National strategy plan for rehabilitation of the hydrometric network in Angola

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National strategy plan for rehabilitation of the hydrometric network in Angola

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Preface

A cooperation agreement between The Norwegian Agency for Development Cooperation (NORAD) and The Norwegian Water Resources and Energy Directorate (NVE) states that NVE shall assist and advise NORAD and the Norwegian Ministry of Foreign Affairs within the framework of NVE's competence in management of water and energy resources. One project in this cooperation is the National Water Sector Management (NAWASMA) project, that was started in Angola in 2003. The NAWASMA project is an institutional cooperation between National Directorate of Water (DNA) in Angola and NVE. A main objective in this project is to strengthen DNA in the regional cooperation on water resources.

Institution and capacity building within hydrology is an important part of the NAWASMA project. A reliable hydrometric network is a prerequisite for good water governance. An evaluation and proposal for a future network is included in this report.

Oslo, September 2004

Kjell Repp

director, hydrology department

Executive summary

Based on principles for a national hydrometric network, the need for water data, and the hydrography of the country, recommendations for a future network in Angola are given. In the recommendations, the stations are classified. Class I includes stations with high priority that should be operated without any time limit. These stations will constitute the minimum network to describe the overall hydrological conditions in Angola. Class II includes stations that also should be operated without any time limit, and will constitute complementary stations in describing the hydrological conditions in Angola. Class III includes stations that can be operated only long enough to establish a stable relationship with a Class I or Class II station. The Class III stations could then be moved to another location.

The basis for the future network is the numerous stations that now are non-operating, due to the civil war. Totally, 47 stations are recommended in the future network, 8 of which are already re-established, 30 of which are old stations, 6 of which are stations at new locations, and 3 of which are situated in neighbouring countries. The total costs to establish and operate the recommended network during three years is estimated to 0.95 million USD.

1. Introduction

One activity of the National Water Sector Management (NAWASMA) project in Angola is to prepare a national strategy plan for rehabilitation of the hydrometric network. The strategy plan should include 1) a national plan for rehabilitation of the hydrometric network, 2) an identification of a primary hydrometric network and 3) a technical and/or organisational recommendation for maximum coordination and optimisation of hydrological and meteorological networks. See Terms of reference in annex 1.

The work on this national strategy plan took place during four weeks (10 March – 2 April 2004) at the office of the National Directorate of Water (DNA) in Luanda, Angola, resulting in the present report.

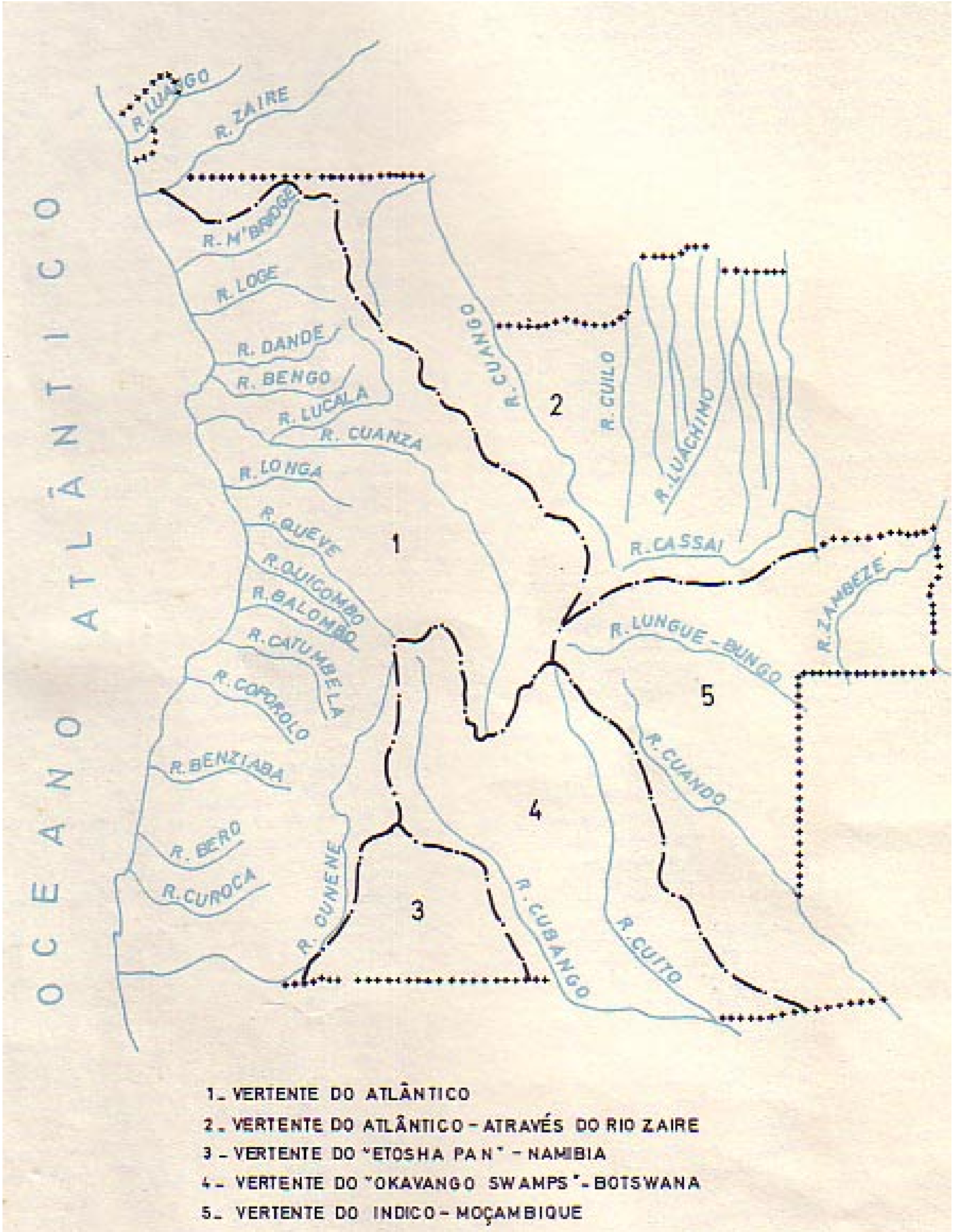
Most of the information on Angolan conditions was found in written papers/reports, see the list of References. In addition, the Angolan database with hydrological data and information (HYDATA) was used, and valuable information was obtained through informal meetings with Mr. Paolo Emilio Mendes and Mr. Olav Osvoll at DNA, Mr. Jan Stensrud (SSB) at the Angolan Statistical Institute, Mr. Bjørn Stenseth (Norplan) at the National Directorate of Energy (DNE), and Mr. Gualberto, director of the Angolan Meteorological Institute (INAMET).

This report focuses on hydrometric stations for runoff, which are stations monitoring water stage, and where the water discharge is estimated by use of a rating curve. Other hydrological parameters like ground water, sediment transport, water temperature, water quality etc. are not considered.

2. The river system of Angola

Angola is situated between latitudes 4º 22´ and 18º 02´ South and between 11º 41´ and 24º 05´ East of Greenwich. The total area is estimated at 1 246 700 km^2, 7 680 of which form the northern coastal province of Cabinda, isolated from mainland Angola by a strip some 40 km wide. To the north, Cabinda is bordered by the Republic of Congo, and to the east and the south by the Democratic Republic of Congo. The mainland Angola is bordered to the north and northeast by the Democratic Republic of Congo, to the east by Zambia, and to the south by Namibia, while the western border is formed by the Atlantic Ocean.

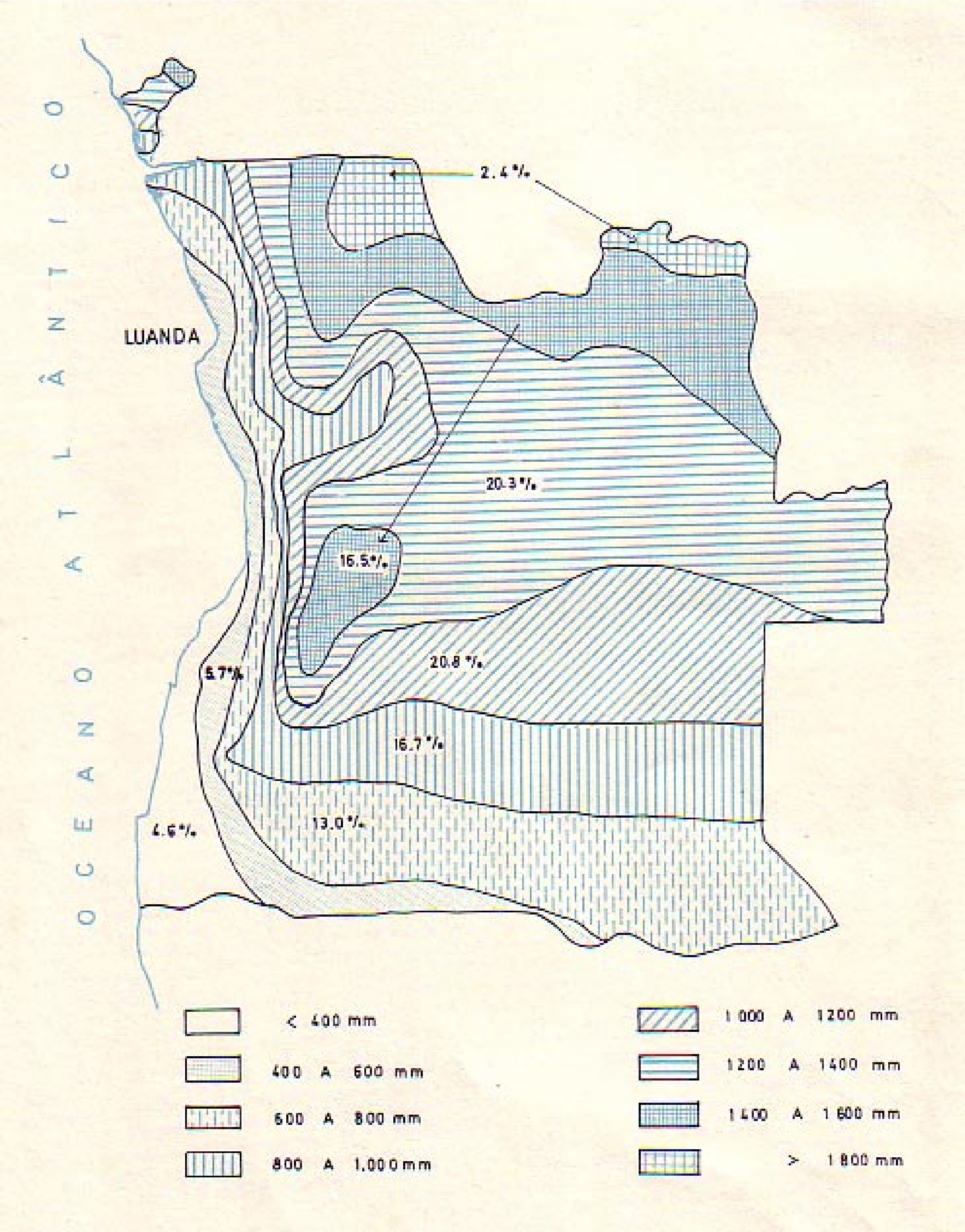
The river system of Angola can be divided into five principal drainage basins or regions: 1) the drainage basins of Western Angola, 2) the drainage basin of River Zaire (Congo), 3) the Cuvelai drainage basin, 4) the Okavango drainage basin, and 5) the Zambezi drainage basin. A characteristic fact is the almost complete absence of natural lakes in the river systems of Angola. However, there are some reservoirs constructed for energy production, irrigation or water supply. The dams at some of these reservoirs are in a bad condition.



Basins and rivers in Angola: 1) Western Angola basins, 2) Zaire (Congo) basin, 3) Cuvelai basin, 4) Okavango basin, 5) Zambezi basin [2].

1) The drainage basins of Western Angola cover about 500 000 km^2 or 40.1 % of the total area of Angola, and drain into the Atlantic. Most of the region is located

exclusively within Angola, while the basins in Cabinda and the Cunene basin are shared with neighbouring countries.



The mean annual precipitation in Angola [2].

The region of Cabinda covers 7 680 km^2 or 0.6 % of the total area of Angola. The only river of any size in Cabinda is Chiluango (Rio Luango), that has its headwaters in the Republic of Congo and the Democratic Republic of Congo. Together with small areas in northern and eastern Angola, in the Zaire and Zambezi basins, Cabinda is the only part of Angola that constitutes downstream areas to other countries.

Cabinda is a lowlying area with quite high annual precipitation. The region has quite high population density, with the city of Cabinda as the tenth biggest city in Angola with respect to number of inhabitants.

In the western part of mainland Angola, there are steep gradients from east to west both in elevation and in annual precipitation. In the eastern part of this region in mid-Angola, the elevation of the country varies between 1500 and more than 2000 m a.s.l. with Morro de Môco at 2620 m a.s.l. as the highest peak, while the annual precipitation is about 1500 mm. In a distance of some 200 km westwards, the terrain falls to sea level, where the climate is very dry, with an annual precipitation of less than 400 mm. There is also a precipitation gradient from north, where the annual precipitation is about 800 mm/year, to south along the coast.

In the northern part of this region, that totally includes 37 river basins, the largest basins are M'bridge, Loge, Dande and Bengo with basin areas between 10 000 and 19 000 km^2. In Dande, there is a small reservoir for energy production, Mabubas. However, that power plant is not in operation at the time. In the lower Bengo lies Quiminha reservoir, which is the water supply to Luanda. In this part of the region, the biggest cities are Uige in the inland, and Luanda and Caxito in the coastal area, and the population density is quite high.

To the south of Luanda is the outlet of Cuanza, the largest river basin in Western Angola with an area of 147 000 km^2. The river has its sources in the central part of Angola. In these upper parts of the basin there is a small reservoir for energy production at Cunje, a small water power plant. In the central part of Cuanza is the water power plant Capanda situated. The Capanda reservoir is quite large. Further downstream, the water power plant Cambambe is situated, with a small reservoir. Capanda and Cambambe are the most important water power plants in the country. The cities of Kuito, Malanje and N'Dalatando are situated in the Cuanza basin. The population density is not very high, except in the cities.

In the central part of Western Angola, the largest basins are Longa, Queve, Catumbela and Coporolo. Longa and Queve have basin areas of about 23 000 km^2, while Catumbela and Coporolo have areas of about 16 000 km^2. Catumbela, which has its outlet in the sea in the highly populated Lobito-Benguela area, has some small reservoirs for energy production, Lomaum and Biópio. Sumbe, in the N'gunza (Cambongo) basin is one of the ten biggest cities in Angola.

In the southern, very dry part of Western Angola, two large basins are Bero, about 11 000 km^2, and Curoca, about 19 000 km^2. Namibe, at the outlet of Bero, is the only city of any particular size in this sparsely inhabited region. However, the largest basin in the southern part of Western Angola is the Cunene basin, that covers 106 500 km^2, of which 94 000 km^2 is situated within Angola, and constitutes 7.5 % of the total area of Angola. The river comes from the highest areas in Angola, and drains to the south. There are four reservoirs in the river: Gove, Matala, Calueqe and Ruacana. Gove is a large reservoir in the upper reaches of the river, completed in 1975. The Matala reservoir is situated further downstream in connection with a small water power plant. In the southernmost part of the country lies the Calueqe reservoir, where water was supposed to be diverted across the border to Namibia and into the Etosha basin. The dam at Calueqe was never completed, so water has been diverted at a lesser magnitude than expected. Downstream of the Calueqe dam are the Ruacana weir for the diversion of water into Ruacana power plant and the power plant itself situated. This facility, which was completed in 1978 and was supposed to deliver energy primarily to Namibia, has not been operating at its full capacity. From the Ruacana power plant, Cunene forms the border to Namibia until it reaches the Atlantic. In the basin, the rather big cities Huambo and Lubango are situated. The population density is quite high in the northern part of the basin, but decreasing fast to the south. There is a distinct precipitation gradient in the basin from ca. 1400 mm/year in the upper part to less than 100 mm/year in the lower part.

2) The Congo river (usually called Zaire in Angola) has next to the Amazonas the largest drainage basin in the world, 3 800 000 km^2. About 290 000 km^2 or ca. 8 % of Zaires basin lies within Angola. This area constitutes 23.2 % of the total area of Angola. A number of rivers drain the northeastern part of Angola, the biggest of them are: Cuango, Cuilo, Chicapa, Luachimo, Chiumbe, Luembe and Cassai. Cassai is the source of the big tributary of river Zaire, river Kasai, and all the other Angolan rivers in this area are tributaries of Kasai, confluencing within the Democratic Republic of Congo. The northeastern part of Angola is a region with high annual precipitation, 1200-1700 mm. The height interval is about 600 – 1300 m a.s.l. Close to Saurimo, the biggest city in the region, there is a water power plant, in the river Chicapa. Some 200 km to the north of Saurimo is another small reservoir for energy production, in the river Luachimo. In the lowest part before draining into the Atlantic, Zaire constitutes the border of Angola, and some lowlying areas in Angola drain into the river. The Angolan part of the Zaire basin has a rather small population density.

3) The Cuvelai drainage basin includes intermedient (ephemeral) rivers in southern Angola and northern Namibia that drain to the Etosha Pan, a lowlying area in Namibia without any outlet. The area in Angola that drains to the Etosha Pan covers about 56 000 km^2, or 4.5 % of the total area of Angola. The annual precipitation in this region is in the interval 400 – 800 mm. The population density is low.

4) In the central part of Angola, the rivers Cubango and Cuito start on their course to the southeast and into the Okavango delta, a lowlying area in Botswana which has no outlet to the sea. The area in Angola that drains to the Okavango delta covers about 156 000 km^2, or 12.5 % of the total area of Angola. For a long distance, Cubango forms the border to Namibia. Cuito is a tributary with confluence into Cubango some 90 km before the river enters into Namibia. After a short distance through Namibia, Cubango enters Botswana, where the Okavango delta is situated. Most of the basin in Angola is in the interval 1000 – 1500 m a.s.l., while the upper part of Cubango starts above 1500 m a.s.l. There is a distinct precipitation gradient in the basin, from about 1500 mm/year in the upper part to about 600 mm/year in the lower part. The population density is low. The only city of any particular size is Menongue.

5) The Zambezi drainage basin, with outlet into the Indian Ocean, covers nearly 247 000 km^2 in eastern Angola, or 19.7 % of the total area of Angola. Some very small areas in northern Zambia drain across the border and into Angola. This is the

source of the Zambezi river. The main tributaries to Zambezi in Angola are Luena, Lungue-Bongo, Luanguinga and Cuando. Luena enters Zambezi before the main river flows into Zambia. Lungue-Bongo and Luanguinga flows into Zambia before they reach the main river. Cuando flows along the border to Zambia for a long distance, enters Namibia and afterwards forms the border between Namibia and Botswana, before it meets Zambezi. Most of the Zambezi basin is in elevations between 1000 and 1500 m a.s.l. The annual precipitation is mostly more than 1000 mm, but in the southern areas it is only some 700 mm. The only big Angolan city in the basin is Luena, and the population density is low.

Region	Drainage basin area, % of Angola
Western Angola	40.1
Zaire (Congo)	23.2
Cuvelai	4.5
Okavango (Cubango)	12.5
Zambezi	19.7

3. Transboundary water resources

Angola is, together with twelve other countries, a member of the Southern Africa Development Community (SADC). As noted above, Angolan rivers form part of five international basins (Shared water courses): Cunene and Cuvelai (shared with Namibia), Okavango (shared with Namibia and Botswana), Zambezi and Zaire (8 states each, Zambia, Namibia and Democratic Republic of Congo being Angola’s immediate riparian neighbours). The development and utilisation of Angola’s water resources should be guided by international law, where the concept that each basin state has a right to an equitable and reasonable share in the utilisation of international water resources is promoted. The major issue for Angola is the implementation of the SADC Protocol on Shared Water Courses, with the country being an upstream state for each of the five shared basins. The overall objective of this protocol is to foster closer co-operation for judicious, sustainable and coordinated management, protection and utilisation of shared water courses.

With Namibia, there have been a number of agreements since the 1960s on the best joint utilisation of Cunene. Since the 1990s there is a Permanent Joint Technical Commission and Joint Operating Authority between Angola and Namibia. Main responsibility is to manage the existing hydropower (Ruacana) and water supply infrastructure. The latter consists of Namibia’s provision to abstract 6 m^3/s at Calueque for diversion to the Cuvelai basin to supply domestic and irrigation demand in northern Namibia. Due to lack of pumping capacity, Namibia can only divert about 3 m^3/s at present. In addition, the Commission shall investigate the feasibility of future hydropower developments in the lower Cunene (e.g. Epupa).

In the Okavango basin there is no utilisation of the water resources in the Angolan part of the basin. However, Angola is a member of the Permanent Okavango River Basin Commission together with Botswana and Namibia. One of the main functions for the commission is to conduct an environmental assessment in the basin in order to develop an integrated management plan. There are plans in Namibia for a future diversion of water (max. 4 m^3/s) from Cubango river at Rundu to the city of Grootfontein in northern Namibia.

In the Zambezi basin there is no utilisation of importance of the water resources in the Angolan part of the basin. There is an organisation established, the Zambezi Water Course Commission (ZAMCOM), with Angola as a member.

In the Zaire basin there is no utilisation of importance of the water resources in the Angolan part of the basin.

4. The need for water data

The Programme for the Development of the Water Sector in Angola [1], approved by the Government in Januar 2004, states that "Water is a key element to assure the essential conditions of human life and to economic and social development, to the well-being and to an environmental balance." The Programme is based on the concept of integrated water resources management, and incorporates among other things the following elements: meeting basic needs for water, preparing for and managing droughts and floods, working with neighbouring countries to achieve equitable access to shared water resources, and reforming institutions. The Programme says "The vastness of the territory, the complex hydrographical net, the geological, morphologic and climatic variety, complicate the study of hydrological resources in Angola and put a great challenge to the country, because without the due knowledge of the potential of its hydrological resources it is not possible to establish long term maintainable development plans."

The renewable water resources in Angola, defined as the total annual runoff from the country, are not well-known. In Neto and Mendes [2], the total annual runoff is estimated to 120 – 170 km^3/year, equal to a runoff of 96 – 136 mm, or a specific runoff of 3.0 – 4.3 $l\ s^{-1}\ km^{-2}$.

Robinson [3] has estimated the expected water stress and scarcity in Angola in 2016, by using the following formulas:
Water stress index = (withdrawal/availability) * 100 (%)
Water scarcity index = availability/capita (m^3/person/year)
Robinson assumed the availability to be 140 km^3/year, the withdrawal to be 3 km^3/year, and the total population in Angola to be 18 million in 2016. The expected magnitude of the withdrawal is based on very uncertain figures for the water use today and the expected increase. The urban-industrial-mining sector is supposed to use 0.36 km^3 per year in 2016, while the annual irrigation demand is supposed to reach 2.64 km^3 that year.

By using the formulas and comparing to tables for Level of stress and scarcity, Robinson found the water stress in Angola to be characterised as low stress (Water stress index = (3 / 140) * 100 = 2.1 %), and that there is no scarcity (Water scarcity index = $140 * 10^9 / 18 * 10^6 = 7778$ m^3/person/year).

Water stress index			Water scarcity index	
Level of stress	%		Level of scarcity	m^3/person/year
Low	< 10		None	> 2000
Moderate	10 – 20		Occasional	2000 – 1700
Medium	20 – 40		Periodic	1700 – 1000
High	40 – 60		Chronic	1000 – 500
Catastrophic	> 60		Absolute	< 500

Even if the basis for this evaluation is uncertain, it is obvious that the renewable water resources in Angola are abundant on national level. However, it is not well known how the situation is on regional level, and in addition, how the situation varies throughout the year and from year to year.

A good knowledge of the renewable water resources includes the knowledge of their geographical distribution, and their variability in time, and of their extremes (floods and droughts). This knowledge will support authorities, municipalities and the private sector in their use and treatment of water (irrigation, water supply, industry, hydro-power, flood control, navigation etc.). An important issue is to know the magnitude and frequency of floods and droughts as a basis for design regarding constructions along water courses and to ensure dam safety. In addition, the knowledge is necessary in the treatment of the transboundary water resources. This knowledge of the water resources can be achieved through the establishment and the operation of a hydrometric network in the country. By utilizing information from a meteorological network, especially precipitation and evaporation data, the knowledge can be increased.

5. Principles for a national hydrometric network

In World Meteorological Organization's "Guide to Hydrological Practises" [4], principles are described for the design of hydrological networks. These are considered when evaluating a network in Angola.

The main intention of the national hydrometric network is that the data collected shall give a description of the total water resources in Angola, including the water exchange with neighbouring states, and give the possibility to estimate hydrological data for ungauged areas within the country. The network shall have a good geographical distribution, with consideration taken to the distribution of the population and the resulting expected need for water information, and the network shall cover the climatic variations in Angola.

The basis for the future hydrometric network in Angola is the numerous stations that now are non-operating, see chapter 6. Older stations with good data quality and/or long observation periods should be considered for re-establishment in the first place.

- Stations should be localized to sites in the lower reaches of the biggest rivers upstreams of the tidal zone, since they monitor the runoff from large areas.

- Stations should be localized in the most important transboundary rivers.

- Stations should be localized in the lower reaches of big tributaries, and in the upper reaches of the main river, since they monitor the runoff from large areas with possible other hydrological conditions than in the total basin.
- Stations should be localized in “small”, climatologically representative basins all over the country, and especially in areas with high population density. In climatologically homogenous areas, the number of stations can be minimalized.

These principles, taking into consideration the need for water described, in chapter 4, will be the starting-point in the valuation of the old hydrometric network and when giving a proposal for a future network in Angola.

In this proposal, the stations will be classified as follows:

Class I will be principal stations with high priority. These stations will constitute the minimum network to describe the overall hydrological conditions in Angola.

Class II will be principal stations, which will constitute complementary stations in describing the hydrological conditions in Angola.

Class III will be secondary stations.

According to Guide to Hydrological Practises, a principal or base station should be operated without any time limit, provide a basis for monitoring long term trends in hydrological conditions in the region, and hence function as a reference station. A secondary station, on the other hand, is operated only long enough to establish a stable relationship (usually by means of correlations) with one or more of the base stations. A new secondary station can then be established with the equipment and funds that had been in use at the discontinued site.

The priorities in establishment/re-establishment of the stations are not considered. These priorities depend on a number of conditions like costs, logistics, safety etc. In Angola there is a special problem with the access to many of the old hydrometric stations and to new gauging sites, due to the numerous land-mines that still are hidden along roads and around bridges.

An important option is that stations with long series of high quality data in neighbouring countries can compensate for lacking stations on Angolan territory. A mutual cooperation concerning hydrological data should be established with neighbouring countries. In transboundary rivers, data from such stations can give information on runoff conditions in Angola. Data from stations close to the Angolan border can function as reference stations when calculating long term averages for runoff in Angolan areas with sparse data.

6. The history of the hydrometric network

The oldest hydrometric stations in Angola date from 1951, and by the early 1960s there were about 40 operational stations [2]. In 1974 the hydrometric network comprised 181 operating stations with a further 91 classified as being not operational but still possessing a source of reliable data. During the civil war, which started in 1975, almost all the stations were abandoned. In 1982, after a steady process of rehabilitation and reconstruction, the hydrometric network included 110 stations, almost all recording both water levels and discharges. However, by 1985 the number had again fallen dramatically, to only 11. By 1988 this had recovered to 23 operating units, 19 of which recorded both levels and yielded discharge estimates. Due to war activities, these stations were abandoned, and during the 1990s the hydrometric activity in Angola was absent.

In 2003, through the NAWASMA project, 8 hydrometric stations were re-established. Of these stations, five are included in the SADC-HYCOS system. WHYCOS is a World Hydrological Cycle Observing System started in 1993 by World Meteorological Organization and based on a global network of hydrometric reference stations with real-time satellite-based transmission data to enable the development of consistent, high-quality and constantly updated distributed national, regional and international data bases on river flow, water quality and certain climatic variables. SADC-HYCOS is the Southern African version of this system.

7. The meteorological network

Meteorological data, especially precipitation data are an important support to the runoff data. Precipitation data can complete the survey of the water resources in areas without any hydrometric stations. Precipitation data can be a good support in quality checks of existing data, or when filling in missing data at a hydrometric station. A co-operation should be established with the national meteorological institute regarding data exchange, to ensure an optimum assessment of the runoff data. Historical precipitation data should be available when analysing hydrological data, new precipitation data should be made available for hydrologists each year, and information on changes in the meteorological network should be communicated. In addition, precipitation data will be essential for a future development of mathematical hydrological models in Angola.

The precipitation network included some 270 stations in the 1970s. Observations from this network were the basis for a map of the annual precipitation that was prepared in the 1980s. A version of the map is shown in chapter 2.

Many of the precipitation stations were abandoned during the civil war. At present INAMET (The national meteorological institute) operates 12 climatological stations and about 100 precipitation stations. The climatological stations are located mostly at airports in the bigger cities in Angola. Some are manually operated, some are automatic. These stations observe among other parameters: air temperature, evaporation and precipitation. The precipitation stations are located mostly in areas of agricultural interest.

INAMET has plans to increase the meteorological network to about 24 climatological stations and about 200 precipitation stations.

8. Recommendations on the future hydrometric network

Based on the principles for a national hydrometric network, chapter 5, the need for water data, chapter 4, and the hydrography of Angola, chapter 2 and 3, recommendations for a future network are given. The recommendations are given for each region, as described in chapter 2.

Western Angola, Cabinda

One Class I station is recommended. Station 400401 N'hama (basin area 354 km^2) in River Lucola at Cabinda city, alternatively station 400301 Bucumaze in Lulondo, should be re-established if possible. One of these stations could be representative for the coastal areas in Cabinda, and also for areas to the south of River Congos outlet, even if there is a precipitation gradient along the coast.

Western Angola north

Two Class I station are recommended in this region, in the lower reaches of the two important rivers, Dande and Bengo. In addition one Class II station in the Uige area is recommended, and to complete survey of the runoff in the region, two Class III stations, where one should be in a large basin and one in a small.

The Class I stations should be 601701 Porto Quipiri (10660 km^2) in Dande and 601804 Cabiri (8053 km^2) in Bengo. Cabiri is situated downstreams of the Quiminha reservoir and the water discharge is regulated for water supply. However, the station monitors the total runoff from the basin, since the intake for water supply is downstreams of the station.

The Class II station could be obtained by the re-establishment of 601301 Barragem (182 km^2) in the tributary Luquixe in the Loge basin. An alternative to this station could be 601101 Fazenda Loa (484 km^2) in the tributary Loa in the M'bridge basin.

One Class III station should be established in the lower reaches of M'bridge or Loge to find the gradient in runoff from north to south in the northern part of Angola. This could be a completely new station in M'bridge, or one of the old stations 601302 Fazenda Loge and 601304 Freitas Morna in Loge. One Class III station should be in the upper part of Dande or Bengo to find the gradient in runoff from coast to mountain in this region. Alternatives could be either stations in small basins (601702, 601703 or 601704 in Dande) or stations in larger basins (601706 in Dande or 601810 in Bengo). The need for re-establishment of the station 601806 Lalama (6364 km^2) should be considered specially, since that station was situated upstreams of the Quiminha reservoir in Bengo, and was monitoring the unregulated flow in the river. Nevertheless, the water stage in the Quiminha reservoir should be registered continually.

Western Angola, Cuanza

Three Class I stations, one Class II station and two Class III stations are recommended in the Cuanza basin. Of the Class I stations, one should be in the lower reaches of the river, one in the central reaches of the river and one in the upper reaches of the main river or in one of its upper tributaries. The Class II station should be in the large tributary Lucala. The Class III stations should be in small basins, less than 1000 km^2, one in the northern part, and one in the southern part of the Cuanza basin.

The most important station in Cuanza river is 601908 Cambambe, with a basin area of 121470 km^2 or about 83 % of the whole Cuanza basin. Cambambe should be one of the Class I stations in the basin, even if the discharge is regulated. Another one could be 601906 Cauisso (62790 km^2) in the central part of Cuanza river. An alternative could be 601942 N'harea (38270 km^2). In the upper Cuanza basin, the candidates to be a Class I station are 601921 Chimbunde (8202 km^2) and 601954 Ponte Da Cambandua (5943 km^2) in the tributary Cuquema and 610961 Umpulo (9510 km^2) in the main river.

The Class II station, in the large tributary Lucala, could be one of 601930 Km 34 (25290 km^2), 601953 Ponte Pinheiro Chagas (23270 km^2), 601931 Lucala (19450 km^2) and 601951 P.Vieira Machado (15000 km^2).

The Class III station in the northern part of the Cuanza basin could be one of 601947 Ponte do Lau (251 km^2) and 601952 Ponte de Quizenga (840 km^2), both situated in the Malanje area. The Class III station in the southern part could be 601943 Catabola (942 km^2), alternatively 601916 Capeio (996 km^2), 601920 Chavaia (941 km^2) or 601956 Quedas Do Lau Lau (1007 km^2), all four stations situated in the Kuito area.

The water stage in the reservoirs at Capanda and Cambambe power stations should be registered continually. The station 601935 Lucunga (29290 km^2) in the large tributary Luando could be of special interest to re-establish. The discharge at this station would together with the discharge at 601906 Cauisso give the total unregulated discharge a relatively short distance upstream of the Capanda reservoir.

Western Angola central

Two Class I stations are recommended in this region, in the lower reaches of two of the largest basins. Two Class II stations are recommended, one in the lower reaches of a main basin and one in the highlands. To complete the survey of the runoff conditions in the region, another three Class III stations are recommended, two in the highlands, and one in the lowlands.

The two Class I stations should be 603004 Cachoeiras da Binga (20352 km^2) in Queve and 603809 Biopio (15800 km^2) in Catumbela. One of the Class II stations should be 603202 Quicombo (5581 km^2) in Quicombo river. The other could be 602501 Buia (1264 km^2) in the upper part of Nhia, a tributary to Longa. Other stations in the upper part of the Longa basin could be considered as alternatives.

One of the Class III stations could be 602504 Capolo (18065 km^2) in the lower reaches of Longa, or 604603 Dombe Grande (close to 15000 km^2) in the lower reaches of Coporolo. The other two, localized to the highlands, should be obtained by the re-establishment of one of the stations in upper Queve, in the maximum zone for precipitation, and one in the upper Catumbela.

Western Angola south

One Class I station and two Class III stations are recommended in this very dry region.

The Class I station should be established in River Bero (Cubal), which has its outlet in the sea close to the city of Namibe. An old station in this river was 606701 Tampa. The Class III stations should be localized to the upper and lower Curoca, the largest basin in the region. This could be obtained by the re-establishment of the two stations 607201 Maxaxa (4170 km^2) and 607202 Pediva.

Western Angola, Cunene

Two Class I stations are recommended in the basin, one in the upper part of the river, and one in the lower part upstreams of the Calueque reservoir. A Class II station should be localized to a tributary, while two Class III stations should complete the survey of the runoff conditions in the basin. One of these should be localized to a tributary, while the other one should be established in the lower reaches of the river, along or near the border to Namibia.

The Class I station could be 607322 Xangongo (53254 km^2) in the lower part and one of 607314 Jamba ia Homa (8637 km^2), 607315 Jamba ia Mina (13817 km^2) and 607316 Luceque (18849 km^2) in the upper part of Cunene. The Class II station could preferably be one in the northernmost part of the basin close to Huambo, 607310 Chissola (837 km^2) in Calai, or 607345 Gongoinga (537 km^2) in Cunhangamua.

The Class III station in the lower Cunene could be 607311 Foz do Cunene at the outlet in the sea, at a suitable site along the Namibian border, or 607308 Iacavala (86188 km^2) alternatively 607302 Calueque (84742 km^2) immediately north of the border. The other Class III station should be in the Lubango area in the upper part of the large tributary Caculuvar (607313 Humpata in Nene, 607350 Chibia in Nene or 607351 Nene). In addition, the water stage in the Gove reservoir should be registered.

Zaire

Two Class I stations are recommended, one in the western part, in the lower reaches of River Cuango, and one in the eastern part, preferable in the lower reaches of River Cassai, or one of its trubutaries. These stations will give a rough survey of the runoff conditions in the Angolan part of River Congos basin, and be the basis for assessments of the transboundary water resources in this region. To complete the survey, three Class II stations and two Class III stations are recommended.

In Cuango, a Class I station could be obtained by re-establishment of station 430508 Borio, or by establishment of a station some distances downstream of Borio. Alternatives could be re-establishment of one of the other stations in the area, 430507, 430509 or 430510. The station site with the largest possible basin area should be preferred. In the western part of the region, the station 430504 Ponte Alfandega in River Cuilo is recommended to be re-established as a Class II station, to complete the survey of the runoff conditions in this part of the region.

The Class I station in the eastern part of the region is recommended to be a new station in River Luachimo close to the city of Dundo. A station here will cover a large basin, and be representative for the main part of the region. Two Class II stations in this part of the region are recommended to be re-established, 430502 Saurimo (5410 km^2) in River Chicapa, and 430501 Dala (2100 km^2) in River Chiumbe alternatively 403503 Ponte (5400 km^2) in River Cassai.

In a longer time perspective, two Class III stations are recommended to be established in the region. In River Cuango, in the lower reaches where it forms the border to the Democratic Republic of Congo, a station would give worthy information of the total runoff from the western part of the region. A station with a small basin, less than 500 km^2, in the Saurimo area would be of interest to describe runoff conditions in local areas.

Cuvelai

In this region a runoff station will stay dry during the main part of the year, and it is probably not worth the effort to establish a station in the region. Nevertheless, it is recommended one Class II station and one Class III station. The Class II station could be the old station 607304 Catembulo (4510 km^2) in Colui, which is a tributary to Cunene and is an intermedient river close to the Cuvelai basin. This station might be representative for the runoff conditions in the northern part of the region. The Class III station could be a weir in a small basin with good accessibility along the main road through the Cunene province. The purpose with this station would be to monitor the frequency and magnitude of runoff in the region.

Okavango (Cubango)

One Class I station should be localized in the Cubango river downstream of the confluence with Cuito river. Alternatively a station in Okavango river in Namibia or in Botswana might function as the main station in the basin. Another alternative is to localize one station in Cubango and one in Cuito upstreams of their confluence. This alternative will give most information on the runoff conditions in the basin since both main rivers will be monitored.

In Cubango downstream of the confluence with Cuito the station 637525 Mucusso (>160000 km^2) could be re-established. In the lower Cubango upstream of the confluence the alternative stations are 637516 Sambio (86800 km^2), 637502 Cuangar (ca. 73000 km^2), 637509 Chissombo (71960 km^2) and 637511 Foz do Cuatir (70080 km^2). In Cuito, the most obvious choice is to re-establish 637510 Dirico (59170 km^2).

In addition, two Class II stations and one Class III station are recommended. The Class II stations should be in the upper reaches of Cubango and Cuito respectively. The Class III station should be in a tributary in the upper part of the basin.

The Class II station in upper Cubango could be either 637513 Mumba (12570 km^2) or 637520/637540 Vila Artur de Paiva (7320 km^2), while in upper Cuito it could be 637507 Cuanavale (27100 km^2). The alternatives as the Class III station are 637505 Cutato (3720 km^2), 637517 Menongue (4520 km^2) and 637514 Missao Velha (5230 km^2). These three stations are situated in three different tributaries to Cubango.

Zambezi

The Zambezi basin is in a remote area of Angola, and the river system makes it complicated to monitor the runoff from the Angolan territory. The best alternative to obtain knowledge of the runoff is to make use of gauging stations in Zambia and Namibia. A co-operation with these countries regarding exchange of hydrological data should be established. There are, due to Zambezi River Authority [8], stations in Zambia and Namibia which can give very good information on runoff conditions from the Angolan part of the subbasins of Zambezi, since a main part of the subbasins are within Angola. The station in upper Zambezi, on Zambian territory, is at Zambezi Pump House, the station in Luanginga is at Kalabo, Zambia, while the station in Cuando is at Kongola, Namibia.

In addition, one Class II station and two Class III stations are recommended in this region. The Class II station should be in a relatively small river in the upper part of the basin, preferably, 627402 Chafinda (2970 km^2) in Luena river, a tributary to the upper Zambezi. The Class III stations should be localized to a suitable site in Lungue-Bongo, another tributary to Zambezi, and to the upper Zambezi at Cazombo.

Summary

In the table the recommendations are summarized. The details are found in the sections above. In addition to the proposed stations, it is recommended that old stations which are found to have long data series and/or to be very stable concerning the control in the river (the same reliable rating curve for years) should be considered for re-establishment. The findings in the Bjøru report [10] should be considered when alternative stations are evaluated for the final decision on the future network.

FUTURE NETWORK			
Basin/region	**Class I** **18 stations**	**Class II** **12 stations**	**Class III** **17 stations**
Western Angola Cabinda	400401 N'hama in Lucola (or alternative)		
Western Angola north	601701 Porto Quipiri in Dande	601301 Barragem in Luquixe in Loge (or altern.)	In lower M'bridge or lower Loge
	601804 Cabiri in Bengo		In upper Dande or upper Bengo
Western Angola Cuanza	601908 Cambambe	601930 Km 34 in Lucala (or alternative)	601947 Ponte do Lau (or altern.) in Malanje area
	601906 Cauisso (or alternative)		601943 Catabola (or alternative) in Kuito area
	601921 Chimbunde in Cuquema (or alternative)		
Western Angola central	603004 Cachoeiras da Binga in Queve	603202 Quicombo in Quicombo	In lower Longa or lower Coporolo
	603809 Biopio in Catumbela	602501 Buia in Nhia, a tributary to Longa (or alt.)	In upper Queve
			In upper Catumbela
Western Angola south	In river Bero (Cubal), e.g. 606701 Tampa		In upper Curoca, e.g. 607201 Maxaxa
			In lower Curoca, e.g. 607202 Pediva.
Western Angola Cunene	607322 Xangongo	607310 Chissola (or alt.) in Huambo area	In lower Cunene, e.g. 607308 Iacavala
	In upper Cunene, e.g. 607314 Jamba ia Homa		In Caculuvar in Lubango area
Zaire (Congo)	430508 Borio in Cuango (or alternative)	430504 Ponte Alfandega in Cuilo	In lower Cuango river
	In Luachimo river at the border	430502 Saurimo in Chicapa	In a small basin in Saurimo area
		430501 Dala in Chumbe (or alternative)	
Cuvelai		607304 Catembulo in Cunene basin	In a small central basin
Okavango (Cubango)	637516 Sambio (or alt.) in lower Cubango	637513 Mumba (or alt.) in upper Cubango	In a tributary to Cubango
	637510 Dirico in Cuito	637507 Cuanavale in upper Cuito	
Zambezi	Zambezi Pump House in upper Zambezi, Zambia	627402 Chafinda in Luena	In Lungue-Bongo
	Kalabo in Luanginga, Zambia		In upper Zambezi at Cazombo
	Kongola in Cuando, Namibia		

In addition, the water stage in the reservoirs Quiminha in Bengo, Capanda and Cambambe in Cuanza, and Gove in Cunene should be monitored.

9. Operation of a hydrometric network

The establishment of the proposed future network in Angola includes both the re-establishment of older stations and construction of some new stations. The operation of the network includes visits to the stations with checks of their condition, water discharge measurements, reading data from the loggers etc. Frequent discharge measurements are essential in the Angolan rivers, since at most stations there are shifting controls, which means that the relation between water stage and discharge is frequently changed. The operation of the network also includes data processing at the office.

A cost estimate is prepared, assuming that the proposed future network is established during three years, and the number of employees working with the network is eight. The cost estimate is based on discharge measurements by boat and current meter/ADCP. If cable-ways should be used, the cost of the establishment will increase by 20 000 USD per station. The instrument at the stations is supposed to be OTT Thalimedes. The cost estimate is based on the following rates:

Wage per person	4 800 USD per year
Travelling expenses per person	100 USD per day
Re-establishment of an old station	4 000 USD
Establishment of a new station	6 000 USD
Instrumentation at a station	2 000 USD
Transport (car)	40 000 USD
Transport expenses per car	2 000 USD per year
Measuring/field equipment	
Levelling instrument	1 000 USD
Current meter	20 000 USD
ADCP	25 000 USD
Boat	7 000 USD
Generator	3 000 USD
Electrical equipment	1 000 USD
Miscellaneous tools	1 000 USD

Three field-teams, two persons in each, are supposed to be stationed at three region offices. This means that it is necessary with three cars and three sets of measuring/field equipment. It is also assumed that the number of field days per person is 150 per year. The proposed future network involves the re-establishment of 30 old stations and the establishment of 6 new stations, while 8 of the totally 47 recommended stations already are re-established. The 3 recommended stations that are situated in neighbouring countries are included in the cost estimate by regarding them as new stations.

The annual expenses, including wages, travelling expenses and transport expenses will be 134 400 USD, or during a three years period, 403 200 USD. The costs to re-establish/establish the stations, including instrumentation, will be 252 000 USD. The total costs for car and measuring/field equipment for three teams will be 294 000 USD.

The total costs to establish and operate the proposed future network during three years will be approximately 0.95 million USD.

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[9] Mendes, P.E. (2002): Relatório Sobre Recursos Hídricos de Angola. *Luanda 3 October 2002*.

[10] Bjøru, A. (2004): Quality Check – Historical Hydrological Data in Angola. *NVE-report in preparation*.

Annex 1. Terms of reference

TERMS OF REFERENCE

Consultancy services for a National Strategy Plan for rehabilitation of the hydrometric network

1 Background

-Historical background

A National Strategy plan for rehabilitation of the hydrometric network is Activity B of the larger "National Water Sector Management" (NAWASMA) project, carried out since 2002 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 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 27 years of civil war. This situation makes proper water development planning practically impossible. The development of the old station network was more project driven and therefore did not give a good hydrological picture all over Angola. This planned work will make a proposal for a National Hydrological Network that covers whole of Angola. The future network should be based around a primary network that will give sufficient knowledge of the Angolan hydrology and a secondary network that will give specific project information.

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. An operational hydrological network of measuring stations and a database with quality hydrological data is essential in order to evaluate Angola's renewable water resources.

3 Scope of work

3.1 General

The work to be done is a part of the institutional agreement between NVE and MINEA/DNA regarding output 3 in the Project Document:

The completion of a national strategy plan for rehabilitation of the hydrometric network

> *3.1 A national plan for rehabilitation of the hydrometric network prepared*
> *3.2 A primary hydrometric network identified*
> *3.3 Technical and/or organisational recommendation for maximum co-ordination and optimisation of hydrological, (meteorological and climatically) networks developed*

In order to do the work above a close cooperation with the Head of Water Resources is necessary. An analysis of the almost 200 stations that have been in operation and future demand for data will be used to select the location of the stations to be rehabilitated and new locations to better describe the Angolan Hydrology. A primary network dense enough to comply with international standards should be identified. A proposal for coordination of the hydrological and meteorological networks should also be prepared.

3.2 Preparatory work

It is required to have good knowledge in the use of HYDATA hydrological software and knowledge of Angola's river basins and international river systems.

4 Mode of work

The project shall be carried out in close cooperation with the head of Water Resources Department. The client, DNA, shall provide access to necessary maps, historical material and hydrological data for Angola. The work shall be carried out in DNA´s office in Luanda and a Pc with access to the National database will be provided.

5 Time schedule

The work is estimated to take one month, and should take place in March / April 2004.

6 Reporting

The final report should give DNA a National rehabilitation plan and a list of primary stations in Angola. A proposal for cooperation with the

Meteorological services regarding optimising of networks should also be included in the final report. The final report should be submitted in 5 copies as well as in electronic form within 1 month after the mission was completed.

7 Budget

Fee NVE , 10 Days in Norway preparatory work	48 300
Fee NVE , 30 days in Luanda	144 900
Fee NVE , 10 Days in Norway, Report	48 300
Travel to Angola, 30 days stay	74 000
Visas, vaccination and Rental car	27 500
Sum (Norwegian Kroner, NOK)	NOK 320 500

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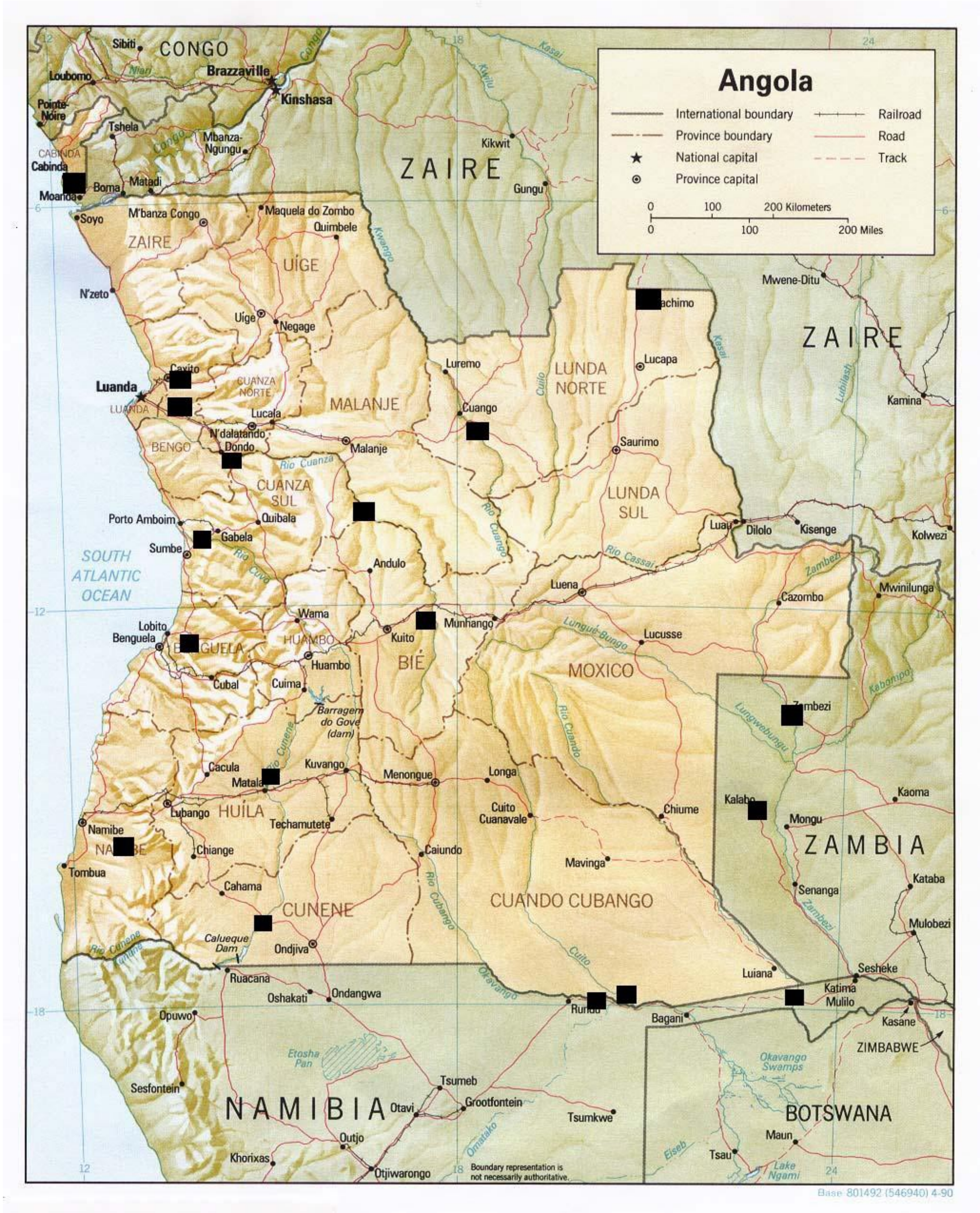
National Director of Water, DNA

Annex 2. River basins in Angola

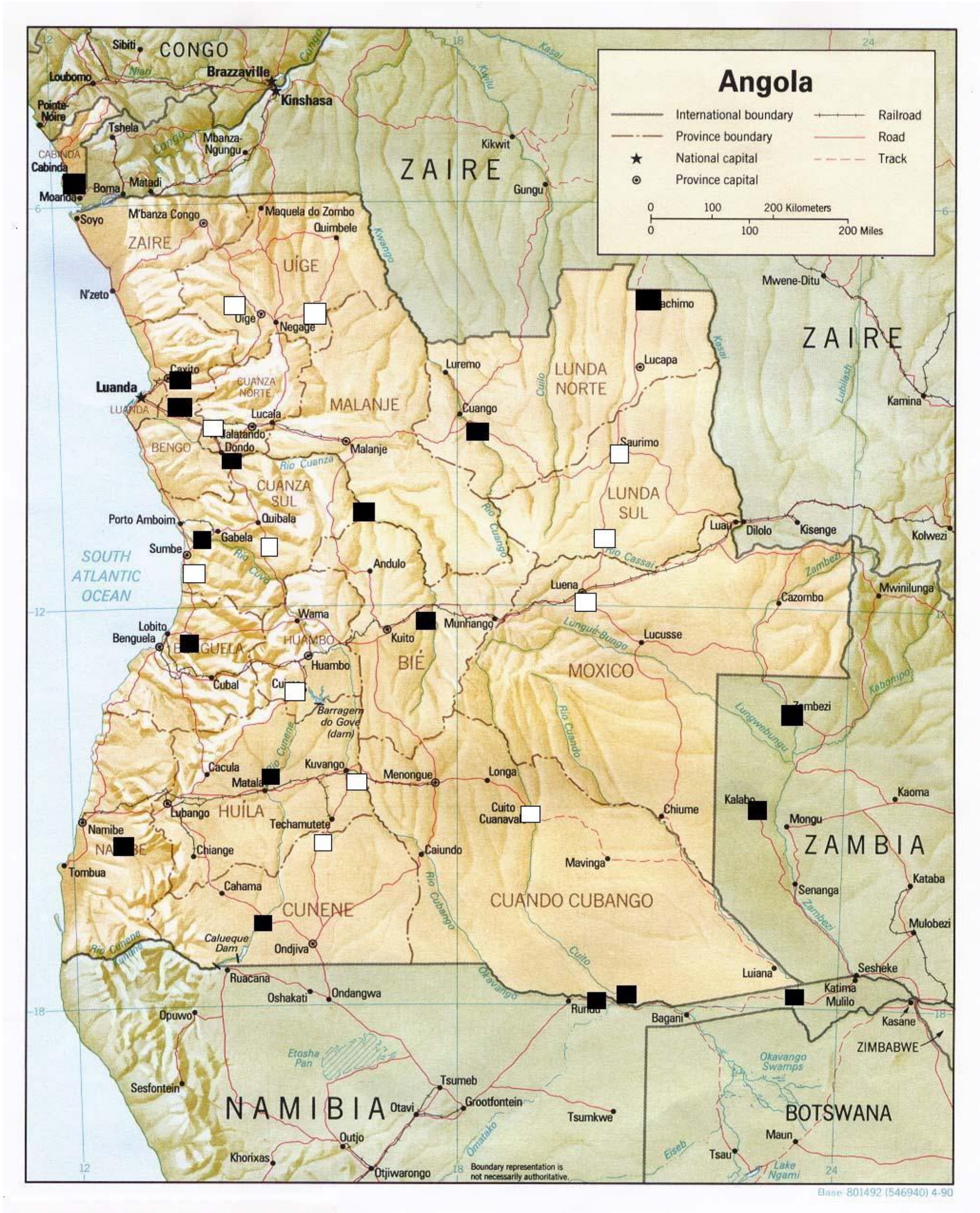
Rivers in Angola	Area in Angola	Total basin area
	km^2	km^2
Angolan coast (Cabinda)		
Lubinda	668	668
Chiluango	4638	?
Lulondo	511	511
Lucula	354	354
Coastal areas	1509	
Sum Cabinda	**7680**	**?**
Zaire (Congo)	**289206**	**3800000**
Angolan coast		
Luculo	2010	2010
Sange	693	693
Lucunga	3995	3995
M'bridge	18937	18937
Sembo	4152	4152
Loge	13482	13482
Uezo	1329	1329
Onzo	2808	2808
Ló	432	432
Lifune	2497	2497
Dande	10802	10802
Bengo	12371	12371
Cuanza	147157	147157
Mengueje	1290	1290
Tanda	254	254
Longa	22489	22489
Queve	23169	23169
N'gunza (Cambongo)	2540	2540
Quicombo	5510	5510
Eval	1386	1386
Balombo	5087	5087
Cuula	574	574
Cubal da Hanha	2779	2779
Catumbela	16640	16640
Cavaco	4000	4000
Coporolo	15495	15495
Equimina	2584	2584
Catara	1520	1520
Carunjamba	2738	2738
Inamangando	2091	2091
Bentiada	6557	6557
Chapéu Armado	342	342
Mutiambo	1821	1821
Giraul	4619	4619
Bero (Cubal)	10601	10601
Flamingos	720	720

Curoca	19436	19436
Coastal areas	23805	23805
Sum Angolan coast	**398712**	**398712**
Cunene	**94003**	**106500**
Cuvelai	**55977**	**100000**
Okavango (Cubango)	**156122**	**570000**
Zambezi	**246737**	**1800000**
SUM Angola	**1246700**	

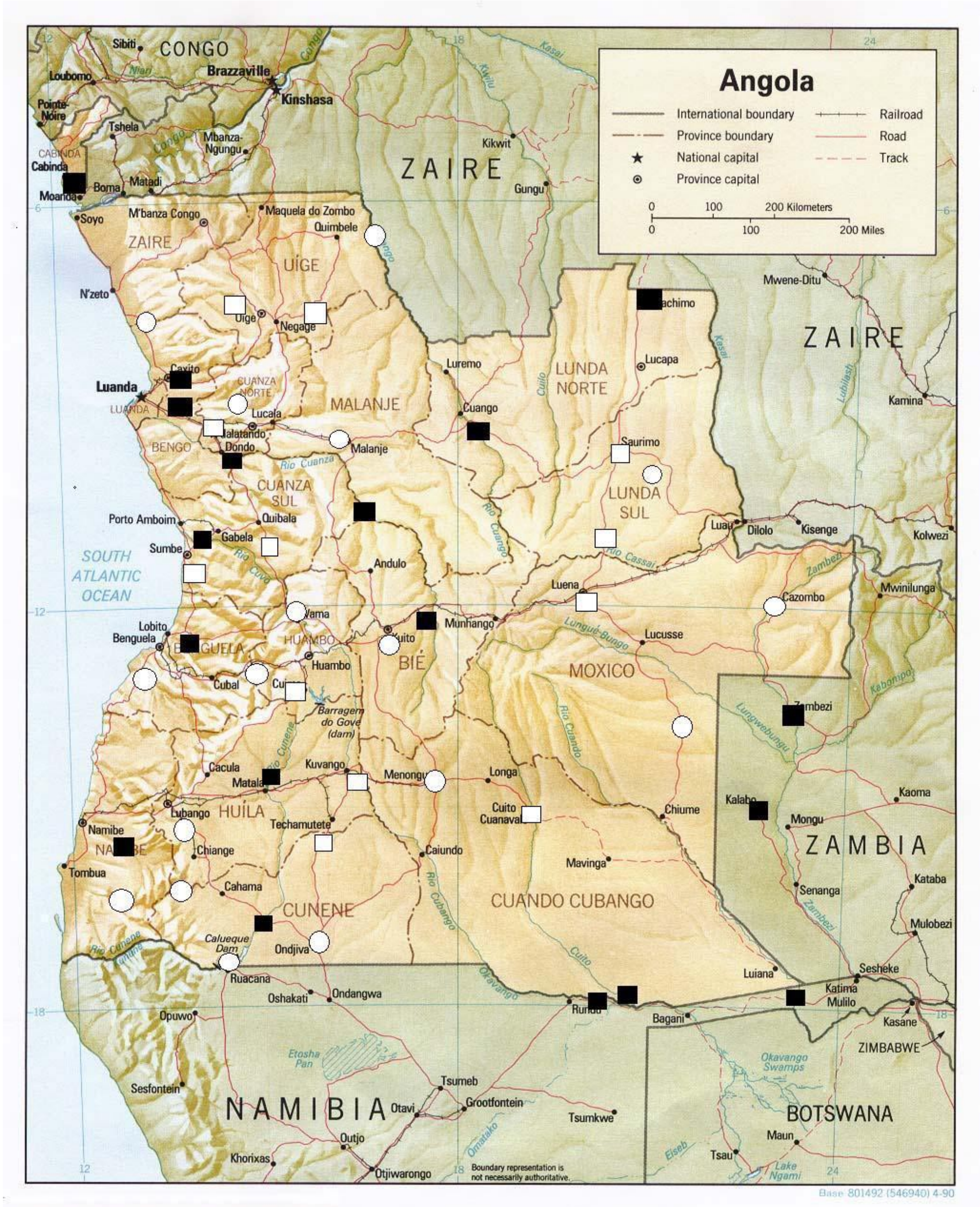
Annex 3. Maps on the recommended future hydrometric network in Angola



Class I stations



Class I and Class II stations



Class I, Class II and Class III stations

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Nr.1 Per F. Jørgensen, Peter Bernhard, KanEnergi AS: Elproduksjon basert på biobrensler. Teknisk/økonomisk potensial (s.)

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Nr.4 Eli Alfnes og Hans-Christian Udnæs: Satellite-observed Snow Covered Area and spring Flood Prediction in the HBV-model (26 s.)

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Nr. 6 Hervé Colleuille: Groset forsøksfelt (016.H5) Grunnvanns- og markvannsundersøkelser (22 s.) - Årsrapport 2003 (28 s.)

Nr. 7 Hervé Colleuille: Skurdevikåi tilsigsfelt (015.NDZ) Grunnvannsundersøkelser - Årsrapport 2003 (21 s.)

Nr. 8 Lars-Evan Pettersson: National strategy plan for rehabilitation of the hydrometric network in Angola (31 s.)