defense Mapping Agency Operational Navigation Chart (ONC) series and the Jet Navigation Charts (JNCs) for the region of Antarctica were the primary sources for the Digital Chart of the World database. The ONCs have a scale of 1:1,000,000, and they are the largest scale, unclassified map series produced by the DMA that provides consistent, continuous global coverage of essential base map features.

Some collateral sources have been used to enhance road and railroad connectivity through selected urbanized areas. The DMA's Digital Aeronautical Flight Information File (DAFIF) was the primary source for the aeronautical layer. The Defense Intelligence Agency Manual (DIAM) 65-18 is the source for the Geopolitical codes and the ocean boundaries information contained in the Political and Oceans layer. The product specifications for the ONCs and JNCs have been used extensively in the design of the database.

The 1:1,000,000-scale ONCs were designed to meet the needs of the pilots and aircrews in medium and low altitude en route navigation by visual and other techniques. The ONC series was also designed to support military operational planning, intelligence briefings, preparation of visual cockpit displays, and other DMA uses.

Operational Navigation Chart (ONC) Product Specification are designed and produced to support medium altitude en route navigation by dead reckoning, visual pilotage, celestial, radar, and other techniques. These charts are also widely used for mission planning/analysis, intelligence briefings, and the preparation of visual cockpit navigational display/navigational filmstrips. They provide a small-scale translation of the cultural and terrain features for the pilots/navigators flying at medium (2,000 feet to 25,000 feet AGL) and low altitudes (500 feet to 2,000 feet AGL).

1.2.2 Political and Oceans Layer

1.2.2.1 DCW PONET (polygon)

Political/Oceans polygon type

POPYTYPE	*Code Definition*
1	Land

1.2.3 Populated Place Layer

1.2.3.1 DCW PPPOLY (polygon)

Populated place polygon type. This coverage contains depictions of the urbanized areas (built-up areas) of the world that can be represented as polygons at 1:1,000,000 scale. The built-up areas represent the shape of an urbanized area as viewed by the air observer. These outlines do not necessarily conform to political boundaries.

PPPYTYPE	*Code Definition*
1	Urbanized area

1.2.3.2 DCW PPPOINT (point)

Populated place point type

PPPTTYPE	Code Definition
1	Populated place (no subcategories*)
2	Populated place (associated with place names within urbanized areas)

PPPTNAME	Code Definition
"Place name"	The item PPPTNAME contains a thirty-character field to carry the specific name of the populated feature as it appears on the ONC. Names are contained in this item.

1.2.4 Railroad Layer

1.2.4.1 DCW RRLINE (line)

Railroad line type

RRLNTYPE	Code Definition
1	Single track railroad
8	Added railroad connector within urbanized area polygons

RRLNSTAT	Code Definition (Railroad line status)
1	Functioning
2	Non-operating, abandoned, destroyed, or under construction
9	Functioning, within urbanized areas

1.2.5 Road Layer

1.2.5.1 DCW RDLINE (line)

Road line type

RDLNTYPE	Code Definition
2	Primary and secondary road
3	Track, trail, or footpath
8	Added road connector within urbanized area polygons

Road line status

RDLNSTAT	Code Definition
1	Functioning
4	Compile road connector (used for arcs added from other source materials in order to provide cartographically correct connectivity within urbanized area polygons)
5	Compiled from adjacent, more recent sheet (used for arcs added for edgematch or network connectivity in the ONC sheet overlap areas)
9	Schematic road (used for arcs added within the urbanized area polygons for network connectivity only)

1.2.6 Utilities layer

1.2.6.1 DCW UTLINE (line)

Utility line type

UTLNTYPE	Code Definition
1	Power transmission line

1.2.7 Drainage layer

1.2.7.1 DCW DNNET (polygon)

Drainage feature type

DNPYTYPE	Code Definition
1	Perennial inland water. Includes perennial lakes and streams, estuaries, lagoons, unsurveyed perennial streams, reservoirs, and navigable canals
2	Nonperennial inland water. Includes nonperennial and seasonally fluctuating lakes and streams, wadis, sabkhas, and abandoned navigable canals

1.2.7.2 DCW DNNET (line)

Drainage line type

DNLNTYPE	Code Definition
1	Stream, river, canalised river
2	Inland water body shoreline

Drainage line status

DLNSTAT	Code Definition
1	Perennial (used for rivers and streams only
2	Nonperennial (used for rivers and streams only)

3	Definite (used for inland shorelines only)
4	Indefinite (used for inland shorelines only)
8	Under construction

1.2.7.3 DCW DNPOINT (point)

Drainage point type

DNPTTYPE	Code Definition
3	Falls
4	Rapids
6	Dam*

*Those dams shown on the ONCs with their true shape and extent are also present as line data in the Cultural Landmark layer.

1.2.8 Supplemental Drainage Layer

1.2.8.1 DCW DSPOINT (point)

Supplemental drainage point type. This item contains those ONC drainage features that could not be captured as polygons during the scanning process. Polygons less than 0.12 inches in circumference were automated as point features. The resulting point location is located on the perimeter of the former polygon feature.

DSPTTYPE	Code Definition
1	Small lake, inland water body (lakes, reservoirs, lagoons)
2	Small island within inland water areas

1.2.9 Hypsography Layer

1.2.9.1 DCW HYNET (polygon)

Hypsography polygon type. The hypsography polygons are coded to form elevation zones, as indicated in the classification scheme below.

HYPYTYPE	Code Definition
2	0 to 1,000 feet above mean sea level
3	1,000 to 3,000 feet
4	3,000 to 7,000 feet
5	7,000 to 11,000 feet

1.2.9.2 DCW HYNET (line)

Hypsography line

HYLNVAL
The item HYLNVAL contains the elevation value of the contour line expressed as feet above mean sea level. When contour lines for different elevations become coincident, as in areas of steep local relief, only a single carrying contour is shown and is coded for the value for the highest elevation present. Valid contour line codes range from –1,000 feet to 29,000 feet incrementing by 1,000 feet. Boundaries associated with no data areas are assigned a value of 99999.

Line Type

HYLNTYPE	Code Definition
0	Country border
1	Closed contour
8	Connector (an arbitrary connector of the contour network, used to define no data or irreconcilable source data areas. These connections were made to establish elevation zones as polygons.)

1.2.9.3 DCW HYPOINT (point)

Hypsography point type

HYPTTYPE	Code Definition
1	Spot elevation
2	Spot elevation, questionable or doubtful location

HYPTVAL
Point value. This item contains the elevation of the point, expressed in feet above the mean sea level. The value "99999" is used for spot locations without an assigned elevation value.

1.2.10 Hypsography Supplemental layer

1.2.10.1 DCW HSLINE (line)

Supplemental hypsography line type. This item indicates the specific type of the supplemental contour line. This coverage contains unclosed contours and/or contours at intervals other than 1,000 feet.

HSLNTYPE	Code Definition
1	Intermediate or auxiliary contour*

* An intermediate contour is one that is required between basic contours to portray form, degree of slope, and elevation not shown by the basic contour interval. An auxiliary contour is one that is used to portray configuration and relative relief significance of additional landforms not adequately portrayed by basic and/or intermediate contours.

HSLNVAL
Supplemental hypsography line value. The item HSLNVAL contains the elevation value of the contour line in feet above mean sea level (MSL). The code 99999 is used when an elevation value is not applicable.

1.2.11 Land Cover Layer

1.2.11.1 DCW LCPOLY (polygon)

Land cover polygon type.
Agricultural/Extraction Features

LCPYTYPE	Code Definition
1	Rice field
3	Cultivated area, garden
9	Unknown

1.2.11.2 DCW LCPOINT (point)

Land cover point type

LCPTTYPE	Code Definition
1	Mine
3	Miscellaneous land feature (e.g., mountain name, cave, sink hole, basalt pinnacle)

1.2.12 Aeronautical Layer

1.2.12.1 DCW AEPOINT (point)

Aeronautical point type. Airport feature in Codes 1 through 4 were derived from the DMA Digital Aeronautical Flight Information File (DAFIF). Where this file was incomplete, data were added from the ONCs (primarily in Eastern Europe and the former Soviet Union).

AEPTTYPE	Code Definition
1	Active civil
2	Active civil and military
3	Active military
4	Other

Also AEPTNAME (airportname)

1.2.13 Cultural Landmark Layer

1.2.13.1 DCW CLPOINT (point)

CLPTLABEL
Cultural landmark point label. Labels are entered for the symbols, if any, with labels. About 150 representative values are listed in the Digital Chart of the World *Data Dictionary*. Examples are: ancient ruins, cemetery, gas well, mountain pass, military area, power plant, racecourse.

1.2.14 Transportation Structure layer

1.2.14.1 DCW TSLINE (line)

Transportation structure line type.

TSLNTYPE	Code Definition
1	Road structure
2	Railroad structure

Line status

TSLNSTAT	Code Definition
2	Bridge

1.3 Geology, Earthquake and Soils

1.3.1 Geology

Polygon coverage's of the geology and hydrogeology of the country, and for the whole region. Data compiled from "Southern Africa FRIEND Phase II"

These geological and hydrogeological coverages were created by digitising national maps and integrating with some degree of standardisation to create a new regional geology/hydrogeology coverage. Each coverage contains five attributes showing the national lithology (as defined on national maps), a new regional lithological classification which integrates the different national lithological schemes, aquifer type, aquifer productivity and aquifer yield. Note that the coverage of Angola is incomplete, and the South African coverage does not contain the same attributes as the other countries. By selecting 'All Southern Africa' the user can obtain the same coverages across the whole SADC region, except for South Africa. These data were obtained via the FRIEND project, and from DWAF in South Africa, where the coverages originate from the WRC projects 517 and 483 (Vegter, 1995), which were contributions to the National Groundwater Map series. Further details of the maps used can be found in UNESCO (1997).

The attributes of interest in the coverage, and options required to view them, are (in all maps except for South Africa):

Attribute	Explanation	Classification Option
NAT_LITH	National geological classification for each country, adopted directly from the separate geological map legends.	Unique Values
REG_LITH	Unified geological classification for the whole region, developed by the British Geological Survey for the whole of Southern Africa (see table "Description of the REG_LITH attribute", below).	Unique Values
AQU_TYPE	Predominant aquifer type, based on the UNESCO hydrogeology legend: I = Intergranular, F = Fissured, L = Local	Unique Values
AQU_PROD	National aquifer productivity categorisation: H = High, M = Medium, L = Low	Unique Values
YIELD_LOW YIELD_MID YIELD_HIGH	National aquifer yield categorisation (in units of litres per second), with each polygon assigned values for lower, mid and upper yields	Unique Values

Description of the REG_LITH attribute:

Age	Formation	REG_LITH value	Lithology
Tertiary to Quaternary	Alluvium	1	Sands, silts, clays including lake beds
Tertiary to Quaternary	Kalahari Sands	2	Sands
Late Jurassic – Late Cretaceous – Tertiary		3	Marine sandstones, siltstones, shales
Upper Carboniferous to Lower Jurassic	Karroo Basalts	4	Lavas and associated igneous rocks
Upper Carboniferous to Lower Jurassic	Karroo Sediments	5	Sandstones, mudstones, siltstones
Upper Ordovician to	Cape System	6	Marine sandstones, shales

Lower Carboniferous			
Late PreCambrian to Lower Palaeozoic	Transvaal and Waterberg groups	7	Dolomites, quartzites, shales, sandstones
Middle to Late PreCambrian		8	Metasediments, igneous complexes, volcanic
Old PreCambrian Archaean		9	Basement granites and gneisses of shield areas

1.3.2 Gazetteer

Countryfile for Angola obtained from GeoNet Names Server at:

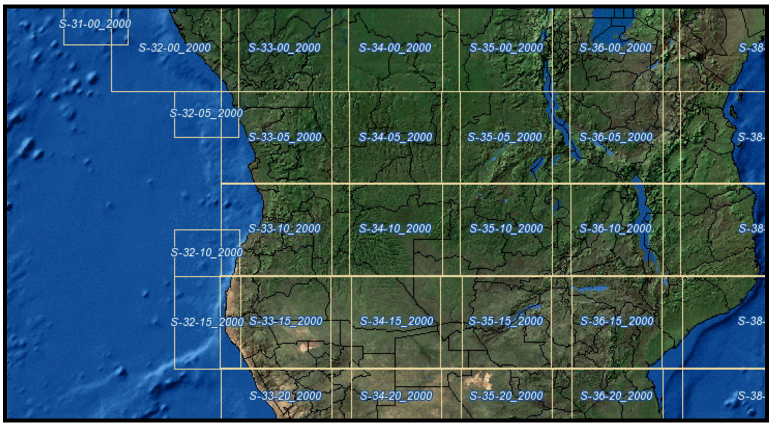
http://earth-info.nga.mil/gns/html/index.html

1.3.3 **Field Name and Descriptions**

Field Name	Field Description	Field Type	Maximum Field Length
RC	Region Code. A code that determines the character mapping used in the Full_Name field (refer to REGIONS.PDF for character mapping): 1 = Western Europe/Americas; 2 = Eastern Europe; 3 = Africa/Middle East; 4 = Central Asia; 5 = Asia/Pacific; 6 = Vietnam.	number	**1 Digit**
UFI	Unique Feature Identifier. A number which uniquely identifies the feature.	number	**± 10 Digits**
UNI	Unique Name Identifier. A number which uniquely identifies a name.	number	**± 10 Digits**
UGI	Unique Geospatial Reference Coordinate (GRC) Identifier. A number which uniquely identifies a GRC. A GRC is a set of multiple coordinates identifying a feature (in most cases the feature would be linear in nature). *This field is not normally selected by default.*	number	**± 10 Digits**
LAT	Latitude of the feature in ± decimal degree (WGS84): no sign (+) = North; negative sign (-) = South.	number	**± 2.15 Digits**
LONG	Longitude of the feature in ± decimal degree (WGS84): no sign (+) = East; negative sign (-) = West.	number	**± 3.14 Digits**
DMS_LAT	Latitude of the feature in ± degree, minuets, and seconds (WGS84): no sign (+) = North; negative sign (-) = South.	number	**± 6 Digits**
DMS_LONG	Longitude of the feature in ± degree, minuets, and seconds (WGS84): no sign (+) = East; negative sign (-) = West.	number	**± 7 Digits**
UTM	Universal Transverse Mercator coordinate grid reference.	character	**4 Characters**
JOG	Joint Operations Graphic reference.	character	**7 Characters**
FC	Feature Classification: A = Administrative region; P = Populated place; V = Vegetation;	character	**1 Character**

	L = Locality or area; U = Undersea; R = Streets, highways, roads, or railroad; T = Hypsographic; H = Hydrographic; S = Spot feature.		
DSG	Feature Designation Code. A two to five-character code used to identify the type of feature a name is applied to.	character	**5 Characters**
PC	Populated Place Classification. A graduated numerical scale denoting the relative importance of a populated place. The scale ranges from 1, relatively high, to 5, relatively low. The scale could also include NULL (no value) as a value for populated places with unknown or undetermined classification.	number	**1 Digit**
CC1	Primary Country Code. A two alphabetic character code uniquely identifying a geopolitical entity (countries, dependencies, and areas of special sovereignty).	character	**2 Characters**
ADM1	First-order administrative division. A two alphanumeric character code uniquely identifying a primary administrative division of a country, such as a state in the United States.	character	**2 Characters**
ADM2	Second-order administrative division. The name of a subdivision of a first-order administrative division, such as a county in the United States.	variable character	**200 Characters**
POP	Population Figures.	number	**10 Digits**
ELEV	Elevations (in meters, decimal values accepted).	number	**± 22 Digits - floating decimal point**
CC2	Secondary Country Code. A two alphabetic character code uniquely identifying the country code of a particular name if different than that of the feature.	character	**2 Characters**
GCC	Geospatial Reference Coordinate (GRC) Country Code. A two alphabetic character code uniquely identifying the country code of a particular name of a GRC. *This field is not normally selected by default.*	character	**2 Characters**
NT	Name Type: C = Conventional; D = Not verified; N = Native; V = Variant or alternate.	character	**1 Character**
LC	Language Code. A two alphabetic character code uniquely identifying a language of a country if multiple official languages are used.	character	**2 Characters**
SHORT_FORM	A specific part of the name that could substitute for the full name.	variable character	**128 Characters**
GENERIC	The descriptive part of the full name (does not apply to populated place names).	variable character	**128 Characters**
SORT_NAME	A form of the full name which allows for easy sorting of the name into alpha-numeric sequence. It is comprised of the specific name, generic name, and any articles or prepositions. This field is all upper case with spaces, diacritics, and hyphens removed and numbers are substituted with lower case alphabetic characters.	variable character	**200 Characters**
FULL_NAME	The full name is a complete name which identifies the named feature. It is comprised of the specific name, generic name, and any articles or prepositions (refer to REGIONS.PDF for character mapping).	variable character	**200 Characters**
FULL_NAME_ND	Same as the full name but the diacritics and special characters are substituted with Roman characters (refer to REGIONS.PDF for character mapping). ND = No Diacritics / Stripped Diacritics.	variable character	**200 Characters**
MOD_DATE	The date a new feature was added or any part of an existing feature was modified (**YYYY-MM-DD**). *This field is not normally selected by default.*	date-time	**10 Characters**

1.4 Satellite Imagery



Landsat 7 scenes from year 2000 were collected and visualized in the GIS system

Detail image from Landsat 7 scene

1.4.1 Orthorectified Landsat Enhanced Thematic Mapper (ETM+) Compressed Mosaics

Mosaic Specifications:

Spectral Bands:
Three Landsat ETM+ bands, each sharpened with the panchromatic band.
Band 7 (mid-infrared light) is displayed as red
Band 4 (near-infrared light) is displayed as green
Band 2 (visible green light) is displayed as blue

Coverage:
The GeoCover Landsat mosaics are delivered in a Universal Transverse Mercator (UTM) / World Geodetic System 1984 (WGS84) projection. The mosaics extend north-south over 5 degrees of latitude, and span east-west for the full width of the UTM zone. For mosaics below 60 degrees north latitude, the width of the mosaic is the standard UTM zone width of 6 degrees of longitude. For mosaics above 60 degrees of latitude, the UTM zone is widened to 12 degrees, centred on the standard even-numbered UTM meridians. To insure overlap between adjacent UTM zones, each mosaic extends for at least 50 kilometres to the east and west, and 1 kilometre to the north and south.

Pixel size: 14.25 metres.

Contrast Enhancement:
In order to maximize the information of each mosaic, EarthSat has applied a company proprietary contrast stretch known as LOCAL (Locally Optimized Continuously Adjusted Look-up-tables) stretch. This stretch uses multiple, locally collected histograms, to create a radiometrically seamless blend of contrast adjustment across areas of potentially extreme contrast ranges. The suffix "__loc" is added to the mosaic name to signify the application of the LOCAL stretch.

Absolute Positional Accuracy: ±75

File Naming Convention:
Within each UTM zone the "partitions" extend from the equator to the north and south (in the northern and southern hemisphere respectively) in 5-degree increments. The naming convention for the mosaics is comprised of three components, separated by hyphens; the first element is the hemisphere (either N or S), the second is the UTM zone number (1-60), the last element is the latitude of the southern edge of the mosaic in the northern hemisphere and the northern edge of the mosaic in the southern hemisphere.

For example:

N-13-25_2000_loc: names a LOCAL stretched mosaic partition in the northern hemisphere, in UTM zone 13, extending between 25 and 30 degrees north latitude.

S-21-10_2000_loc names a LOCAL stretched mosaic partition in the southern hemisphere, in UTM zone 21, extending between 10 and 15 degrees south latitude.

GeoCover Mosaic Image Product Delivery Format:

The GeoCover Landsat image mosaics are being delivered to NASA both as uncompressed colour imagery in GeoTIFF format and as compressed colour imagery in MrSID^{TM} file format. The data are delivered in 24-bit colour.

More information on the MrSID compression format and viewing software can be found at http://www.lizardtech.com

Source (Input) Data:

Imagery:

Spectral Bands: Landsat ETM+ bands 7, 4, and 2

Coverage: 5x6 degrees (south of 60 degrees North), and 5x12 degrees (north of 60 degrees North),

Projection/Datum: UTM / WGS84

Pixel Size: Mixture of 14.25

Interpolation Method: Cubic Convolution

Orientation: North Up

Coverage Date: Scene dependent (nominally 2000 +/- 3 years)

Control:

Horizontal:
Image matching to 1990 GeoCover scenes where available, otherwise Landsat-7 ephemeris was used.

Vertical:
DTM with 3-arc second postings, where available. Where 3-arc second data not available, GTOPO30 (30-arc second) digital elevation models are used.

Mosaicing:
Radiometrically balanced across automatically collected seam lines.

Image Enhancements:
The data are spatially and spectrally unenhanced.

APPENDIX D

TERMS OF REFERENCE

Consultancy services for a rapid water resources and water use assessment of Angola

1 Background

-Historical background
The present project, ***A rapid water resources and water use assessment of Angola,*** is Activity C of the larger "National Water Sector Management" (NAWASMA) project, carried out since 2000 as institutional co-operation between the Angolan National Directorate of Water, DNA (Direcção Nacional de Águas) and the Norwegian Water Resources and Energy Directorate, NVE. The project covers the whole of Angola.

-*Tasks and problems*
The potential of renewable water resources of Angola is not known with sufficient accuracy, mostly due to lack of data. The same is the case for data on total water use, water consumption, and future water demand. Almost all of the 200 hydrometric stations in operation at independence in 1975 have been abandoned during the years of civil war. This situation makes proper water development planning practically impossible. In addition to providing up-dated estimates of resources and use, the future capacity for managing and planning water resources should be improved through the project by organising it in a way which transfers knowledge and capability to DNA.

-*Co-ordination with other activities*
The South Africa Development Community, SADC, where Angola is a member state, has developed a programme framework for the water sector. SADC has moreover developed a Protocol on Shared Water Courses. Angola is a party to this protocol. Angola shares important river basins with other countries, cf.3.1.

2 Objectives

2.1 Development goals

The development objective of the NAWASMA project is improved water sector management in Angola through a strengthened institutional capacity of DNA.

Proper water management requires solid knowledge. The specific objective of Activity C is therefore to assess rapidly the water resources, water use, and future water demand of Angola.

2.2 Immediate objectives

Activity C, the rapid water resources and water use assessment, has seven indicators of outputs:

1. Establishment of clear assumptions and methodologies to be applied in assessment estimates;
2. Estimation of Angola's renewable water resources (surface and groundwater) by river basins and aquifers;
3. Preliminary estimation of sediment transport in the different river basins, and the identification of river basins where soil erosion problems are most severe;
4. Development of scenarios for urban, peri-urban, and rural population growth in Angola up to the year 2025;
5. Development of scenarios for growth of water intensive industrial and mining activities;
6. Estimation of Angola's water demand for the different sub-sectors, with special emphasis on consumptive water use, and particularly the demand for full or supplementary irrigation;
7. Establishment of criteria and recommendations for future water resources and water use and demand assessment activities.

3 Scope of work

3.1 General

The project should identify sources of relevant hydrological and meteorological data, and make available qualified estimates of the main water balance elements.

The areal resolution of surface water assessment should be based on the major river drainage basins draining to the international rivers Congo, Zambezi, Okavango, and Cunene, and the coastal rivers draining to the Atlantic. A major catchment in this Atlantic region is the Luando-Kwanza (Cuanza) system, having a large hydropower potential. Where possible, the resolution should preferably be more detailed, and reported on the basis of catchments. The assessments should as a minimum quantify long-term (standard normal period) averages, and wherever possible, also indicators of variability.

Groundwater resources have been developed particularly in the dry coastal provinces in the southwest. Sustainable groundwater yields should be estimated. It is expected that groundwater observations may be scarce indeed, but geological information should be utilised as much as possible. The same applies to assessments of sediment transport (see 2.2, output indicator 3)

Scenarios of the growth of population and industrial/mining industries should be based on existing statistics and governmental policies. Water use in Angola is probably well below the average potential use, both within agriculture and public water supply, partly because of lack of infrastructure. Particular problems were caused during the civil war by migration from rural to urban and peri-urban areas, mostly unplanned and informal townships around urban centres.

It is not foreseen that the project should scrutinise raw data. However, assessments of data quality and judgment of the reliability of quantitative estimates and scenarios are important aspects, which should guide the reporting.

3.2 Preparatory work

The lack of relevant data is a major problem (cf. 1 above). Recently, 5 hydrometric stations have been rehabilitated. Hydrological data from the 1950-1975 period and sporadic data since 1975 are stored in a HYDATA database at DNA. The quality of the digitisation of data is uncertain, and a quality check of the rating curves has not been done, but is expected to take place soon.

In addition to data and other background material which will be provided by the client (see 4.1), the following material may be of probable importance for the study. However, the list is in no way exhaustive:

- Africonsult (1998): Republic of Angola. Management and development of the water resources. Report of country situation. Round Table June 1998
- NVE-SEEA (1994): National Meeting on Water Sector Management, NAWASMA-seminar, Luanda October 1994
- Robinson, P. (2003): Angola Water Policy Review. SADC Water Sector
- World Bank (2002): Africa's International Rivers. An Economic Perspective. By C.W.Scott, D.Whittington and D.Grey.

3.3 Specific tasks

- Desk study of existing reports
- Define the data sets needed.
- Decide on geographical (or other) basis for reporting.
- Decide on methodology for analysis.
- Collect and analyse information.

- Reporting, including ideas for maintaining and developing water resources and water use assessments in the future.

4 Mode of work

The project shall be carried out in close co-operation with personnel who are working on the NAWASMA project in Angola. The client, DNA, shall provide access to necessary maps, hydrological and statistical data for Angola, and other official material of relevance for the study. The Central Bureau of Statistics of Angola will be an important central data source for water demand assessments and development of scenarios i.e. outputs 4 and 5.

NVE will act as DNA's adviser during the study period, according to the contract between the two institutions.

5 Time schedule

The time for the study is estimated at 8 months. Milestones should be clearly defined, adapted to major work modules.

6 Reporting

A brief inception report is required 6 weeks after project start in order to allow possible minor adjustments, but still within the framework of the ToR. Brief monthly progress reports should be submitted thereafter to the client.

The final report should enable DNA and other Angolan authorities to move on in their work with national master plans for the water sector. It should also identify bottlenecks for further planning and management, in terms of data quality and availability. The final report shall present the methodology applied, and the results of the study for each of the seven components, cf. 2.2. The reliability of quantitative assessments is an important aspect, which should guide the reporting.

The final report should be submitted in 20 copies as well as in electronic form.

A copy of all reports shall be submitted directly to NVE, International Section.

Luanda, ……………………2003

National Director of Water, DNA