REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SOCIETE DE DEVELOPPEMENT AGRICOLE ET INDUSTRIEL
SODAGRI

ANAMBE BASIN DEVELOPMENT PROJECT

Volume I

MAIN REPORT

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH – DAKAR 1980

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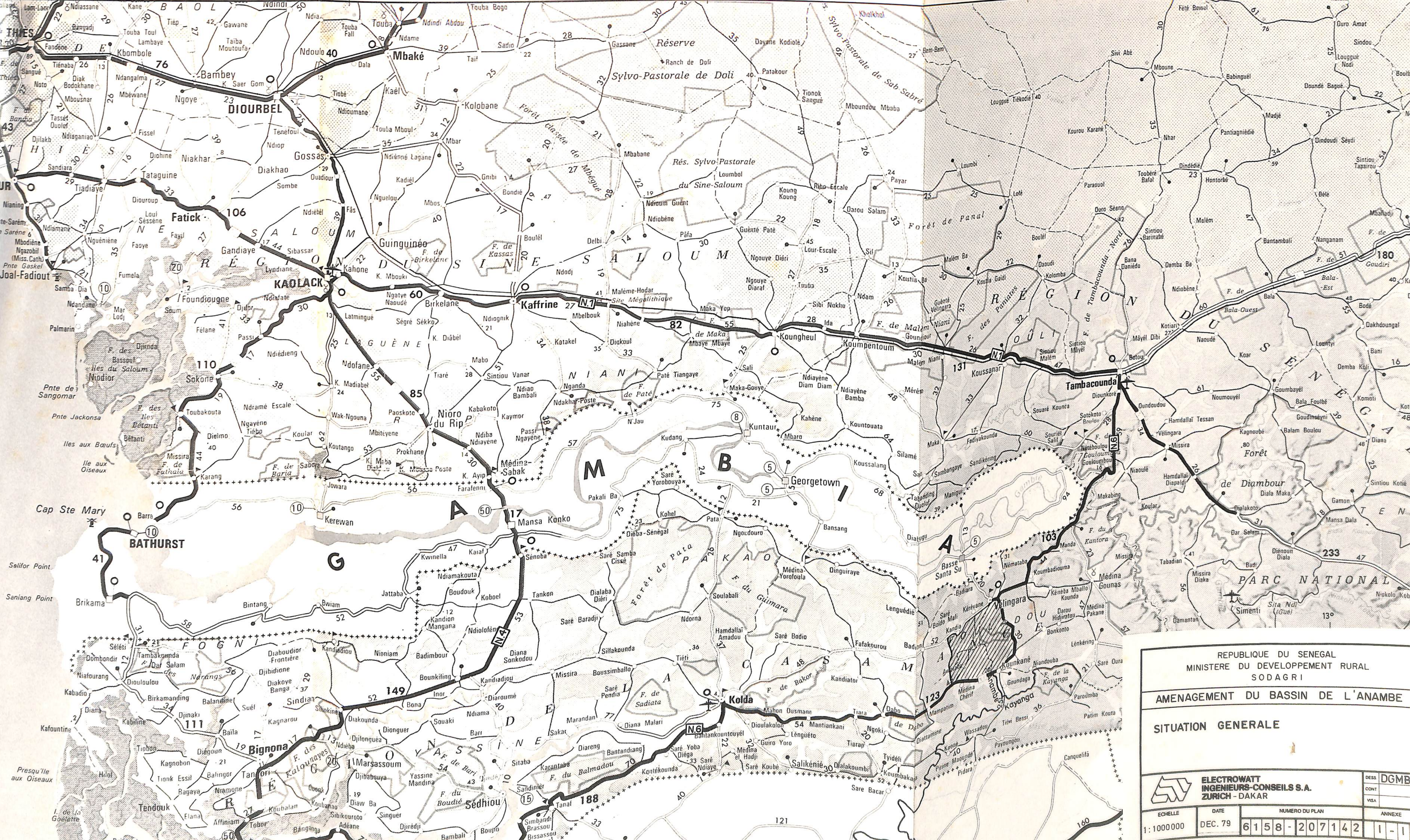

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

SITUATION GENERALE

ELECTROWATT INGENIEURS-CONSEILS S.A. ZURICH - DAKAR

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SELECTED REFERENCES

1. ADRAO 1977 PERSPECTIVES DU COMMERCE INTRA-REGIONAL DU RIZ EN AFRIQUE DE L'OUEST, MONROVIA

2. BRUNET-MORET Y. et CHOURET A. 1967/70/71 ETUDES HYDROLOGIQUES EN CASAMANCE, DAKAR, ORSTOM

3. DANCETTE C. 1976 MESURES D'EVAPOTRANSPIRATION POTENTIELLE ET D'EVAPORATION D'UNE NAPPE D'EAU LIBRE AU SENEGAL ; AGRONOMIE TROPICALE N° 4, p. 321 - 338

4. DUNSMORE J. et AL. 1976 THE AGRICULTURAL DEVELOPMENT OF THE GAMBIA : AN AGRICULTURAL, ENVIRONMENTAL AND SOCIO-ECONOMIC ANALYSIS. LAND RESOURCE STUDY 22, LAND RESOURCES DIVISION, MINISTRY OF OVERSEAS DEVELOPMENT, SURBITON, ENGLAND

5. FAUCK R, TURENNE J-F et VIZIER J-F 1963 ETUDE PEDOLOGIQUE DE LA HAUTE CASAMANCE, DAKAR, ORSTOM

6. GERCA 1962/63 AMENAGEMENTS HYDRO-AGRICOLE EN CASAMANCE ET EN HAUTE GAMBIE. ETUDE GENERALE. TOME III VOL. 1, ZIGUINCHOR

7. GERCA 1962/63 AMENAGEMENTS HYDRO-AGRICOLES EN CASAMANCE ET HAUTE-GAMBIE. CAMPAGNE HYDROLOGIQUE

8. IBRD (BIRD) 1976 APPRAISAL OF A SECOND SEDHIOU PROJECT, WASHINGTON

9. INSTITUT D'ELEVAGE ET DE MEDECINE VETERINAIRE DES PAYS TROPICAUX (IEMVT) 1970 PATURAGES NATURELS DE HAUTE ET MOYENNE CASAMANCE. ETUDE AGROSTOLOGIQUE N° 27, PARIS

SELECTED REFERENCES (suite I)

10.	MICHEL P.	1973	LES BASSINS DES FLEUVES SENEGAL ET GAMBIE. ETUDE GEOMORPHOLOGIQUE. MEM. ORSTOM, PARIS N° 63
11.	SERDA	1976	PROJET DE MISE EN VALEUR DU BASSIN DE L'ANAMBE ; ETUDE DE PREFACTIBILITE, DAKAR, MDRH
12.	SODAGRI	1977	PROJET D'AMENAGEMENT HYDRO-AGRICOLE DU BASSIN DE L'ANAMBE, ETUDE SENERIZ, 4 TOMES, DAKAR MDRH-DGPA
13.	SOMIVAC	1978	PLAN DIRECTEUR DU DEVELOPPEMENT RURAL POUR LA CASAMANCE, ZIGUINCHOR - EN 4 TOMES -
14.	SONED	1977	ETUDE SUR LA COMMERCIALISATION ET LE STOCKA DES CEREALES AU SENEGAL, DAKAR.

ABREVIATIONS

1.	ADRAO/WARDA	ASSOCIATION POUR LE DEVELOPPEMENT DE LA RIZICULTURE EN AFRIQUE DE L'OUEST
2.	BIRD/IBRD	BANQUE INTERNATIONALE POUR LA RECONSTRUCTION ET LE DEVELOPPEMENT
3.	BNDS	BANQUE NATIONALE DE DEVELOPPEMENT DU SENEGAL
4.	FOB	FREE ON BOARD
5.	IEMVT	INSTITUT D'ELEVAGE ET DE MEDECINE VETERINAIRE DES PAYS TROPICAUX
6.	IGN	INSTITUT GEOGRAPHIQUE NATIONAL
7.	IRRI	INTERNATIONAL RICE RESEARCH INSTITUTE
8.	ISRA	INSTITUT SENEGALAIS DE RECHERCHES AGRICOLES
9.	ONCAD	OFFICE NATIONAL DE LA COOPERATION ET DE L'ASSISTANCE POUR LE DEVELOPPEMENT
10.	ORSTOM	OFFICE DE LA RECHERCHE SCIENTIFIQUE ET TECHNIQUE OUTRE-MER
11.	SERDA	SOCIETE D'ETUDES ET DE REALISATIONS POUR LE DEVELOPPEMENT EN AFRIQUE
12.	SISCOMA	SOCIETE INDUSTRIELLE SENEGALAISE DE CONSTRUCTIONS MECANIQUES
13.	SODAGRI	SOCIETE DE DEVELOPPEMENT AGRICOLE ET INDUSTRIEL
14.	SODEFITEX	SOCIETE DE DEVELOPPEMENT DES FIBRES TEXTILES
15.	SOMIVAC	SOCIETE DE MISE EN VALEUR DE LA CASAMANCE
16.	SONED	SOCIETE NATIONALE DES ETUDES DE DEVELOPPEMENT
17.	UBT	UNITE DE BETAIL TROPICAL

SUMMARY

The Anambé Basin Development Project must be viewed in the light of the Government's objectives and policies for reducing Senegal's dependence on imported food grains and developing the rural economy. The need for such an orientation of the agricultural economy is striking when present projections of food imports and the recent stagnation in agricultural production are considered.

The Anambé Basin which covers 1 100 km^2 in the Upper Casamance is an extraordinary circular natural depression drained to the south by the Anambé River, a non-perennial watercourse. The Anambé is the most important tributary within Senegal of the Kayanga River. The Kayanga rises to the east of project area at the foot of the Fouta Djallon hills just within Guinea and flows north west and then west, receiving the Anambé River on its right bank before turning south to enter Guinea Bissau.

The economy of the area is almost entirely based on subsistence agriculture and livestock raising. The main restraint on present production is water - the short wet season and erratic rainfall. Without the project those remaining uncultivated lands which are susceptible to cultivation with present farming methods will come under increasing pressure both for agriculture and cattle raising, leading to a familiar pattern of rural migration and progressive.

Rainfall apart, the agricultural development area, covering the inner half of the Basin including all the lands identified as most suitable for irrigation, has a favourable environment for intensive agricultural development. The climate is suitable for year-round farming and the soils are capable under good management of producing high yields of crops. Whereas other surface or subsurface water resources in the area are inadequate, the Kayanga River can be exploited to provide a supply of excellent quality water for multi-cropping of large areas in the Anambé Basin. Agricultural studies have confirmed the potential of the area for the production of rice, maize and sorghum. By providing a package of modern inputs, including irrigation water, peasant agriculture can be lifted out its seasonal underemployment and its dependence on unreliable rainfall.

As some of the most suitable lands are located on heavy soils remote from existing villages, development will feature a flexible mix both of peasant farms and commercial mechanized farm units. Peasant farmers are accorded priority by providing for the transfer of lands initially under mechanized farming to peasant management as required to satisfy future demand for small land holdings. The distribution of land holdings and cropping patterns at full development is a follows :

Cropping pattern	Farming system	Area (ha)	Cropping intensity (average) (%)
Rice - rice	Mechanized	4 935 (30,3 %)	175
Rice - rice	Smallholder	7 210 (44,3 %)	160
Rice - diversified crops	Smallholder	3 410 (21,0 %)	160
Diversified crops both seasons	Smallholder	710 (4,4 %)	160
		16 265	average 165 %

Rice will be grown over 96 percent of the cultivated area in the wet season and 75 percent in the dry season.

Kayanga runoff will be stored behind a homogeneous rolled earthfill dam located near the village of Niandouba and providing a reservoir with a storage volume of 420 million m^3 at maximum storage level. Irrigation releases will be used to generate hydroelectricity by being passed through turbines housed in a power station at the toe of the dam and developing the head between reservoir pool and the Kayanga channel.

A second dam on the Kayanga located immediately downstream of its confluence with the Anambé, will divert the controlled releases from Niandouba dam up the Anambé River to two main pumping stations located 2-3 km south of the town of Kounkané. The pumping stations are disposed at either end of a third dam which, by closing the Anambé channel, protects the Basin against flooding and helps maintain a pool for supply to the pumps. One pumping station will be driven by the hydroenergy generated at Niandouba dam, the other will be diesel driven.

The two main pumping stations independently supply distribution systems commanding irrigation service areas on either side of the Anambé Basin. The distribution systems consist of lined main canals and an unlined secondary and tertiary network. Distribution at the farm level is by earth channels to basin or furrow irrigated plots.

Other components of the development plan include provision of a farm road network, facilities for research on adaptive technology, rice mills, rice seed treatment facilities, a livestock and poultry feed farm, and agricultural support and extension services to farmers.

The programme of agricultural development extends over 1980 to 1996 and over five phases of development. The first phase will serve as a pilot scheme and concerns the development of 1 420 ha on the Anambé right bank near the village of Anambé. Works to be constructed for the first phase include the confluence dam and a temporary pumping station. The pilot phase will provide the justification and guidelines for larger scale development during subsequent phases. The first dry season crop will be harvested in 1982. The major construction period lies in Phase II it runs from 1984 to 1987 and includes the main storage works, flood protection works and main pumping station for the right bank perimeter. Construction of irrigation facilities for the left bank perimeter will start in 1987. Land will be developed for irrigation at a steady rate from 1984 to 1996, averaging 1 350 net ha per year.

The capital cost of all works and facilities is estimated at 40,3 milliard FCFA (1 milliard = 1 000 million) including 19,8 milliard FCFA (49 percent) in foreign currency. The capital cost of the first phase is 3,6 milliard FCFA or 4,7 milliard FCFA if price escalation is allowed for.

The main direct benefits of the project will be annual production at full development of 102 000 tons of cereals including 88 500 tons of rice, 7 000 tons of sorghum and 6 500 tons of maize. This production will satisfy the food requirements of local farmers and leave a marketable surplus of 50 000 tons of milled rice, up to 9 000 tons of maize and sorghum, and 4 400 fattened cattle. Other direct benefits will include a road network and improved water supplies. Secondary benefits will be represented by increased opportunities for employment for both skilled and unskilled labour and savings in foreign exchange.

Peasant farmers will be the main beneficiaries from the project and these will be recruited primarily among the local Basin population. Annual income per capita, including the imputed value of home consumption, will approximately double after deducting debt service and water charges. The latter cover all project operation and maintenance costs.

The economic rate of return of 6 percent obtained for the project as a whole is a modest one. It lies below rates generally considered acceptable as a basis for implementation of capital projects in the public sector. Among the reasons which explain the economic forecast one may note:

- The prevailing rate of exchange between local and foreign currency
- Consumer preference for low grade imported rice
- The distance of the project from centres of rice consumption
- The absence of physical, social and economic infrastructure.

The same factors apply in other potential rice producing areas of Senegal, where projects of a similar nature and scale give comparable economic results. The modest rate of return also derives from the cautious approach which must be adopted toward the introduction and development of large-scale modern agriculture in a relatively remote area, this approach being reflected in conservative estimates of costs and benefits.

Economic profitability is one objective of project formulation but other aims merit equal consideration. The Anambé project will make a major contribution to self-sufficiency in food grains, a factor which will become of vital importance if, as seems inevitable, Senegal is increasingly exposed to the ups and downs of world food prices.

The development proposed forms the most productive use of the water resource potential of the Kayanga river, and is the key element of the integrated development of the Anambé Basin. It will provide economic opportunity and employment in a region where such benefits will help to stabilize rather than destabilize the rural economy.

The project as formulated will be developed in phases, so that the experience gained in the early phases will be progressively applied to subsequent development, and will provide the technical and economic justification for such development. Implementation of the first or pilot phase of the Anambé project is justified on the basis of the arguments considered above, and it is strongly recommended that efforts be directed to this end forthwith.

1. INTRODUCTION

1. INTRODUCTION

1.1 The agricultural sector

1.1.1 General

Despite poor soils and erratic rainfall agriculture is central to Senegal's economy providing the livelihood of about 70 percent of the population, about one third of gross domestic product (GDP) and about half of merchandise exports. The sector will continue to be the major source of employment for the foreseeable future.

The agricultural economy is dominated by small family farms of less than 10 ha producing cereals, mainly millet, for consumption and groundnuts, destined for processing into oil, as a cash crop. Rural per capita income averaged 31 000 FCFA in 1975.

1.1.2 National plans and objectives

The main objectives for the agricultural sector in the period since independance have been :

- to develop the cooperative movement as a means of involving rural people in economic development
- to diversify exports
- to increase domestic production of food crops
- to increase rural income

The performance of the sector towards attainment of these goals has been mixed. Confectionery groundnuts, cotton fibre and fish production have increased but groundnuts for oil continue to dominate agricultural exports. Domestic food crop production has experienced marked fluctuations in the past decade, about a slightly rising trend. Neither food crop nor livestock production has kept pace with demand. Rural incomes have also experienced sharp fluctuations. Cooperatives have generally proved too small to provide the range of services or to achieve the financial independance desired.

While the objectives remain basically unchanged their realisation is being placed increasingly in the hands of semi-autonomous regional development agencies charged with the coordination, control and execution of projects in their region.

Programmes in the present Plan to support Government objectives include :

- increase of groundnut and millet production and productivity, especially in the Groundnut Basin

- greater emphasis on rice and cotton in the higher rainfall areas of the Casamance and Eastern Senegal

- development of the irrigation potential of the Senegal River

- resettlement schemes in Eastern Senegal

1.1.3 Regional development plan

The Casamance region is projected to play an increasingly important role in the Government's programme to increase food grain production, largely due to its relatively high annual rainfall and also to its relatively underdeveloped status which provides great potential for growth in agricultural production. To coordinate development, the Government has established a regional development agency, the SOMIVAC, based in Ziguinchor.

Of the 48 milliards of FCFA (1 milliard = 1000 million) allocated to the agricultural sector in the 5th four-year Development Plan (1977-1981), 13 milliards of FCFA or 27 percent of the total was allocated to the Casamance, a region with 17 percent of the rural population. The major part was to be invested in irrigated crop production, predominantly rice, so that by 1981 the Casamance was to become the leading producer of rice, cotton and maize providing respectively 51 percent, 44 percent and 30 percent of national production. In Lower Casamance irrigated production was to be based on salt exclusion dams, in Middle Casamance on development of small valleys by simple water control structures and in Upper Casamance on the Anambé project. Recent setbacks have occured in the Middle Casamance, partly due to a series of drought years. In the Lower Casamance there are major technical problems to overcome, above all on the mangrove soils. The Upper Casamance, with no problems of saline soils and with greater water resource potential, appears therefore as a favourable area for development.

The Master Plan for Rural Development of the Casamance (SOMIVAC, September 1978) proposes that in the Lower Casamance efforts be directed toward intensification of wet season production in non-saline areas and in the Middle Casamance to continue development of the small valleys. The Upper Casamance is not a zone in which SOMIVAC is active, development being undertaken either by SODAGRI or SODEFITEX (see section 2.7 below).

1.2 Supply and demand for cereals

1.2.1 The role of cereals

At the present time, the use of cereals as feed for livestock or in industry is insignificant ; cereals in Senegal serve almost exclusively for the satisfaction of human nutritional needs.

For urban populations, and some rural areas - notably the Lower Casamance - rice is the basic foodstuff. Consumers in general, both urban and rural, show a preference for rice. Wheat consumption, in the form of flour for bread, is also accorded a high preference.

The consumption of maize is small in comparison to the other cereals, and its role in the diet of city dwellers is very restricted. Nonetheless, maize has its place in traditional cuisine. Consumption is on the rise, largely as a function of its availability. Significant progress in the production of this crop, above all in the Sine-Saloum, in the Casamance, and in Eastern Senegal, has resulted from expansion of animal powered cultivation and chemical fertilizers.

Consumption of millet and sorghum is higher than for all other cereals. They are the traditional basic foodstuff, especially in the rural environment. Cereal production in Senegal has not yet reached the stage where it supports a major milling industry (the exceptions are two wheat and maize flour mills in Dakar, which mill fairly large amounts of these grains).

1.2.2 Cereals production and consumption

Production and consumption statistics for cereals over the period 1960-1975 are given in table 1-1.

For cereals as a whole, imports in recent years have averaged about 30 percent by volume of total consumption if food aid is included. Rice represents about 60 percent of cereals imports by volume - see table below.

Table 1 - 2 CEREALS IMPORTS 1961 - 74 (tons)

		Period	
	1961-65	1966-70	1971-74
Wheat	40 625	59 313	91 840
Maize	13 922	16 372	30 403
White rice	138 481	152 605	181 086
Millet/sorghum	16 535	9 759	22 325
Other	3 110	10 032	19 317
Total	212 673	257 801	344 872

Source : SONED, Etude sur la commercialisation et le stockage des céréales au Sénégal, 1977.

Demand for foodgrains is increasing at about 3 percent per year and, in terms of untreated grain, is expected to reach 2 million tons in 1990. Rainfed production can contribute about 1 million tons towards this amount. Therefore, unless there is a major increase in irrigated cereals production, imports of cereals will rise more rapidly than demand, increasing the already substantial pressure which grain imports exert on the balance of payments. Even assuming a reasonable rate of development of irrigated

Table 1-1 CEREALS PRODUCTION AND CONSUMPTION (1 000 tons)

Year	Millet and sorghum		Rice		Maize		Wheat	Misc.	Total	
	Production	Consumption	Production	Consumption	Production	Consumption	Consumption	Consumption	Production	Consumption
1960	392,4		81,5		27,2				501,1	
1961	406,5	398,9	83,8	157,6	28,3	36,7	52,7	4,5	518,6	651,4
1962	424,1	424,7	90,4	172,8	26,6	40,2	32,7	2,3	541,1	672,8
1963	478,4	460,7	105,8	157,2	26,6	47,0	45,2	3,7	610,8	713,9
1964	531,8	512,1	108,8	256,2	37,2	40,4	38,1	2,7	677,8	849,6
1965	554,1	559,8	125,2	254,8	40,8	54,7	34,3	2,3	720,1	905,9
1966	423,2	524,5	125,2	241,7	41,8	51,0	51,0	11,2	590,2	879,5
1967	654,9	484,4	134,5	239,4	56,8	65,5	52,4	4,4	846,2	846,2
1968	450,0	606,7	58,8	264,0	25,3	84,3	40,0	3,2	534,1	998,2
1969	634,8	535,0	140,8	201,3	48,8	72,4	69,1	25,2	824,4	903,1
1970	400,9	576,5	98,7	212,8	38,7	51,3	84,0	6,1	538,3	930,7
1971	528,7	476,6	108,2	251,1	38,5	71,5	105,4	6,3	675,4	910,9
1972	322,9	528,2	43,6	230,4	20,2	44,3	95,2	4,2	386,7	902,3
1973	510,8	411,2	64,3	221,2	33,8	77,9	105,4	51,4	618,9	867,1
1974	777,0	560,6	117,0	226,4	43,2	71,4	61,4	15,4	937,2	935,2
1975	630,0		144,0		45,2				819,2	
1976										
1977										

Source : Actions Planifères de Production Céréalière, Ministry of Rural Development, and Hydraulics, December 1976 production in the Casamance, in Eastern Senegal and in the Senegal River valley the volume of imports is not expected to decline before 1990. In terms of untreated grain the import gap in 1990 is projected at 0,5 million tons.

For rice alone, a summary of demand, production and the resulting trade balance for the West African region is given in table 1-3. The volume of imports in 1990, projected at 193 000 tons, is equivalent to about 60 percent of the projected 0,5 million tons of imported untreated foodgrains. The share of rice in foodgrain imports is therefore projected to remain at its historic level.

The value of rice imports over 1972-75 averaged 9,5 milliards of FCFA and amounted to 25 percent of the merchandise trade deficit and 75 per cent of the deficit on current account.

1.3 The project area

1.3.1 Location and extent

The Casamance has been introduced above as an area having an important potential for agricultural production. Within the Casamance region the Anambé Basin has long been identified as one of the most promising areas for large scale development of rice cultivation. The Anambé Basin lies in the Upper Casamance with its centre at about 13°00' north and 14°08' west (figure 1-1). The basin covers an area of 110 000 hectares and is the catchment for the Anambe river which flows south to join the Kayanga river some 10 kilometers south of the small town of Kounkané. This study is largely concerned with the agricultural development area comprising 54 000 hectares of the central part of the basin. The limits of the agricultural development area are the Velingara-Kandia-Kolda road in the north, the main Velingara-Teyel-Kounkane-Kolda road in the east and south, and a line approximating to the 55 m IGN contour in the west and passing through the villages of Sare Bourto, Kossanke and Sare Mardi (shown on figures 1-1 and 1-2). Studies also have been carried out in the reservoir area and in the Kayanga valley downstream of the Anambe confluence,both of which areas will be affected by the proposed development.

Table 1-3 DEMAND, SUPPLY AND TRADE POSITION OF RICE FOR WARDA MEMBER COUNTRIES (1 000 tons)

Country	1975[a]			1980			1990		
	Demand[b]	Supply[c]	Trade position[d]	Demand	Supply	Trade position[d]	Demand	Supply	Trade position[d]
Benin	10,0	4,7	5,3	15,6	5,6[e]	10,0	23,1	23,1[f]	0,0[f]
Gambia	39,0	21,9	17,1	47,7	28,0	19,7	67,9	50,0	17,9
Ghana	56,8	56,8	0,0	84,7	84,7[f]	0,0[f]	117,2	117,2[f]	0,0[f]
Ivory Coast	206,0	204,0	2,0	378,8	293,0	85,8	613,6	394,0	219,6
Liberia	174,0	143,0	31,0	197,7	156,0	41,7	256,4	224,0	32,4
Mali	99,0	79,0	20,0	131,9	171,0	-39,1	215,2	291,0	-75,8
Mauritania	13,2	2,2	11,0	31,3	6,7	24,6	47,2	35,0	12,2
Niger	25,8	17,2	8,6	26,8	24,0	2,8	52,1	41,4	10,7
Nigeria	304,7	299,7	5,0	400,1	400,1[f]	0,0[f]	689,9	689,9[f]	0,0[f]
Senegal	245,0	121,2	123,8	277,0	102,0	175,0	404,3	211,3	193,0
S. Leone	330,8	332,3	-1,5	387,7	388,0	-0,3	496,3	541,0	-44,7
Togo	7,0	6,0	1,0	13,0	8,8[e]	2,5	15,3	15,3[f]	0,0[f]
H. Volta	27,3	17,6	9,7	33,8	26,3	7,5	54,3	53,7	0,6
WARDA region[g]	1 538,6	1 305,6	233,0	2 024,4	1 694,2	330,2	3 052,8	2 725,6	365,9

Notes :

a) Source : Table Four, "Prospect of Intra egional Trade of Rice in West Africa," WARDA/77/STC 7/9, September 1977,

b) Net availability, defined as milled rice equivalent of paddy net of seed and losses minus increases in stocks plus net imports.

c) Net availability less net imports.

d) Trade position is defined as demand less supply.

e) Supply projections for 1980 are national estimates based on recent performance.

f) In the absence of supply projections, supply is assumed to equal demand, and the net trade position is assumed to equal 0,0.

g) Excludes Guinea and Guinee Bissau.

The Anambé Basin is situated in the department of Velingara with the exception of the south western portion which is in the department of Kolda. The future reservoir area lies entirely in Velingara department (figure 1-2).

1.3.2 Communications

The project area is reached from Dakar via Kaolack and Tambacounda on 565 km of bitumen surfaced road (N1 and N6), much of which has been completed in last two years. The N6 also links Velingara with Kolda and Ziguinchor. Ziguinchor is a secondary port whose entry provides insufficient draft for larger vessels. The port of Dakar is capable of dealing with all project needs and is regularly served by European lines. The nearest railhead to Velingara is at Tambacounda which lies on a narrow gauge railway linking Dakar to Bamako in Mali. Telephone links to Kolda and thence to Dakar, exist but the service is unreliable. Air Senegal operates daily services to Ziguinchor and several flights a week to Tambacounda. No maintained airstrip exists in Velingara department.

1.3.3 Topography and mapping

The general relief of the Upper Casamance presents a very flat aspect broken only by river valleys, notably the valleys of the Gambia in the North, the Koulountou in the East and the Kayanga to the South.

The Anambé Basin forms the most extraordinary topographic feature of the region. An extensive depression roughly circular in shape, it has a single outlet, the Anambé River, which flows southwards to join the Kayanga. Both Anambé and Kayanga river beds have flat gradients, are encumbered with vegetation, and have low discharge capacities.

Runoff from the highest part of the catchment, at 70-80 m, is concentrated and directed towards the lower basin by a series of radially disposed shallow valleys with flat gradients and poorly defined beds carrying very irregular flows. From the sandy plateau areas above about 30 m, which cover about two thirds of the Basin,runoff descends on to the alluvial terraces which lie in an extensive belt around the central floodplain (figure 1-3). The alluvial terraces are flat, with slopes averaging 1-2 per thousand, and almost entirely uncultivated. Runoff therefore moves very slowly over this zone, filling numerous local depressions to one metre or more for up to three months depending on location and rainfall. The alluvial terraces are the zone of greatest interest for irrigated agriculture and constitute about one quarter of the Basin and one half of the agricultural development area.

The centre of the Basin forms a plain below about 22 m which, except in dry years, is subjected to seasonal flooding by accumulation of surface runoff ; high water levels in the Kayanga reduce discharge from the Anambé Basin and possibly also occasionally reverse the direction of flow in the Anambé River.

Aerial photography was flown in 1978 over the study area and the reservoir area at scales of 1 : 25 000 and 1 : 40 000 respectively. Topographic maps of the study area have been produced at 1 : 10 000 with 1 metre contours and of the reservoir area at 1 : 25 000 with 2 metre contours (figure 1-4). This represents the only large scale controlled mapping of the project area.

1.3.4 Economy

The economy of the project area is almost entirely based on subsistence agriculture and livestock raising. The largest town is Velingara with 9 000 inhabitants followed by Kounkané with about 1 640. The largest villages have close to 500 inhabitants and include Kabendou, Medina Cherif and Diaobé in the south and Kandia in the north. The main industry is the SODEFITEX cotton ginnery at Vélingara. Vélingara also has the largest market, smaller markets being found at Kounkané and at Diaobé.

1.4 The SODAGRI

SODAGRI (Société de Développement Agricole et Industriel du Sénégal) was created in 1974 as a "société mixte" in which ownership is shared between the Government and private shareholders. Majority ownership and control now lies with the Government, which through a state holding and capital subscribed by ONCAD and the Caisse de Péréquation et de Stabilisation des Prix, has 79 % of the total share capital of 120 million FCFA, the remainder being held by BNDS.

The objectives assigned to the SODAGRI by the Government have always been and remain the identification of areas with potential for rice cultivation, the carrying out of feasibility studies, and the execution of projects and their subsequent management. In pursuit of these objectives SODAGRI has :

- identified the Anambé Basin as an area of particular potential ;
- carried out prefeasibility studies (SODAGRI, 1977) ;
- started the planning and implementation of 3 programmes in the Anambé Basin and immediate vicinity (see para 2.7.4)
- initiated and coordinated feasibility studies and detailed designs for the development of irrigated agriculture in the Anambé Basin.

SODAGRI through a Supervisory Board is responsible to the Ministry of Rural Development. Its headquarters is presently in Dakar. A field office in Vélingara under a project manager is responsible for SODAGRI's activities in the Anambé Basin and the Kayanga valley.

1.5 Previous studies

During the past 20 years the Anambé Basin has been the subject of three studies, those of GERCA, SERDA and SODAGRI.

The GERCA (Groupement d'Etudes Rurales en Casamance) studies carried out in 1962/63 covered agronomy, demography and socio-economy. At the same time a small pilot perimeter was established at Kounkané and a campaign of hydrological data collection was initiated. The study proposed the development of the small radially-oriented watercourses by defining their watercourses, improving evacuation of floods and distributing flow to an irrigation network for supplementary wet season irrigation. Reduction of flooding was also to be achieved by improving the Anambé outlet capacity and by protecting rice-lands with dykes. The study emphasized the need for further data collection, for a pilot farm to test agricultural practices and the development concepts, and the need to start by developing a single sub-catchment.

The SERDA study of 1976 appears to have been a desk study as no new data are given. A reservoir in the centre of the Basin was proposed, surrounded by a dyke assuring both storage and flood protection. A series of 2 m high contour dykes on the alluvial terraces complemented the supply by storing surface runoff. Further upslope a development of the radial watercourses as proposed by GERCA was envisaged. The overall irrigable area was estimated at 22 500 ha.

The most recent study is the SENERIZ study carried out by SODAGRI and completed in 1978. The study included some topographic, pedological and sociological investigations. Development of the Anambé Basin was to be based on provision of irrigation and drainage works to the 25 000 ha of alluvial terraces for mechanized farming of rice. The water supply for double cropping was secured by storage of Kayanga runoff behind a dam and delivery to the Basin was via a pumping station and appropriate conveyance works. Intensification of wet season cultivation on lands surrounding the irrigated perimeter would further boost cereals production. An agro-industrial complex was provided for processing cereals and fattening livestock.

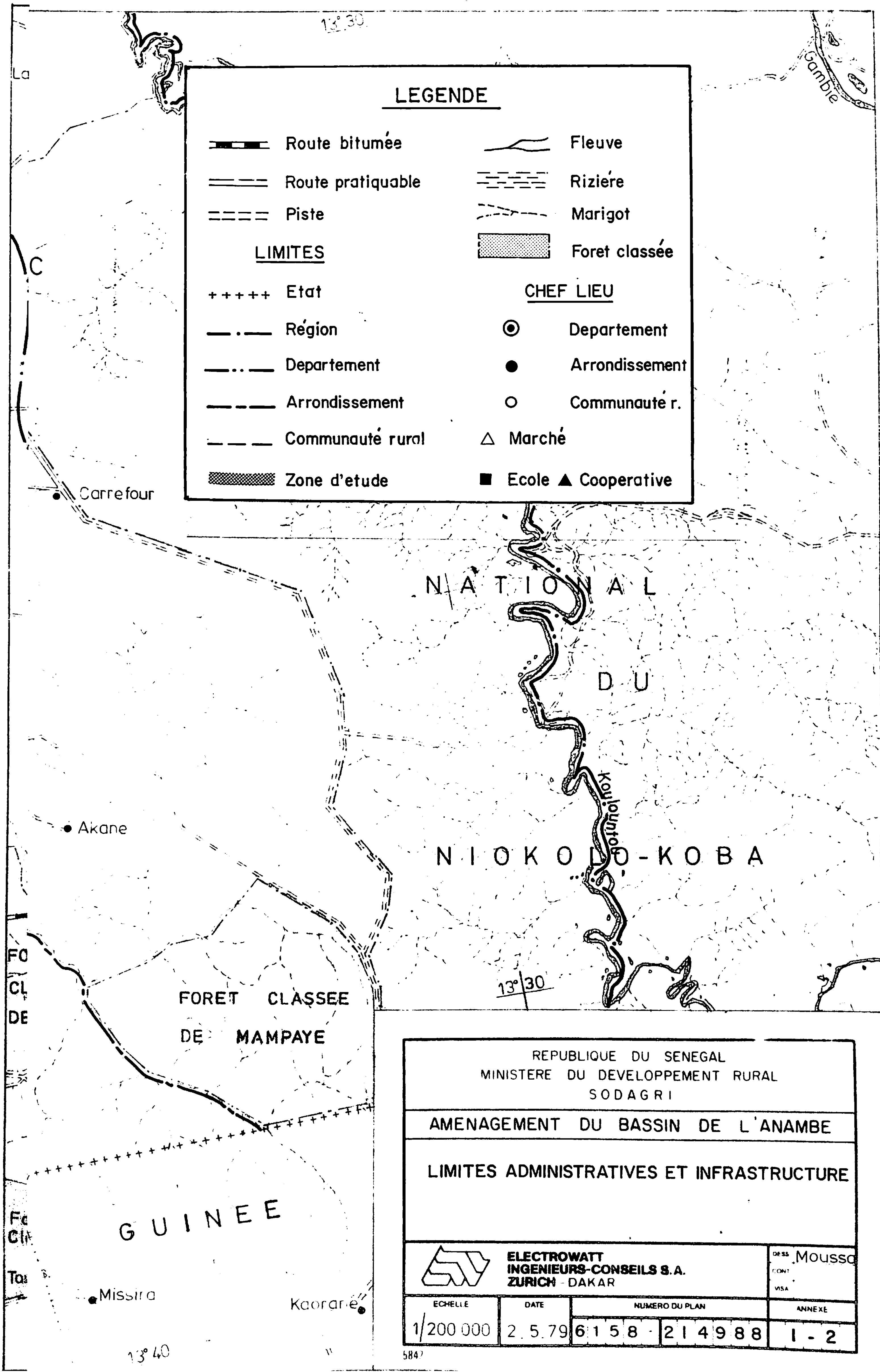
1.6 Purpose and scope of present study

The feasibility studies presented in this report have been carried out under an agreement for engineering services (Marché d'Etudes No C/143/FM) between the Ministry of Rural Development and Hydraulics (Ministère du Développement Rural et de l'Hydraulique) represented by the SODAGRI acting as executing agency and Electrowatt Engineering Services Ltd, Zurich, dated the 1st August 1978.

The contract calls for the Consultant to review and carry further the previous prefeasibility studies (SENERIZ studies) and in particular to

- set up and run a pilot farm
- collect and analyse basic data and carry out project planning studies to feasibility level and preliminary design
- carry out final design and preparation of tender documents

The studies started in August 1978.


LEGENDE
Route bitumée
Route pratiquable
Piste
LIMITES
Etat
Région
Departement
Arrondissement
Communauté rural
Zone d'etude
Fleuve
Rizière
Marigot
Foret classée
CHEF LIEU
Departement
Arrondissement
Communauté r.
Marché
Ecole
Cooperative
13°30
Gambie
Carrefour
Akane
NATIONAL DU NIOKOLO-KOBA
Koulountou
13°30
FORET CLASSEE DE MAMPAYE
GUINEE
Missira
Kaoraré
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REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI
AMENAGEMENT DU BASSIN DE L'ANAMBE
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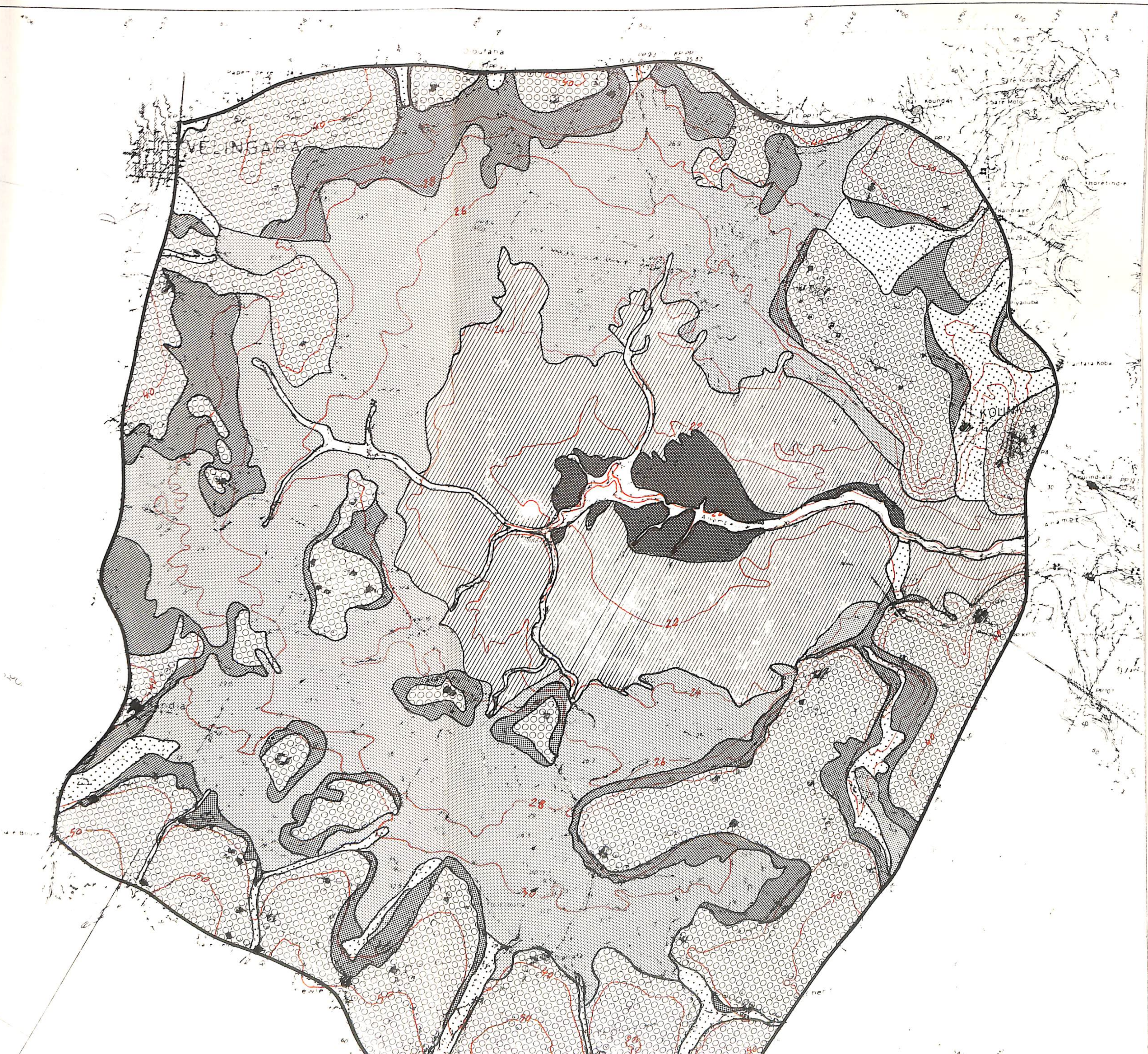

LEGENDE

- ZONE CENTRALE D'INONDATION (LAC DE
- TERRASSES INFERIEURES
- TERRASSES SUPERIEURES
- PENTES SABLEUSES
- PLATEAUX
- VALLES PERIPHERIQUES
- RIVIERE ANAMBE ET MARIGOTS TRIBUT
- LIMITE DE LA ZONE D'ETUDE

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANA

UNITES PHYSIOGRAPHIQUES

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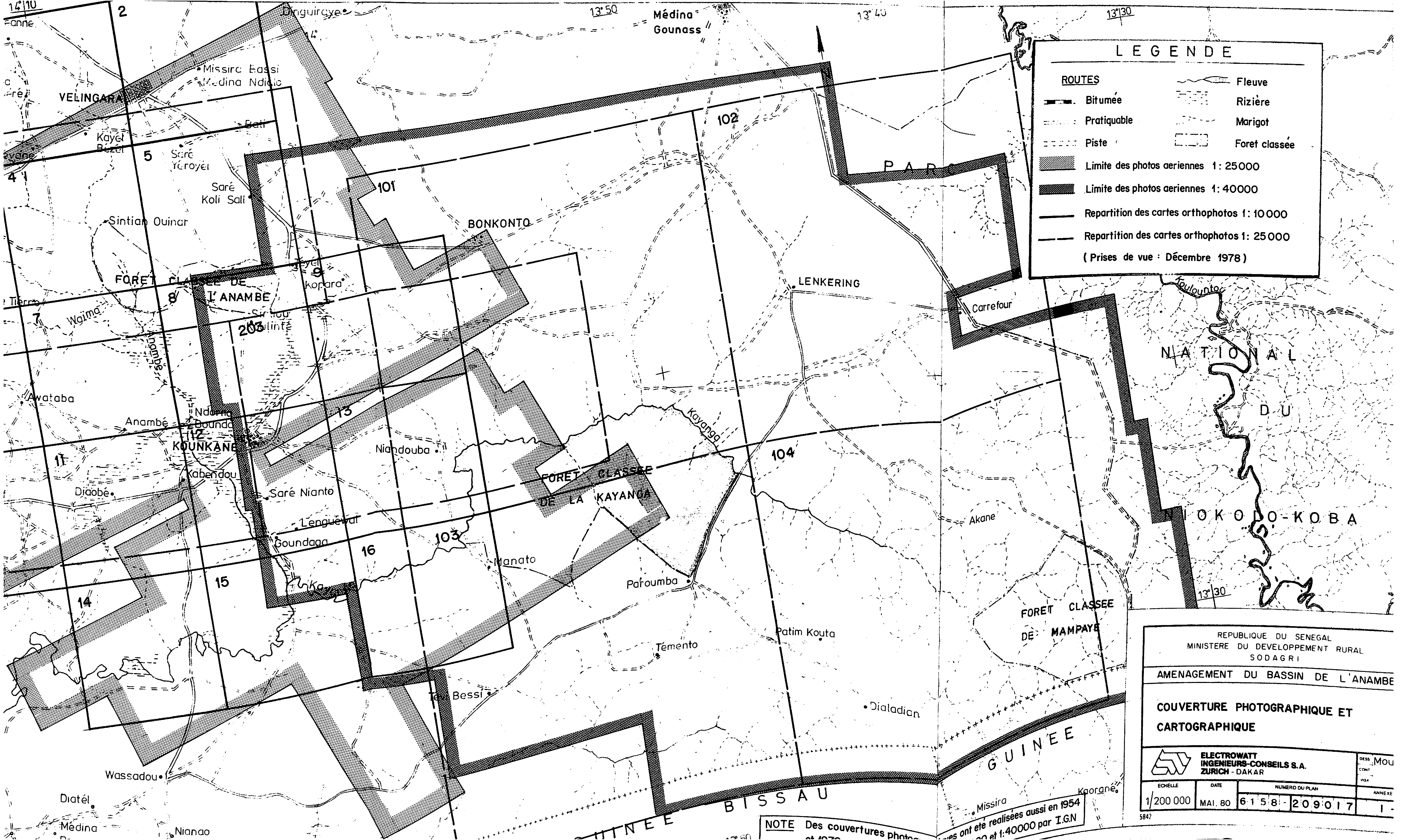
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ROUTES
Bitumée
Pratiquable
Piste
Fleuve
Rizière
Marigot
Foret classée
Limite des photos aeriennes 1: 25000
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Repartition des cartes orthophotos 1: 25000
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MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI
AMENAGEMENT DU BASSIN DE L'ANAMBE
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Missira Bassi
Médina Ndiolo
VELINGARA
Kayel Bozel
Saré Yéroyel
Saré Koli Sali
Sintian Ouinar
FORET CLASSEE DE L'ANAMBE
Wajima
Anambé
Awataba
Ndorna
Bounda
KOUNKANE
Kabendou
Diaobé
Saré Nianto
Lenguéwal
Goundaga
Niandouba
Manato
BONKONTO
Kopara
LENKERING
Carrefour
Kayanga
FORET CLASSEE DE LA KAYANGA
Paroumba
Témento
Patim Kouta
Akane
FORET CLASSEE DE MAMPAYE
Dialadian
Tesi Bessi
Wassadou
Diatél
Médina
Nianao
Missira
Kouloumbou
Koorané
PARC NATIONAL DU NIOKOLO-KOBA
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2. THE PROJECT AREA

2. THE PROJECT AREA

2.1 Climate

The climate of the project area is characterized by a rainy season from about mid June to mid October followed by a dry season of about 8 months. Mean annual rainfall is 1 063 mm at Vélingara in the north of the project area and about 100 mm higher in the south. Mean monthly temperatures reach a maximum in May and a minimum in January varying between 24° and 32°. Winds are slight to moderate throughout the year.

From the standpoint of development planning for irrigated agriculture the essential parameters of climate are temperature, insolation, precipitation and potential evapotranspiration. The latter is the water use for evaporation and transpiration from land which has a maximum cover of vegetation and sufficient soil moisture to satisfy all consumptive demands of the growing plants.

Summary data for these parameters as estimated for the Anambé Basin are given in Table 2-1. The implications of these data on development planning are as follows :

- in the absence of irrigation, agriculture can only be practiced during the brief wet season. It may be noted that studies of daily precipitation, described in Report 2, show that in about 1 year in 2, one or more rainless periods occur which are of sufficient duration to affect crop yields.

- with the provision of adequate irrigation water supplies there are no significant climatic restraints to carrying out profitable perennial irrigated agriculture. Although the moderately cool daily minimum temperatures experienced in January will inhibit the growth of tropical varieties of rice, this will not be reflected in yields, and the extension of the growing season will not be sufficient to interfere with double cropping practices. Similarly,

Table 2 - 1 CLIMATE DATA

Observation/calculation	Reference period	Station	January	February	March	April	May	June	July	August	September	October	November	December	Annual average or total
1. Mean temperature(°c)															
1.1 Daily maxima	51 - 76	Kolda	34,6	37,3	39,6	40,3	39,6	35,8	32,1	31,1	31,6	33	34,2	33,3	
1.2 Daily minima	51 - 76	Kolda	13,0	16,0	18,9	21,2	23,0	24,0	22,9	22,7	22,5	22,3	18,9	14,0	
1.3 Daily means	51 - 76	Kolda	23,8	26,7	29,2	30,7	31,3	29,9	27,5	26,9	27,0	27,6	26,6	23,7	27,6
2. Mean daily sunshine hours	51 - 76	Kolda	270,3	257,9	291,9	288,3	284,6	236,7	211,1	181,2	180,5	226,3	244,1	245,2	264
3. Relative humidity(%)															
3.1 Mean of max.	51 - 76	Kolda	88,6	82,3	81,6	80,6	83,3	91,5	96,8	97,5	97,5	97,9	97,8	94,8	90,9
3.2 Mean of min.	51 - 76	Kolda	18,4	16,8	17,1	20,1	28,8	46,8	61,9	68,1	66,2	59,1	40,4	25,3	39,1
3.3 Mean	51 - 76	Kolda	53,5	49,5	49,4	50,4	56	69,2	79,4	81,8	81,9	78,5	69,1	60	65
4. Mean wind speed(m/s)	72 - 77	Bassé	1,5	2,2	2,2	2,3	2,6	2,6	2,1	1,9	1,5	1,3	1,4	1,6	2,0
5. Rainfall (mm)															
5.1 Mean	32 - 77	Vélingara				3	24	132	218	314	276	90	6		1 063
5.2 80 % exceedance	32 - 77	Vélingara					2	78	154	239	203	42			863
6. Evaporation (mm)															
6.1 Class A Pan	77 - 78	Bassé	167	193	257	279	285	228	214	198	192	167	138	121	2 439
6.2 Open water, Eo	-	Project area	161	164	200	217	238	201	167	123	116	150	152	156	2 035
7. Potential evapo-transpiration (mm)	-	Project area	140	143	174	189	198	183	152	112	105	136	132	136	1 800
8. Moisture surplus or deficit (mm)															
8.1 Mean (5,1 - 7)	-	Project area	(140)	(143)	(174)	(186)	(174)	(51)	66	202	271	(46)	(126)	(136)	(737)
8.2 80 % exceedence (5,2 - 7)	-	Project area	(140)	(143)	(174)	(189)	(196)	(105)	2	127	98	(94)	(132)	(130)	(937)

the moderate insolation during the last half of the rainy season inhibits plant growth, but this has been managed in the past by the introduction of adapted varieties, and with the provision of irrigation supplies the scope for varietal selection will be greatly enhanced.

In summary, except for the moisture constraint the critical climatic factors favour the practice of perennial agriculture. And the lesser factors are equally favourable ; frost is not a hazard, and the incidence of damaging winds or torrential rains is so infrequent as to have negligible consequences on the agricultural economy.

2.2 Land resources

2.2.1 Introduction

An area of about 54 000 hectares comprising the central part of the Anambe basin was surveyed to appraise the suitability of the land for permanent, profitable production of crops under irrigation. National objectives, which emphasize rice production, are reflected in the soil and land classification systems used.

The principal factors studied were the soils, topography and drainage. Other factors investigated include microrelief, natural vegetation and present land use. The main features of the study were a semi-detailed soil survey with an average of one observation site per 62 hectares, and land classification for irrigation suitability. Soil samples from 46 master sites representative of the main soil types were analysed for an appropriate range of physical and chemical properties. Analyses of other soil samples were made as required for the mapping programme. At many of the master sites field tests were carried out for the estimation of surface infiltration rates, soil moisture content at field capacity and subsoil hydraulic conductivity. Soil and land class boundaries were plotted on 1978 air photographs and subsequently compiled on 1:25 000 scale topographic maps.

2.2.2 Soils

In the Anambe basin the distribution patterns of landforms (figure 1-3),drainage conditions, soils and vegetation are roughly concentric.

The gently sloping (mean about 1%) areas above 28-30 m IGN, which are termed the plateaux, have highly weathered residual soils derived from the Continental Terminal, a detrital sediment composed dominantly of quartz, kaolinite and iron minerals. At elevations below 28 m IGN the parent materials of the soils are more recent deposits derived largely from the plateaux by erosion and deposition from water. These materials become finer in texture towards the centre of the basin ; they range in texture from sands on the gentle slopes adjoining the plateaux to heavy clays in the central floodplain. The plateaux are dissected by a number of shallow peripheral valleys in which the soils are derived from alluvial deposits of variable texture.

The inner part of the study area, some 27 000 hectares, is very gently sloping (mean about 0,1 %). This part comprises the central floodplain, which lies between elevation 20,0 to 21,5 m IGN, the drainage channels and the alluvial terraces which extend from the central floodplain to a maximum elevation of 28-30 m IGN.

The soils of the central floodplain and the drainage channels and parts of the alluvial terraces and peripheral valleys are strongly affected by the occurrence of a shallow water table for several months in most years. These soils are grey or greyish in colour and may show mottling. This is due to the process of gleying, which involves the reduction of iron compounds under saturated conditions, and their partial re-oxidation and precipitation when the water table declines and the soil is re-aerated. The clay fraction of these soils is composed dominantly of kaolinite with some montmorillonite, chlorite and interstratified accessory minerals. In other areas where the water table lies at greater depth conspicuous effects of gleying occur only in the lower part of the profile.

The soil classification was designed to group soils with similar potential for irrigated agriculture. The resulting main criteria used to identify the soil mapping units are texture, internal drainage, rooting depth and expansion-contraction properties.

Soils suitable for the production of wetland rice under irrigation occur principally on the alluvial terraces and in parts of the peripheral valleys. These soils have medium to fine textures and slow to very slow internal drainage. The soils of the central floodplain also have these characteristics but other physical properties, especially expansion and contraction on wetting and drying, are less favourable. This area has the further disadvantages of being liable to annual flooding, and of having moderate to severe microrelief in the form of gilgai.

Other soils of the terraces, especially the higher terraces, have moderately permeable subsoils and would have relatively high water requirements if used for wetland rice. Where otherwise suitable for irrigation these lands may be used for rice production in the wet season and for upland crops such as maize in the dry season. These soils have strongly acid subsoils and commonly have exchangeable aluminium in excess of one milliequivalent per 100 g soil within the top 100 cm. This level of exchangeable aluminium would not be a problem for wetland rice production but would inhibit yields of some upland crops.

The soils of the sandy slopes which link the plateaux with the terraces and with the peripheral valleys have coarse textures to at least 50 cm depth. Related to the coarse soil texture are very rapid infiltration rates and rather low available water holding capacity, both properties being highly unfavourable for irrigated agriculture using gravity methods. These soils also have low cation exchange capacity and low reserves of plant nutrients.

The soils of the plateaux also have coarse textured topsoils but they are underlain by medium textured subsoils which provide more favourable conditions for irrigated agriculture. The plateaux soils are mostly moderately to well-drained and are generally suitable for the production of diversified crops under irrigation. However, some areas have insufficient rooting depth for most crops owing to the occurrence of indurated ironstone near to the surface.

None of the soils of the study area are saline. As the water of the Kayanga River, which will be the source of water for the irrigation project, is only weakly mineralized, with proper water management no problems of salinity are likely to arise as a result of irrigation.

The general properties of the soils of the study area are summarized in table 2-2.

2.2.3 Suitability of the lands for irrigation

The purpose of the land classification is to determine the area of irrigable lands in the Anambe basin, and their relative suitability for production of irrigated rice and diversified upland crops.

The land classes provide an approximative measure of relative net income as determined by consideration of productive capacity, costs of production and pertinent costs of development. Land clearing is required for almost all of the potentially irrigable land within the project area but the costs of clearance have been treated as a project cost and do not influence the land class.

Lands highly suitable for wetland rice cultivation must, after appropriate land preparation such as soil puddling, be sufficiently impermeable so that a pond can be maintained on the field without excessive percolation losses. Upland croplands,on the other hand, should drain freely and the water table should remain below the normal rooting depth. However, these categories are not totally exclusive and in certain areas and under appropriate cultural practices rice and upland crops may be grown on the same lands. This is notably true for certain of the medium textured soils of restricted drainability which would be suitable for rice during the wet season but unsuitable during the dry season because of excessive water requirements. These could be used more profitably for selected upland crops.

The lands surveyed have been assigned one of the following classes according to the criteria given in table 2-3.

Table 2 - 2 GENERAL PROPERTIES OF THE SOILS

Property	Divisions	Area (ha)[1]	% of study area
Texture of topsoil (0-30 cm)	Coarse (>65 % sand <18 % clay)	30 440	57
	Medium (finer than above, <35 % clay)	14 750	27
	Fine (>35 % clay)	5 150	10
Texture of subsoil (30-100 cm)	Coarse	3 690	7
	Medium	30 000	56
	Fine	16 700	31
Internal drainage	Very slow	18 790	35
	Moderate to slow	20 170	38
	Rapid	11 420	21
Reaction of the topsoil (pH in water)	Slightly acid to neutral (pH 6,1-6,8)	19 170	36
	Moderately acid (pH 5,6-6,0)	25 620	48
	Acid (pH 5,1-5,5)	5 600	10
Recation of the subsoil (pH in water)	Neutral to moderately acid (pH 6,8-5,6)	28 900	54
	Acid (pH 5,1-5,5)	17 700	33
	Strongly acid (pH 4,5-5,0)	3 800	7
Aluminium (0-100 cm ; extractable by 1 N-KCl)	Low (<0,2 meq/100 g)	23 860	44
	Moderate (0,2-1 meq/100 g)	16 450	31
	High (>1 meq/100 g)	10 130	19
Cation exchange capacity of the topsoil (Ammonium acetate method ; pH 7,0)	Low (<5 meq/100 g)	30 700	57
	Moderate low (6-10 meq/100 g)	7 000	13
	Adequate (>10 meq/100 g)	12 750	24

(1) Excluding about 3 270 hectares of shallow soils and soils of drainage channels (representing 6 percent of study area)

Table 2 - 3 LAND CLASSIFICATION CRITERIA AND LIMITS

Land characteristics	For irrigated rice Class 1R	Class 2R	For diversified crops Class 2
Soil texture, 0-30 cm	Fine sandy loam to clay loam	Loamy sand to clay	Loamy sand to clay loam
Soil texture, subsoil	Loamy sand to clay	Sand to clay	Sandy loam to clay
Soil depth, minimum (cm)			
To sand or to pisolites in a permeable matrix	60	30	60
To horizon dominated by ironstone	60	40	100
Depth to relatively impermeable horizon (m)	less than 2	less than 2	more than 2
Available water holding capacity, minimum (mm)			
0 - 30 cm	n.a	n.a	25
0 - 100 cm	n.a	n.a	70
Reaction of soil within rooting depth (pH in water)	n.a	n.a	more than 5,0
Aluminium [1] (meq./100g)	n.a	n.a	less than 1,0
CEC [2], minimum, 0 - 30 cm	10	6	6
Slope (%)	less than 1	less than 3	0,2-4
Slope irregularities	slight	slight to moderate	slight to moderate
Levelling requirement(m3)	0 - 250	0 - 500	0 - 500
Internal drainage	very slow	moderate to very slow	rapid
Surface drainage	can be slow	can be restricted	unrestricted

1) Absorbed aluminium within rooting depth
2) Cation exchange capacity at pH 7,0 in milliéquivalents per 100 g soil
n.a indicates not applicable

Class 1R - Wetland rice
Highly suitable for rice production under irrigation and capable of producing sustained high yields of rice at reasonable cost. Soil submergence is assured by surface and subsoil textures and internal drainage conditions. Land development costs are slight to moderate.

Class 2 R - Wetland Rice
Suitable for irrigated rice but of lower quality than class 1R, these lands may have a lower productive capacity or they may be more costly to farm or to develop. Under projected production techniques, a moderate net income would be assured.

Class 2 - Diversified crops
Lands moderately suitable for production of a range of irrigated upland crops but generally not paddy rice. In certain soils with restricted drainage they are suitable for wet season rice.

Class 6 - Non irrigable
These lands do not meet the minimum requirements for irrigable land owing to severe deficiencies of soil, topography or drainage which preclude their use for profitable irrigated agriculture. Such deficiencies include pronounced microrelief and/ or macrorelief, texture, liability to prolonged flooding, high cost of drainage, and shallow soils. Land already occupied by towns and villages also is included in this class.

The net income of the Class 2 land is considered to be of the same order as that of the Class 2 R when all direct and indirect costs are taken into account including the higher water requirement of irrigated rice.

The reason for downgrading land to a lower class than Class 1 or Class 1R is indicated by one or more of the subclass symbols s, t or d, corresponding to a deficiency in soils, topography or drainage, respectively.

Table 2-4 gives the general characteristics of the irrigable land classes and subclasses with the corresponding recommended cropping pattern. Of the total study area of 53 670 ha, 41 620 ha are adjudged irrigable and

Table 2 - 4 GENERAL CHARACTERISTICS OF THE IRRIGABLE LAND CLASSES AND SUBCLASSES

Class or subclass[1]	Drainability	Textural range topsoil/subsoil	Other important features	Area (ha)	Cropping pattern	Map Symbol[2]
1 R	Poor	Loam to clay loam over sandy clay loam to clay	.	4 650	Rice-rice	1RR
2Rt	Poor to restricted	Loam to clay loam over sandy clay loam to clay	Undulating/common large termite mounds	1 890	Rice-rice	
2 Rd	Poor	Loam to clay loam over sandy clay loam to clay	Subject to seasonal inundation	1 930	Rice-rice	
2 Rtd	Poor	Loam to clay loam over sandy clay loam to clay	Uneven topography and subject to inundation	2 520	Rice-rice	
2 Rs	Poor	Sandy loam to loam over sandy clay loam to clay	Low topsoil fertility	5 580	Rice-rice	2RR
2 Rsd	Poor	Sandy loam to loam over sandy clay loam to clay	Low fertility and subject to inundation	1 030	Rice-rice	
2 Rst	Poor	Sandy loam to loam over sandy clay loam to clay	Low fertility and uneven topography	950	Rice-rice	
2 Rstd	Poor	Sandy loam to loam over sandy clay loam	Slight limitations in fertility and topography, subject to inundation	4 260	Rice-rice	
2 Rs	Restricted	Sandy loam to clay loam over clay loam	Low topsoil fertility, restricted internal drainage; locally, hight levels of exchangeable aluminium	1 400	Rice-diversified	2RD
2 Rst	Restricted	Sand loam over clay loam	Low topsoil fertility, slightly undulating or with common large termitaria	1 200	Rice-diversified	
2 st	Restricted	Sandy loam to loam over sandy clay loam to clay loam	Low topsoil fertility, high levels of exchangeable aluminium locally, restricted internal drainage, slightly undulating/common large termite mounds	4 640	Rice-diversified	
2 st	Good	as 2 st above	As 2 st but with good drainability	6 300	Diversified	
2 s	Good to restricted	Sandy loam over sandy clay loam to clay loam	Low topsoil fertility	5 270	Diversified	2DD

(1) In approximate order of decreasing suitability for wetland rice
(2) Symbol on summary land classification map (figure 2-1)

12 050 ha non irrigable. The distribution of the lands by subclass is shown at 1:25 000 scale on figure 4-4 in Report 4, Pedology. Land suitability for irrigation is portrayed in summary form in figure 2-1 which shows the distribution of lands in terms of proposed cropping patterns (as denoted by the map symbols given in the last column of table 2-4) and the limits of the proposed irrigation perimeters.

Land suitable for rice production occurs principally in the alluvial terraces, but also in some of the broader peripheral valleys and on parts of the plateaux where a relatively impermeable indurated ironstone horizon occurs in the subsoil. Lands suitable for diversified crops occur principally on the plateaux and parts of the alluvial terraces at higher evaluation.

The principal factors contributing to the soil deficiencies for the Class 2R rice lands are low fertility, associated with coarse textured topsoils, and relatively high subsoil permeability, which could result in high irrigation water requirements. The other factors which resulted in areas of the rice land being downgraded to Class 2R are topography, principally slope undulations and microrelief features such as termite mounds, and drainage deficiencies chiefly due to the lack of natural drainage ways.

All areas classified as suitable for diversified crop production under irrigation have soil deficiencies. These are principally associated with the coarse texture of the topsoils. Much of this Class 2 land also has deficiencies in topography (mostly slight), specifically slope undulations and frequent large termite mounds.

Profitable irrigated agriculture can be carried out on all lands enumerated in table 2-4 which can be served with irrigation water supplies at economic cost. To this end, various canal alignments and secondary pumping stations have been considered to ensure the most economic distribution of irrigation supplies which can be developed for the Anambe Basin. Except for the block of lands lying south and west of Awataba which will be irrigated by pumping from the main canal, all lands lying at elevations above the main irrigation canals would be out of command and hence not irrigated.

Table 2-5 gives a summary of the land suitability units shown on figure 2-1 and the areas to be irrigated under the project plan. These are gross areas and include access roads, small villages and the area required for the proposed distribution and drainage facilities. Of the total area of 41 620 ha suitable for irrigation a gross area of about 19 000 hectares is to be irrigated under the project plan.

2.3 Surface water resources

2.3.1 The river basins

Studies have been carried out in two river basins, those of the Kayanga and of its main tributary the Anambé. The catchment boundaries are shown in figure 2-2.

The Kayanga River rises in Guinea at elevation 80 IGN in a marshy area at the foot of the Fouta Djallon hills. It flows north-west, entering Senegal a few kilometres from its source. After 40 km it turns west and after a further 50 km south to enter Guinea Bissau where it is known as the Rio Geba. Its total length to its mouth at Bissau is 335 km. In its lower course, downstream of Niapo Bridge, the river is very sluggish. At Niapo Bridge the catchment area is 1 755 km^2. Its catchment is covered predominantly in lightly wooded savanna except along the river where a dense forest gallery has formed.

The Anambé is the main tributary of the Kayanga and drains a catchment of 1 100 km^2. It joins the Kayanga about 500 m downstream of Niapo Bridge. The catchment is circular in shape with its divide at about 75 IGN. It is drained by a network of seasonal water courses with broad ill-defined streambeds, in which rice is grown during the wet season, and slopes of about 2-3^{0}/oo. The bottom lands of the Anambé Basin are regularly flooded during high stages of the Kayanga River. The catchment is covered by wooded savanna and cultivated land.

2.3.2 Kayanga runoff

Kayanga streamflow increases during the wet season to reach a peak in

Table 2-5 SUMMARY OF THE LAND SUITABILITY UNITS AND AREAS TO BE IRRIGATED

Map Symbol	Wet Season Crop	Dry Season Crop	Drainability Class (1)	Description of land suitability unit	Total area of unit (ha)	Gross area to be irrigated (ha)
1RR	Rice	Rice	Z	Highly suitable for rice production under irrigation and capable of producing sustained high yields of rice at reasonable cost.	4 650	2 600
2RR	Rice	Rice	Z	Suitable for irrigated rice but land is of lower quality than unit 1RR. These lands may have a lower productive capacity or they may be more costly to farm or develop.	18 160	11 370
2RD	Rice	Diversified	Y	Moderately suitable for irrigation but with a higher water requirement for rice than 1RR and 2RR lands. Some areas unsuitable for diversified crops in the wet season because of restricted drainability.	7 240	4 000
2DD	Diversified	Diversified	X	Lands moderately suitable for production of a range of irrigated upland crops.	11 570	2 840
N	-	-	-	Not suitable for irrigation because of severe deficiencies of soil, topography or drainage or because the land is already occupied.	12 050	0

(1) Drainability classes : X - good, Y - restricted, Z - poor

September-October, then decreases rapidly to December and more slowly thereafter until June.

The hydrometric network for the two river basins comprises the following stations (cf figure 2 - 2) :

River	Location	Catchment area (km^2)	Date first installed	Years of data	Type
Kayanga	Niapo Bridge	1 755	1962	1962,1967-69 1976-78	Stage recorder
Kayanga	Wassadou Bridge	2 870	1976	1976-78	Stage recorder
Anambé	Kounkané Bridge	1 100	1977	No runoff recorded	stage recorder (now removed)

The 7 years of Kayanga streamflow data given in table 2-6 were extended in order to improve estimates of average and extreme runoff and to permit reservoir operation studies to be carried out over a long and continous hydrological sequence. Given the uniform character of variations in climate in this part of the world a similar uniformity could be expected in streamflows. Kayanga annual runoff was compared to that of the Casamance, the Gambia, the Senegal and the Falémé. The most satisfactory correlation (r = 0,93) proved to be that with the Falémé at Kédira for which continous data are available from 1930, extended to 1903 by correlation with the Senegal River at Bakel. Use of this correlation enabled the hydrologic sequence of annual runoff for the Kayanga to be extended over 76 years.

Analysis of the synthetic streamflow sequence reveals a sequence of wet cycles lasting 20-25 years and dry cycles of 6-10 years. This sequence is clearly shown both in a plot of smoothed annual runoff using 5 year moving averages and in the mass curve (figure 2-3). The characteristics of the full sequence compared with those of the wet cycles are as follows :

Table 2-6 KAYANGA MONTHLY STREAMFLOW MEASURED AT NIAPO BRIDGE AND WASSADOU BRIDGE (m^3/s)

	M	J	J	A	S	O	N	D	J	F	M	A	Total
A) NIAPO BRIDGE													
1962 - 63	0,7	1,3	5,2	17,8	50,0	51,5	17,7	5,6	3,7	2,7	1,8	1,0*	13,2
1967 - 68	1,0*	2,88	5,71	6,26	30,64	86,03	14,84	5,24	3,30	2,55	1,94	1,42	13,59
1968 - 69	1,17	2,29	3,60	4,52	12,54	9,21	3,15	1,81	1,38	1,12	0,99	0,82	3,56
1969 - 70	0,69	2,30	5,97	4,50	13,44	10,38	5,88	2,05	1,33	1,07	0,96	0,82	4,12
1970 - 71	0,72												
1976 - 77	0,64	0,70	2,11	1,68	4,08	5,52	1,31	0,85	0,76	0,71	0,69	0,67	1,65
1977 - 78	0,61	0,61	1,01	0,84	2,66	1,50	0,73	0,66	0,65	0,63	0,62	0,61	0,93
1978 - 79	0,6	1,8	3,8	2,5	6,3	6,4	1,7						
Mean	0,77	1,70	3,91	5,44	17,09	24,36	6,47	2,70	1,85	1,46	1,17	0,89	6,18
Standard deviation	0,21	0,86	1,87	5,76	17,29	32,05	6,95	2,18	1,31	0,92	0,57	0,29	5,72

* estimated values

	M	J	J	A	S	O	N	D	J	F	M	A	Total
B) WASSADOU BRIDGE													
1976 - 77	0,35	0,43	2,22	2,05	4,82	8,07	2,35	1,23	0,90	0,70	0,58	0,52	2,03
1977 - 78	0,46	0,47	0,88	0,86	3,13	2,32	0,70	0,54	0,53	0,53	0,58	0,64	0,97
1978	0,63	2,3	4,1	3,7	9,8	11,5							

Sources : 1962-63 GERCA report
1967-71 et 76-77 ORSTOM publications
1977-78 et 1978 ORSTOM unpublished data

Table 2 - 7 KAYANGA ANNUAL RUNOFF : STATISTICAL VARIATION

	Annual runoff (million m^3) 1903 - 76	1918-38 and 1945-67
Mean year	274	355
1 in 10 dry year	86	172
1 in 20 dry year	48	120
1 in 10 wet year	475	538
1 in 20 wet year	532	590

Analysis of monthly runoff data revealed a relationship with annual runoff which enabled monthly runoff data to be generated for each year of the extended cycle. The statistical variation of monthly flows is given in table 2-8.

The area of the intermediate catchment between Niapo Bridge and the dam site 15 km upstream is about 70 km^2, or 4 % of the catchment area. An even smaller proportion of runoff is provided by this area as runoff coefficients in the upper part of the Kayanga catchment are much higher than in the lower - a result of the nature of the subsurface geology. No reduction in Niapo Bridge streamflows has therefore been made in translating them to the damsite.

2.3.3 Kayanga floods

Analysis of the hydrograms for the 7 years of streamflow record enabled a number of floods to be isolated. The highest discharge recorded was 135 m^3/s in 1967. Floods are characterised by relatively long times to peak and total duration. Peak flows are relatively low.

A relationship between peak flow and mea flow in the month when the peak occurred was established and used to obtain peak flows for each year of the 76 year extended streamflow sequence. Several other methods of evaluating extreme floods were used to confirm the validity of the first. Flood peaks and volumes are estimated as follows :

Table 2 - 8 KAYANGA MONTHLY DISCHARGE PROBABILITY AT NIAPO BRIDGE(1)

Exceedance probability			May	J	J	A	S	O	N	D	J	F	M	April	Average or total
90 %	Flow	m^3/s	0,7	1,1	2,6	2,8	8,4	9,4	2,9	1,3	1,0	0,9	0,8	0,7	2,7
	Volume	$10^6 m^3$	1,9	2,9	7,0	7,5	21,8	25,2	7,5	3,5	2,7	2,2	2,1	1,8	86
80 %	Flow	m^3/s	0,7	1,4	4,0	4,5	14,3	16,1	4,6	1,9	1,3	1,1	0,9	0,8	4,3
	Volume	$10^6 m^3$	1,9	3,6	10,7	12,1	37,1	43,1	11,9	5,1	3,5	2,7	2,4	2,1	136
50 %	Flow	m^3/s	0,7	2,0	7,5	8,4	28,5	32,1	8,5	3,0	1,9	1,4	1,1	0,7	8,0
	Volume	$10^6 m^3$	1,9	5,2	20,1	22,5	73,9	86,0	22,0	8,0	5,1	3,4	2,9	1,8	253
20 %	Flow	m^3/s	0,7	2,8	11,8	14,4	46,5	52,5	13,6	4,4	2,6	1,8	1,2	0,7	12,8
	Volume	$10^6 m^3$	1,9	7,3	31,6	38,6	120,5	140,6	35,3	11,8	7,0	4,4	3,2	1,8	404
10 %	Flow	m^3/s	0,6	3,3	14,5	16,5	57,8	65,3	16,7	5,3	3,1	2,1	1,3	0,6	15,7
	Volume	$10^6 m^3$	1,6	8,6	38,8	44,2	149,8	174,9	43,3	14,2	8,3	5,1	3,5	1,6	494

(1) Obtained by analysis of existing data (table 2-6) and synthetic extension using a mathematical model (see report 2, para 4.1.3)

Table 2 - 9 KAYANGA FLOOD PEAKS AND VOLUMES

Return period (years)	Peak flow (m^3/s)	Volume ($10^6 m^3$)	Duration (days)
100	220	545	118
1 000	315	800	126
10 000	400	1 040	132

The specific discharge of floods is relatively low, only 0,13 m^3/s for a 100 year flood. This compares with specific discharge for the 100 year flood obtained by ORSTOM for the Gambia River of 0,06 $m^3/s.km^2$.

The 10 000 year flood has been adopted as the design flood for the sizing of Niandouba dam and spillway.

2.3.4 Anambé runoff

It has not yet proved possible to calibrate the gauging station at Kounkané and estimates of Anambé runoff must be obtained from the difference between flows recorded at the two Kayanga gauging sites. As a low ridge cuts off the Waïma lake formed upstream of Kounkané Bridge it may be assumed that there is no flow from January to May. The following estimates are obtained for the three common years of record at Niapo and Wassadou Bridges :

	1976-77	1977-78	1978-79
Anambé runoff ($10^6 m^3$)	14	3	31
Runoff coefficient (%)	1,5	0,5	2,6

The physiography and geology of the Anambé Basin are closer in nature to that of the Casamance River than to that of the Kayanga River, and this is reflected in the low runoff coefficients. It is estimated that in an average year the runoff coefficient would be about 5 %. The statistical variation of this coefficient has been assumed to follow the same curve (drawn on normal probability paper) as that for the Kayanga. The results agree well with values obtained by ORSTOM for the Casamance River and with recorded data. They are of necessity very approximative and are only valid in the absence of any other data. On this basis Anambé runoff may be estimated from Vélingara rainfall as follows :

Table 2 - 10 ANAMBE BASIN RUNOFF

Frequency of exceedance (%)	Vélingara rainfall mm	Runoff coefficient (%)	Runoff volume ($10^6 m^3$)
2	1 490	9,6	157
5	1 410	9,0	140
10	1 330	8,4	123
20	1 230	7,5	101
50	1 050	5,0	57
80	870	2,2	21
90	780	1,3	11

Annual runoff is assumed to have the following distribution :

August	September	October	November
10 %	40 %	40 %	10 %

2.3.5 Anambé floods

Estimates of Anambé peak flows are even more imprecise than those of Anambé runoff volumes, as a result not only of the absence of data but also the influence of the Kayanga streamflow regime on discharge from the Anambé Basin and the storage,and hence flood peak attenuation,of the Waïma lake.

It has been assumed that the same relationship between peak flow and monthly maximum flow found for the Kayanga applies also to the Anambé, resulting in peak flows as follows :

Table 2 - 11 ANAMBE PEAK FLOW

Return period (yr)	Maximum monthly flow (m^3/s)	Peak flow (m^3/s)
5	16	32
10	19	38
20	22	44
50	24	48

These flood discharges may appear low. They compare however with a maximum flow in the Casamance at Kolda (catchment area 3 700 km^2) of 113 m^3/s over 10 years observation.

2.3.6 Water quality

Eleven samples of Kayanga water were taken between August 1978 and April 1979, 10 at Wassadou Bridge and one at Niapo Bridge. They presented the following physical and chemical characteristics :

Table 2 - 12 KAYANGA WATER QUALITY

	Unit	Mean	Range
Electrical conductivity	µmho/cm	50	
Dry matter	mg/l	64,1	49 - 78
Suspended sediment	mg/l	13,1	3,4 - 27,5
pH		6,4	6,2 - 7,3
Calcium Ca^{++}	meq/l	0,25	0,19 - 0,35
Magnesium Mg^{++}	meq/l	0,12	0,06 - 0,25
Sodium Na^{+}	meq/l	0,05	0,03 - 0,07
Potassium K^{+}	meq/l	0,02	0,01 - 0,03
Carbonate CO_3^{--}	meq/l	0	0
Bicarbonate HCO_3^{--}	meq/l	0,32	0,26 - 0,42
Sulphate SO_4^{--}	meq/l	0,03	0,00 - 0,16
Chlorine Cl^{-}	meq/l	0,08	0,03 - 0,22

Sodium adsorption ratio	(SAR)	=	0,12
Exchangeable sodium percentage	(ESP)	=	11,4 %
Residual sodium carbonate	(RSC)	=	(negative)

Water quality may be characterised as containing a low total salts concentration and a low sodium concentration. It is suitable for irrigating the majority of crops on most soil types with low salinity or sodium hazard. Some leaching is required but normal irrigation practices would assure this except in very impermeable soils.

The concentrations of suspended matter shown above are not valid for estimation of sediment transport as they were obtained during low to average flows. Nevertheless suspended matter concentrations are low, as a result of the slight relief and the vegetation cover existing at the time when peak rainfall and runoff occur.

The envelope curve relating specific erosion to catchment area in subtropical regions gives an erosion of 0,1 mm per year. This value, which lies at the upper limit,would result in a volume of sediment accumulated in the reservoir of 20 million m^3 over 100 years.

2.3.7 Implications for development

Development of large scale irrigation in the Anambé Basin depends on regulation and exploitation of the runoff of the Kayanga river. The long term runoff hydrograph of the Kayanga river has been shown to have a cyclical nature. Given the durations of wet and dry cycles it is not appropriate to adopt a system design criterion based on meeting water requirements with a certain specified regularity, say four years out of five. The result of adopting such a criterion would be the exploitation of a relatively small part only of the mean annual runoff. Rather, the irrigation system should be designed to exploit the runoff during the prolonged wet cycles which dominate the long term hydrograph. During the intervening relatively brief dry cycles the area irrigated during the dry season will be severely reduced, the security of the wet season crop being the first objective

Towards the end of October the bulk of annual runoff will have passed. The inflow expected during the dry season can be quite accurately predicted as a function of total annual runoff. Therefore the amount of water available for irrigation during the dry season can be fairly closely estimated. This has the advantage that, whereas the water supply for irrigation may be rather variable, the risks of crop failure due to lack of water are minimal, as cropped area may be adjusted to water availability.

2.4 Ground water resources

The ground water resources of the Anambé Basin provide no scope for development of a water supply of the magnitude required for intensive, large scale irrigation. No highly productive aquifers have been identified in the sedimentary rock sequence that overlies the crystalline basement of the region. The results of exploratory drilling and geophysical surveys carried out for the present study and of geologic inferences indicate that the yields of properly located, designed and constructed wells are unlikely to exceed 30-40 m^3/hr in the Anambé Basin. By comparison, the minimum yield of an economic irrigation well in the Anambé Basin is of the order of 300 m^3/hr or more. The above values are estimates, but the gap between them is too great to be closed by more refined studies. Accordingly, ground water may be eliminated from consideration as a source of irrigation supplies in the Anambé Basin.

However, as the development of the Anambé Basin proceeds, ground water will have important economic utility as a source for relatively low-demand, high-value uses such as public, domestic, stock and industrial supplies. These requirements can be met from wells drilled to depths of 100 m or less at virtually any site in the Basin, with the possible exception of the central lowlands which is underlain by crystalline rock at relatively shallow depth.

Apart from water supply considerations, the most important implications of the hydrogeology for development planning derive from the conditions of occurrence of ground water as expressed by the configuration and fluctuations of the water table. Typical of conditions in this kind of terrain and climate, the water table is essentially a replica of the topography — a somewhat subdued replica by the end of the dry season, but a more exact replica by the end of the wet season when the water table approaches the land surface throughout much of the basin. Recharge to the water table derives from precipitation during the rainy season when the depth of precipitation exceeds potential evapotranspiration by about 200 mm per month during August and September in a typical year. Ground water discharge occurs largely as evaporation and evapotranspiration during the dry season, resulting from discharge to the Anambé River and Waīma lake in the central floodplain and from withdrawals by vegetation on the surrounding lands. Withdrawals from wells is a minor factor in the ground water regime. Deep percolation gains and losses are unknown but probably are negligible ; however some ground water movement out of the basin occurs as underflow in the alluvial channel of the Anambé River.

The resulting seasonal fluctuation of the water table varies more or less with the topography, ranging from 1 to 2,5 m in the lowlands to 7,5 m or more in the higher lands above about 35 m IGN. Interannual variations of precipitation also influence the fluctuation and attitude of the water table. Data are lacking on year to year fluctuations, but between March 1966 and March 1978, a period including the most prolonged and severe drought in this century, the water table apparently declined 1 to 2 m beneath most of the alluvial terraces and as much as 8 m or more beneath the higher plateaux lands in the northern reach of the basin. Notwithstanding, in March 1978 the general configuration of the water table was essentially the same as in March 1968, and ground water drainage was still tribut ry to the Anambé River in the drainage regime of the Anambé Basin.

In summary, the ground water regime of the Anambé Basin is dominated by local hydrologic features — geology, topography and climate. Recharge is from precipitation on the basin and discharge is largely to evapotranspiration from the basin. The configuration of the water table reflects the topography — more faithfully during wet periods than dry, but always concordant.

These conditions of occurrence of ground water have major implications on project planning and design, and on water management practices. The introduction of perennial irrigation on large and virtually contiguous blocks of land will essentially eliminate the dry season segment of the natural annual hydrologic cycle for the irrigated areas. As a result the mean elevation of the water table will rise beneath the irrigated lands, and unless seasonal fluctuations are suppressed drainage problems will occur in the irrigated areas toward the end of the wet season.

The ground water drainage regime under future conditions of intensive and extensive perennial irrigation can only be approximated on the basis of available data. As rice will be the main irrigated crop only surface drains will be required if appropriate land and water management practices are carried out. Surface drainage requirements will vary with location but in any situation will be largely determined in the first year of irrigation ; because in this environment essentially the full response of the water table to irrigation activities will be manifested in the first season of irrigation rather than over a period of years.

The conditions of occurrence of ground water have other important implications on project planning. As described in chapter 3 , the valleys of the Kayanga and Anambé Rivers upstream of their confluence and downstream of Niandouba dam will be used for conveyance of Kayanga runoff into the Anambé Basin and for afterbay regulation and storage. This involves the construction of a low dam below the confluence to create a reservoir with a normal operating pool level of 23 m IGN, some 7 to 8 m above the natural water surface during the dry season. The question that arises is whether seepage losses from the submerged channel will be prohibitively high, especially during the first phase of development when the confluence pool will be the only source of stored water for irrigation during the dry season.

Given the configuration of the natural water table which is essentially a subdued replica of the topography, seepage losses to ground water storage should be negligible. During the first filling of the storage pool there will be losses to bank storage but these will occur during the wet season and will not affect subsequent reservoir operations during the dry season. The primary effect of creation of the reservoir pool will be to raise the base level of surface drainage in the reach of the rivers upstream of the confluence dam. This, in turn, will cause a proportionate rise in the water table as the ground water drainage regime adjusts to a new equilibrium. But the interrelation between the regimes will be unchanged. The water table will continue to be tributary to the rivers — i.e., the hydraulic gradient will slo toward the surface drainage ways — and under those conditions seepage losses are precluded.

2.5 Human resources

2.5.1 Characteristics of local communities

The Upper Casamance is dominated by the Peul or Fulani, a traditionally nomadic people who have become sedentary over a period of several hundred years, practising both agriculture and livestock raising at the same time. The Fulani constitute 82 percent of the population compared to 7 percent for the Mandingo, the largest ethnic minority.

The Fulani fall into several groups : the descendants of the original settlers, immigrants from present day Guinea Bissau and the Guinean Republic (or Fouta Djallon) and descendants of subject races of the original settlers. While there is a certain cultural and linguistic uniformity there is also a form of caste system in which the Fulani are grouped according to their origins, intermarriage among these groups being rare. These distinctions disappear at the economic level, personal wealth being little associated with origin.

The migratory pattern is now of reduced significance and most inhabitants of the region have been living in the same villages for many generations. Most of the local population live in small villages of up to 200 people. Settlements are concentrated along the numerous small water courses and the main transport routes. In the higher reaches of the Kayanga and Koulountou valleys where river blindness is endemic populations are sparse. Population density averages 15-18 per km^2 for the Upper Casamance. The Anambé Basin is more density populated with an estimated 40 persons per km^2.

Villages are a grouping of compounds. A compound on average has 14-16 members and contains the head of the compound, one or more nuclear families or households dependant relatives and unrelated individuals who perform services for the compound head.

Despite the Fulani's nomadic background, farming takes precedence over cattle raising and the size of herds is modest compared to those of nomadic Fulani. Cattle, however, represent a store of wealth and their possession bestows prestige on the owner.

2.5.2 Land tenure

According to the law of the National Domain of 1964 all untitled land in the country belongs to the national government. The law has not yet has any application in the Anambé Basin where land rights in practice continue to be based on customary tenure, the rights of an individual or community occupying land in accordance with traditional law and custom. Land may be rented, lent or given to another party but land rights cannot normally be sold. Land rights may be revoked if they are required for a public purpose, or in the case of the prolonged absence of the cultivator.

Land rights in practice are passed from father to eldest son, there being sufficient land generally for other sons to clear what they need. Only the depressions suitable for rice cultivation are in short supply, and are often divided among a man's heirs.

Villages have their traditional farmlands and grazing lands the limits of which are recognized by bordering villages. Responsibility for community lands lies with the village chief, compounds,families and individuals having rights over the land they clear and cultivate.

2.5.3 Population and employment

Two recent sources of population estimates are available for the administrative subdivisions in the Casamance. The first, the nationwide census of April 1976, shows a population significantly greater than the second, namely the data collected locally at Arrondissement and Communauté Rurale level for annual tax purposes. The census data are considered more reliable.

The Anambé Basin does not correspond to administrative boundaries and the population has therefore been estimated on the basis of village populations, obtained at Sub-Prefect level, duly increased to allow for the underestimations revealed by the 1976 census. The population in 1976 is estimated as follows :

Table 2 - 13 POPULATION OF THE ANAMBE BASIN IN 1976

Town/communauté rurale	Within Basin	Outside Basin	Total
Velingara	8 775	-	8 775
Arrondissement of Kounkané			
Kounkané	9 603	1 811	11 414
Saré Coly Sallé	8 181	377	8 558
Kandia	6 836	1 602	8 438
Némataba	33	3 930	3 963
Arrondissement of Dabo			
Mapatim	6 593	6 853	13 446
Total	40 021	14 573	54 594

Recent population growth is estimated at 3 percent annually, composed of a natural rate of increase of 2,4 percent and a net immigration, principally of Fulani from Guinea of 0,6 percent. On this basis the present population of the Basin (1979) numbers about 44 000 persons.

The long term population growth rate in the absence of agricultural development would not sustain the recent high levels. However the proposed development of the Anambé Basin will create a major pole of attraction and substantial natural migration can be predicted. It is therefore assumed that population growth with project development will be maintained at 3 percent throughout the development period, resulting in a population of 75 000 in 1997 when irrigated land development will be complete.

According to 1976 census data the age and sex structure of the population of Vélingara department is a follows :

Table 2 - 14 POPULATION STRUCTURE BY AGE AND SEX

Age group	Male	Female	Total
0 - 14	22,1	21,0	43,1
15 - 64	26,9	26,6	53,5
Over 65	2,2	1,2	3,4
Total	51,2	48,8	100

Of the present population of 44 000 about 38 000 or some 86 % are engaged in farming. The remaining population are based predominantly in Vēlingara, where they work in the various government services, for SODEFITEX or in trade and commerce. In February 1977 there were 783 registered applicants for employment, principally as agricultural labourers and extension agents. Most were young men in their twenties, living in Vēlingara.

Seasonal migration in search of cash is common. It affects both younger men among the local population, who assist with the harvest in the groundnut basin further north,and also migrants from Guinea who attach themselves to a compound and in exchange for their labour on fields farmed by the compound are given food,lodging and an area of land on which they can grow cash crops.

The extent of this form of migratory share cropping varies with the political and economic climate of neighbouring countries. In 1978/79 it provided almost a third of adult male farm labour, but seems to have declined somewhat the following year.

2.5.4 Attitudes and aspirations

Farmers generally appear very favourable to the development project, in the expectation that it will bring new opportunities for food and cash crop production and for seasonal wage labour. Their misgivings relate to the effect the project will have on their control of decision making on their farms and to the possibility that the project may foreclose on aspects of their present way of life. Thus they express the desire to be more actively involved in the planning process through a coordinating body or "citizens committee". Moreover they clearly intend to continue cultivation of traditional crops and livestock raising and expect the project to take this into account. The distance of project ricefields from existing villages, to which the local farmers are strongly attached, is also seen as a possible disadvantage.

People are opposed to ceding control over their lands to the project and would strongly object to schemes involving the settlement of large numbers of farmers from outside the area.

Whereas there is a perceived conflict between the use of the lower lying lands for irrigated farming and their traditional use for grazing and watering cattle, there is general agreement that the villagers would experience no great inconvenience in moving their cattle to higher ground if watering points were created.

2.5.5 Implications for development

The cultural and economic homogeneity of the Basin and its young and active population are favourable factors. An adequate supply of labourers for the project is manifested by the applications for work at Vēlingara prefecture.

Development of the project area must respect customary land rights as far as possible. Reallocation of village lands is not desirable. However most farmers' land holdings are fragmentary and there is therefore a strong argument for excluding from development those areas presently under cultivation, at least as far as possible,and developing uncultivated lands at lower elevation where grazing land is available to the village or community for common use and no customary land rights exist.

Development should be based primarily on the present population in the project area and on its natural rate of increase. A certain net inward migration is likely to occur spontaneously,attracted by work on the project. Such migration should be controlled at levels similar to those prevailing in recent years in order that absorbing new migrants does not place undue stress on the present social structure.

Irrigated smallholder farming will compete with traditional agriculture for labour, especially during the peaks of the agricultural calendar. Development must proceed at a pace determined by the farm labour supply, increasing as natural population growth, resettlement and improved dryland farming techniques provide an increasing labour supply.

Skilled labour is also in short supply in the project area. A substantial training programme will be required to create the necessary drivers, mechanics and supervisory personnel. A large proportion of the technical and managerial skills required will have to be obtained from outside the project area.

In order to create an independent and self-assured farming population two aspect of development require emphasis. Firstly it will be necessary to introduce the new techniques initially on a modest scale, introducing as many farmers as possible to their potential while minimizing the risks. Secondly it is essential that the farming community be involved in the planning process from the very beginning and therefore that an appropriate channel of communication be established between the implementing agency and the farmer, through locally elected councils.

2.6 Present agricultural development

2.6.1 Land use

Present land use is shown on figure 2 - 4. The pattern of land use may be portrayed as a series of concentric bands. The innermost zone, the central floodplain, is an area of grassland which is used for grazing and watering cattle in the dry season. This is surrounded by extensive savanna woodland of varying density also used as dry season pasture. Some higher pockets of cultivated land occur within this zone. Moving radially outwards the woodland gives way to cultivated land. Locally in depressions and drainageways rice is grown as a wet season crop. Towards the catchment boundary the cultivated land gives way once again to woodland on the upper plateaux.

The Basin includes the Anambé classified forest, a protected area of woodland conventionally accepted as covering 6 200 ha. However on the basis of the statutary limits obtained from the Eaux et Forêts at Vélingara the area of the forest is found to be 3 900 ha.

Maps and air photographs permit the following estimates of current land use and vegetation :

Table 2 - 15 PRESENT LAND USE

Vegetation	Land use	Area (ha)	Physiographic unit
Cleared land, isolated trees	Cultivation	26 000	Plateaux
" "	Fallow	11 000	Plateaux
Wooded savanna	Pasture, fuel	66 600	Alluvial terraces and sandy slopes
Wooded savanna	Pasture,class-ified forest	3 900	Alluvial terraces and sandy slopes
Grassland	Pasture	2 500	Central floodplain

2.6.2 Size of holding and division of labour

Based on a survey of 30 compounds, a typical compound in the Kounkané arrondissement has 16 members of which 7 are children below 15 years of age. In addition it contains two seasonal migrants who work three days a week for the compound head. The area cultivated by the compound is 11 ha. The compound has a herd equivalent to 25 UBT, including two pairs of oxen.

An average household of about 7-8 members, will cultivate about 5 ha of land, about $^2/3$ being worked collectively and the remaining $^1/3$ by individual members,predominantly for cash crops such as peanuts and cotton. Traditionally nen have cultivated sorghum and millet and women rice and vegetables, but there appears to be little cultural prejudice in this division of labour. Indeed, nen and women are tending increasingly to raise the same crops, although on different fields.

On a yearly basis the available rural labour supply is very underemployed, less than 50 percent being utilised for agricultural production.

2.6.3 Cultivation practices

Most compounds own one or more pairs of oxen and other draught animals --

horses and donkeys. Ploughs, multipurpose toolbars, seeders, and carts were also owned in more than half the compounds interviewed. However much equipment is in a poor state of repair or waiting for spare parts.

Most of the land preparation is carried out by using oxen. Ploughing can be done only after the first rains have provided enough moisture to allow penetration and turning of the soil. The depth of ploughing is very shallow, estimated at 7 to 10 cm . Ploughing is followed by harrowing in some cases, but mostly for cotton. Typically, ploughing is the only cultural operation carried out with draught animals (other operations being manual) though a small amount of sowing and weeding is also mechanized. Weeding constitutes the major labour bottleneck.

Use of farm inputs differs greatly between crops. SODEFITEX, the monopoly trader, provides free inputs for cotton (seeds, fertilizer and insecticide) recovering the cost in the producer price paid. Annual inputs for other crops are provided on credit by ONCAD through the cooperatives. Their use is almost negligible. The amount of fertilizer used, for example, averages about 5 to 6 kg/ha.

Crop rotations depend on the distance from the compound. Millet and maize are grown each year on lands closest to the village. Cash crops and periodic fallowing usually appear in a concentric circle around the perennially cultivated nucleus. More distant fields are cultivated even less intensively or used for pasture.

Rice is grown only as a rainfed crop. Land is prepared with a hoe or daba. Seeding is usually in rows with 20-25 cm spacing at 100 kg/ha of seed. Weeding is usually by hand pulling. The crop is harvested by sickle. The most common pests and diseases are stem borer and pericularia oryzae (blast) respectively. Insignificant amounts of fertilizer are used. Varieties grown include TS 123, 302 B and I Kong Pao.

2.6.4 Cropping patterns and crop production

Climate, producer prices and the influx of seasonal migrants result in significant fluctuations in the cropping pattern, especially for the cash crops - cotton and groundnuts. The following table gives the distribution of crops grown in the Basin, average yields and total production based on data for the 1977 and 1978 crops.

Table 2-16 CROPPING PATTERNS, YIELDS, AREAS AND PRODUCTION

Crop	Distribution (%)	Area (ha)	Yield (t/ha)	Production (t)
Millet	12	3 120	0,95	2 964
Sorghum	23	5 980	1,0	5 980
Maize	5	1 300	0,8	1 040
Rice	5	1 300	1,2	1 560
Groundnuts	29	7 540	1,1	8 294
Cotton	26	6 760	1,2	8 112

Cash crops and food crops (which include part of the groundnut crop) are grown over approximately equal areas. The greatest expansion in cultivated area in recent years has been that of cotton, the area cultivated increasing from 1 000 ha to 14 000 ha in Vélingara department over the 10 years ending in 1978. This expansion has been supported by increasing mechanisation.

The production of cereals in a normal year is just sufficient to cover the calorie and protein needs of the population of the Basin. However this masks seasonal shortages and the lack of a balanced diet.

2.6.5 Livestock

There is little integration of livestock raising with agriculture. Oxen are used as draught animals, and cattle folded in fields near the compound help fertilise the soil.

Herds are formed from the cattle belonging to one or more compounds and average about 50-60 head. The herd provides milk, work oxen, and a source of cash in time of need. Cattle are seldom slaughtered for their meat,smaller animals - sheep, goats, pigs and chickens - providing most animal protein. Estimated livestock numbers in the Basin are as follows :

Table 2 - 17 LIVESTOCK NUMBERS

Type	Number	UBT(1) per animal	Number of UBT
Cattle	64 000	0,8	51 200
Sheep & goats	55 000	0,1	5 500
Horses	500	1,2	600
Donkeys	3 000	0,5	1 500

(1) The UBT (Unité de Bêtail Tropical) or Livestock Unit corresponds to an animal of 250 kg live weight.

Cattle are predominantly of the N'Dama race with some signs of cross breeding with Zebu. They are resistant to trypanosomiasis.

The local livestock service estimates the growth rate of the herd at about 2 %. The rate of offtake is estimated at 10 % annually, the fertility rate at 70 % and the mortality rate over the first 3 years at over 40 percent. Dry season grazing is characterized by long daily marches, overgrazing of natural pasture and weight loss.

2.6.6 Value of production and rural income

At present producer prices, given in table 5 - 3, the crop production in the Anambé Basin is valued at 1143 million FCFA. Livestock production is estimated at 295 million FCFA, giving a total of 1438 million FCFA or 38 000 FCFA per year per person engaged in farming. Crops represent 80 percent of farm income, groundnuts and cotton alone representing 53 percent.

As shown in the farm budget for the typical compound (table 5 - 7) the net income per man day is 436 FCFA, close to the minimum wage in force in Vélingara.

2.7 Infrastructure and institutions

2.7.1 Physical and social infrastructure

The present road system in the project area is shown in figure 1 - 2. Apart from the N6 and the laterite surfaced spur to Wassadou, roads are generally little more than tracks, virtually impassable to most vehicles for much of the wet season.

Few villages have a reliable year-round water supply, wells generally being of limited depth. Only Vélingara has a SENELEC electricity generating plant, the distribution network being confined to the town.

Schools are shown in figure 1-2. School enrolment in Upper Casamance at 18 percent is low by national standards and in the project area is undoubtedly lower still.

Health services are given high priority by villagers who at present suffer from the lack of both pharmaceutical supplies and medical services.

2.7.2 Government services

Both in Vélingara and Kolda, the chief towns of their respective departments, there are the following governmental services

- Service de l'Elevage (Livestock service)
- Eaux et Forêts (Forestry and fisheries service)
- Perception (Tax office)
- Travaux Publics (Publics works)
- Information (Information)
- Promotion Humaine (Social development)
- Santé (Health)
- Enseignement (Education)

ISRA has a small unsophisticated experimental station (PAPEM-Point d'Appui d'Etudes Multilocales) located about 2 km south of Vēlingara.

2.7.3 Other institutions

ONCAD is responsible for the supply of agricultural inputs, acting through the cooperative movement (figure 1- 3).

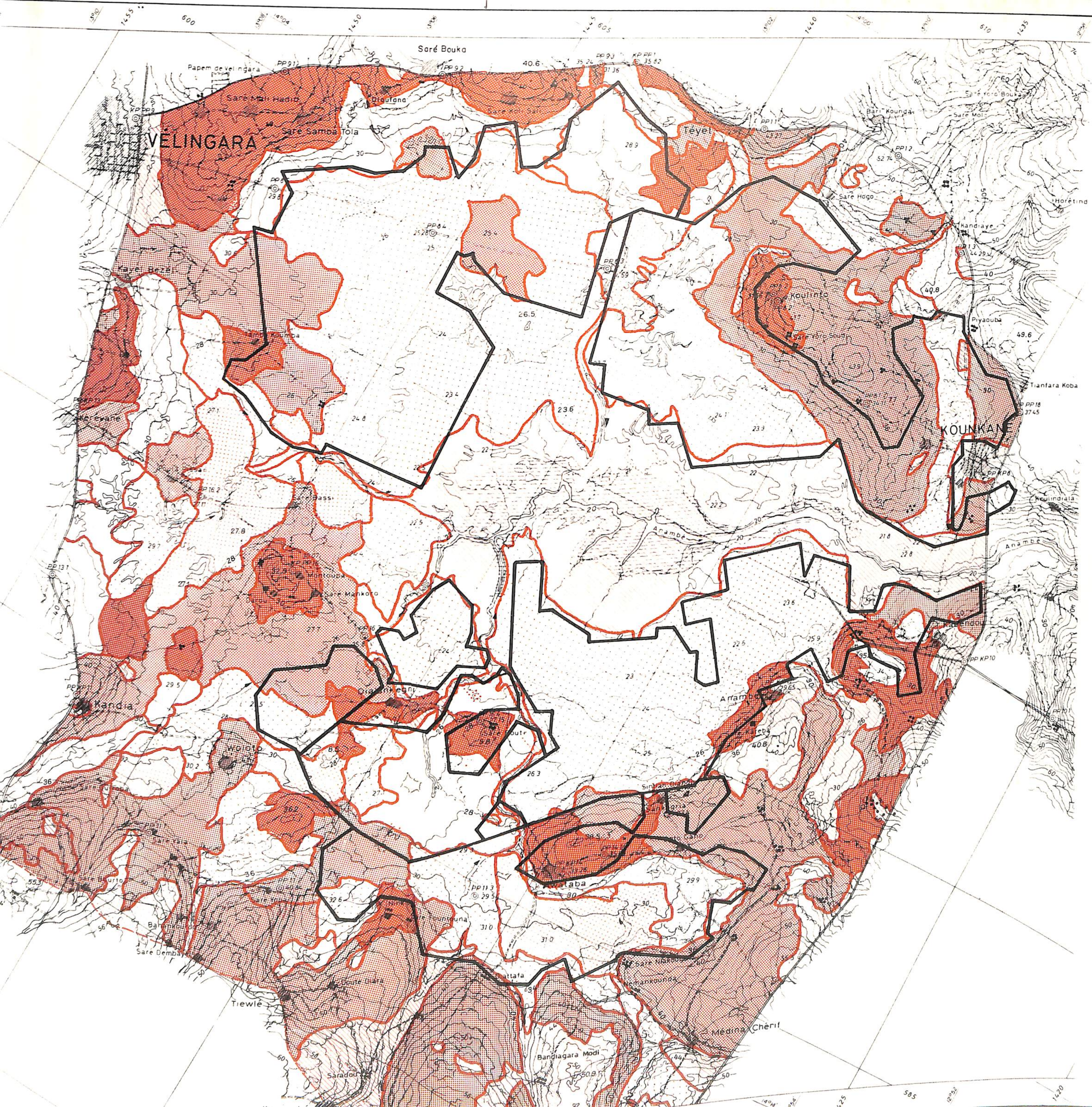
SODEFITEX has a cotton ginnery in Vēlingara and has promoted cotton cultivation throughout the area. Production from the Anambē Basin represents about 20 percent of national production and appears to have reached a peak in terms of area cultivated. SODEFITEX is also active as a regional development agency in Upper Casamance and Senegal Oriental but in the Anambē Basin and lower Kayanga valley has ceded these responsibilities to SODAGRI.

2.7.4 SODAGRI

SODAGRI currently is carrying out three programmes for the development of rice production. The first is concentrated in the lowest lying lands of the Anambē Basin where, by mid 1979, SODAGRI had cleared an area of about 200 ha of which 100 ha were planted to rice in the 1979 wet season. These first trials with rainfed rice are to be followed by development of a mechanized irrigated pilot farm as described in chapter 3.

The second programme envisages the gradual introduction of irrigated agriculture to small farmers, initially using animal drawn implements to cultivate two crops of rice and/or other cereals each year. The first phase of the Anambē project provides an area of 755 ha for small farmers.

The third programme is intensifying production from lands presently or previously cultivated to rice and generally located at higher elevation than those to be developed under the second programme. About 1000 ha had come under this programme by the 1979 cropping season.



LEGENDE

Classe des terres	Aptitude culturale hivernage	contre saison	Classe de drainabilité (1)	Description
1RR	Riz	Riz	Z	Terres convenant très bien à la culture irriguée avec de fort re ments et des coûts de production raisonnables.
2RR	Riz	Riz	Z	Terre aptes à la riziculture irr guée mais avec des rendements pl faibles que la classe 1RR et/ou coûts de production plus élevés. coûts d'aménagement sont en géné plus élevés.
2RD	Riz	Poly-cultures	Y	Terres aptes aux cultures irrig mais exigeant des apports d'eau élevés que celles des classes 1R 2RR. Dans certaines zones à drai interne restreint, les polycultu ne peuvent être pratiquées qu'er contre-saison.
2DD	Poly-cultures	Poly-cultures	X	Terres aptes à un grand nombre c cultures irriguées autre que le
6	-	-	-	Terres inaptes à toute forme de ture irriguée à cause des contra pédologiques, topographiques ou drainage ou encore à cause d'une utilisation actuelle qui exclue aménagement pour l'irrigation.

Périmètres d'irrigation

(1) Classe de drainabilité : X-bon, Y-restreint, Z-faible

(Figure dérivée de la figure 4-4 du rapport 4, pédologie)

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RUR
SODAGRI

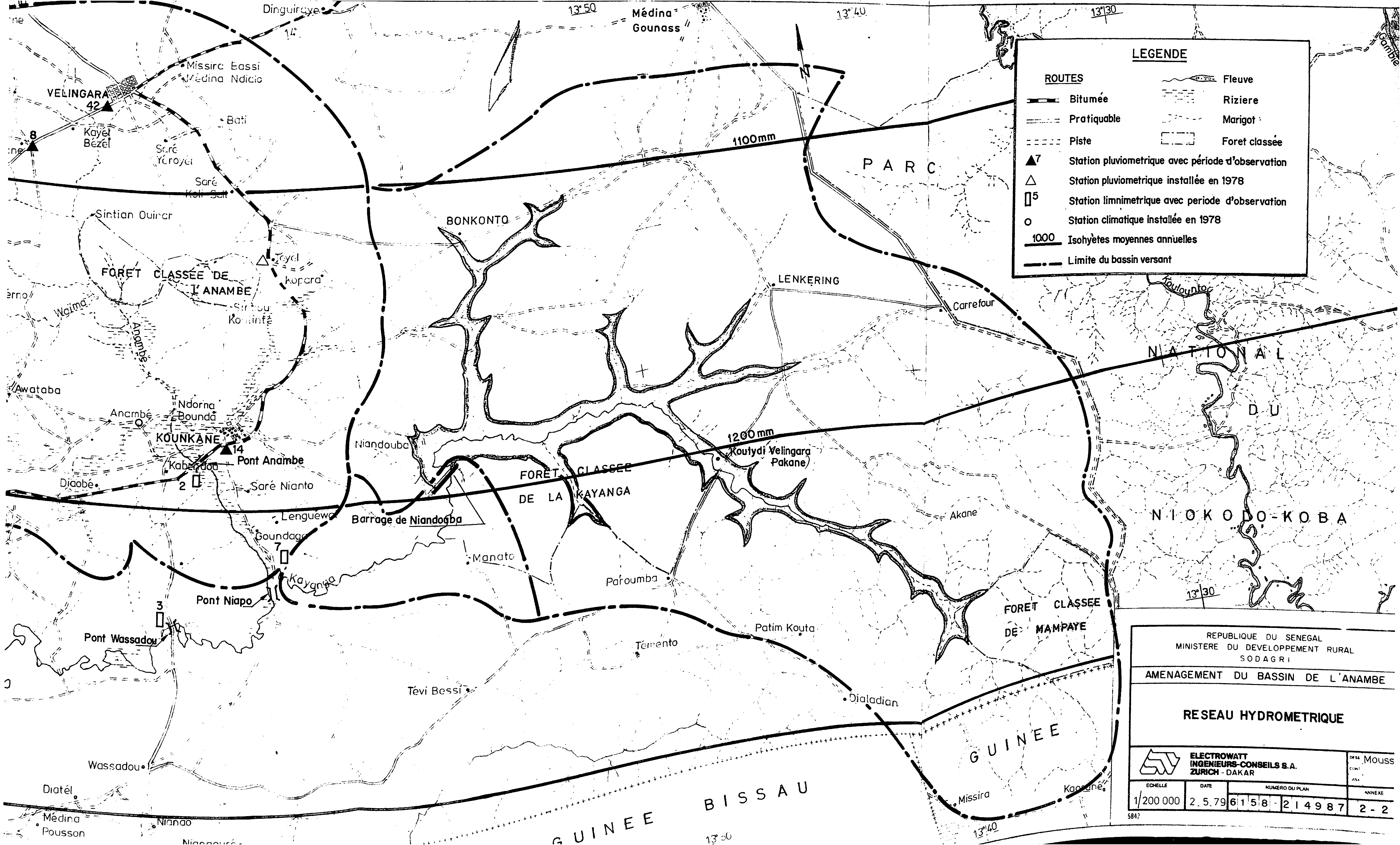
AMENAGEMENT DU BASSIN DE L'

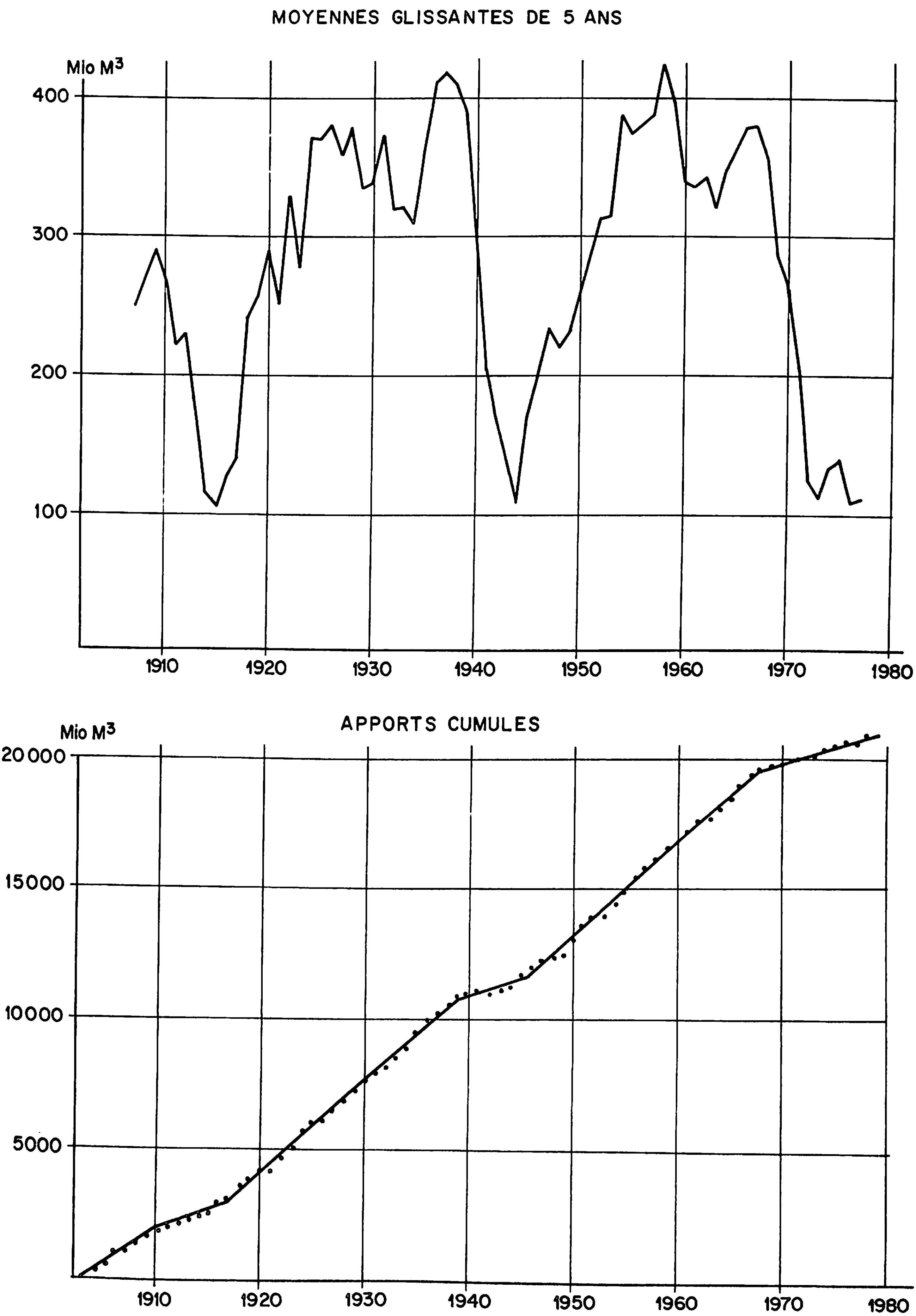
CLASSIFICATION DES TERRES

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

ECHELLE	DATE	NUMERO DU PLAN
1:100'000	12.8.80	6158-20901

5842


LEGENDE
ROUTES
Bitumée
Pratiquable
Piste
Fleuve
Riziere
Marigot
Foret classée
Station pluviometrique avec période d'observation
Station pluviometrique installée en 1978
Station limnimetrique avec periode d'observation
Station climatique installée en 1978
1000 Isohyètes moyennes annuelles
Limite du bassin versant
REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI
AMENAGEMENT DU BASSIN DE L'ANAMBE
RESEAU HYDROMETRIQUE
ELECTROWATT INGENIEURS-CONSEILS S.A. ZURICH - DAKAR
ECHELLE 1/200 000
DATE 2.5.79
NUMERO DU PLAN 6158-214987
ANNEXE 2-2
1100mm
1200mm
PARC NATIONAL DU NIOKOLO-KOBA
FORET CLASSEE DE L'ANAMBE
FORET CLASSEE DE LA KAYANGA
FORET CLASSEE DE MAMPAYE
GUINEE
GUINEE BISSAU
VELINGARA
KOUNKANE
Barrage de Niandouba
Pont Anambe
Pont Niapo
Pont Wassadou
Médina Gounass
Dinguiraye
Missira Bassi
Médina Ndiclo
Bati
Kayel Bézel
Saré Yéroyel
Saré Koli Salt
Sintian Ouinar
Kopara
Anambé
Ndorna Bounda
Awataba
Kabendou
Diaobé
Saré Nianto
Lenguewal
Goundaga
Kayanga
Niandouba
Manato
Paroumba
Bonkonto
Lenkering
Carrefour
Koutydi Velingara Pakane
Akane
Patim Kouta
Témento
Tévi Bessi
Dialadian
Wassadou
Diatél
Médina Pousson
Niando
Missira
Kounkané
Koulountou
13°50
13°40
13°30
14°



APPORTS DE LA KAYANGA A NIAPO
Correlation avec la Falémé

FIGURE 2-3

LEGENDE

- FORET CLAIRE
- SAVANE BOISEE DENSE
- SAVANE BOISEE CLAIRE
- SAVANE ARBOREE
- SAVANE ARBOREE OU SAVANE PARC
- PLAINE HERBACEE OU DEFRICHE
- RIZIERES
- CULTURES DE PLATEAUX
- LIMITE DE LA FORET CLASSEE DE L'ANAMBE

Carte mosaïque non controlée, assemblée a partir des photos aeriennes prises en 1978

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

CARTE DE VEGETATION ET D'OCCUPATION DES TERRES

ELECTROWATT INGENIEURS-CONSEILS S.A. ZURICH - DAKAR

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
~ 1:100'000	AVRIL 80	6158-214985	2-4

DESS Bru
CONT
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3. PROJECT PLANNING

3. PROJECT PLANNING

3.1. Development potential

3.1.1 Restraints on growth of traditional agriculture

Availability of land has till now not been a constraint on growth of traditional agriculture. Expansion of cash crops, especially cotton, in response to the price incentive has been impressive. Farmers have chosen to farm the lighter soils on the plateaux which are more easily cultivated using available means. Land is still available on the plateaux although the proportion under fallow appears to be decreasing. The lands which constitute the greater part of the inner basin are subject to poor surface drainage and flooding. Whereas this may appear to favour rice production, the depth, duration and extent of flooding are in fact highly variable. Under these conditions rice cultivation has not proved very successful under traditional agriculture.

The traditional cropping patterns, low intensity of production inputs and low yields prevailing in the area probably represent to the farmer the most advantageous integration of all crop production factors under present conditions of inputs supply, soil management problems and price incentives. Whereas these factors all play a role in limiting productivity, the basic restraint on production is water - the short wet season and erratic rainfall. Management both of soil moisture and soil fertility is a problem on the plateau soils, and compounded by inadequate support services.

Without the project the remaining uncultivated plateau lands, would come under increasing pressure both for agriculture and cattle raising. This pressure could be absorbed for a few more years but would thereafter lead to increased out migration and progressive soil impoverishment.

Rainfall apart, the Anambe project area covering the inner part of the Basin has a very favourable environment for intensive agricultural development. The climate is suitable for year-round farming, the soils are capable under good management of producing high yields of crops and a supply of excellent quality water can be developed for irrigation. There is a limited amount of direct unemployment and a considerable underemployment of labour during most of the year.

3.1.2 Requirements for development

The major components of any programme for development of irrigated agriculture in the Anambe Basin will include flood protection and drainage of the basin ; provision and distribution of irrigation water ; provision of a farm road network ; establishment of a commercial mechanized farm and of small farmers to produce crops on previously idle land ; facilities for research on adaptive technology;facilities for processing or treatment of crops ; a livestock production scheme ; and agricultural support and extension services to farmers to increase their productivity in respect to both crops and livestock. All of these needs and programmes must be closely coordinated. How they will be met is discussed in this and subsequent chapters.

However rural development requires a commitment not only to provision of the necessary production facilities but also to considerations of welfare and provision of social services. Included in this list of needs are health and education programmes ; schools ; improved markets, not only for selling locally produced commodities but also to meet increased local demands for goods from outside the region ; and electric power and domestic water supplies.

3.2. Planning guidelines

The primary objectives of the development of irrigated agriculture in the Anambe Basin are :

- to promote the cultivation of rice as a profitable cash crop, rather than as a subsistance crop, so as to reduce Senegal's dependance upon imported rice.
- to transform the socio-economic prospects of the region by increasing peasant farm income, providing greatly expanded opportunities for permanent, full time agricultural labour, and otherwise stimulating development and growth of the agricultural economy.

SODAGRI has been pursuing these aims since its creation, intensifying and extending its activities in the Anambe Basin over the last two years (see para. 2.7.4). These activities and the development of the Anambe Basin in general were the subject of discussion at a seminar held in Velingara in March 1979, under the chairmanship of the Minister of Rural Development. In addition to the development aims and requirements already mentioned, the following recommendation was made :

- that development integrally involve the peasant farmer, and that trials on a reduced scale with both mechanized and small-holder farms, and using both animal traction as well as mechanized cultivation practices, be carried out on the uncultivated lands in the centre of the Basin.

It was also recommended that livestock be integrated with agriculture, that the existing cooperative structure be used as a basis for cooperative development and that care be taken to protect the environment.

The above objectives and recommendations have led to the adoption of certain specific guidelines for project formulation. These provide for :

- initial establishment of a pilot, commercial farm to carry out applied research on varietal selection, fertilizer management, plant protection and other practices which will be essential to the development of rice monoculture in the area. The pilot farm will include areas assigned to mechanized farming and areas under small-holder farming. The sizes of fields and layout of the works will permit testing of the irrigation and cultural practices proposed for application on a wider scale.

- subsequent development which will feature a flexible mix both of peasant farms and commercial mechanized farm units with maximum participation of peasant farmers in the agricultural programme. Provision will be made for the transfer of lands developed for commercial mechanized farming to peasant management and operation as required to satisfy future demand for small land holdings.

- distribution of project benefits to the farming populations on both sides of the Anambe Basin,both on grounds of equity and so as least to disturb the socio-economic unity of the Anambe Basin.

- development of the Anambe project with close regard to the development and future integration of all resources of the Basin including rainfed agriculture, livestock, and forestry.

- project works which will have a minimum demand for imported energy.

3.3. Agricultural development

3.3.1 Crops and cropping patterns

The climate in the project area allows almost any warm season crop to be grown. However rice is to be of primary importance and this consideration guided the land resources survey as regards the classification of lands in terms of irrigation suitability. Three double cropping patterns are indicated :

- rice in both wet and dry seasons
- rice in the wet season followed by diversified crops in the dry season
- diversified crops in both seasons

In fact the areas where competition between rice and other crops may occur represent only a small proportion of the total area. Generally, for one or other season, soils, topography and drainage considerations preclude cultivation of either rice or diversified crops.

Maïze, sorghum, cotton, soja and sugar cane were the principal crops considered as diversified crops. Diversified crops will be grown almost exclusively under smallholder farming . This factor, and the lack of sufficient suitable land, ruled out sugar cane. Growing of cotton in the dry season risks creating increased problems of insect infestation. Moreover the longer growth cycle makes double cropping more difficult with this crop. Soja presents an attractive alternative to the present dependence on groundnuts but the lack of practical experience and of the necessary processing facilities makes its introduction on a large scale premature.

Maïze and sorghum have therefore been adopted as diversified crops. They have the advantage of being well known in the area, and their cultivation enables small farmers to achieve self-sufficiency in food grains. Their production supports the Government's aim to reduce the cereals deficit. They are assumed to be grown in the ratio 2 : 1 sorghum to maïze, sorghum being the more widely used foodgrain. Unfortunately the yield potentials of the locally preferred white sorghum and maïze are well below those of red or yellow sorghum and yellow maïze. The latter are therefore restricted initially to a small part of the commercial farm for production of animal feed.

Some vegetables will certainly be grown to satisfy local need, but as the main markets cannot be reached profitably, vegetable production must remain marginal in economic terms. The same is true of fruit production.

The way that the three cropping patterns proposed fit into the agricultural calendar is shown on figure 3-1. The relative importance of rice, maïze and sorghum in the cropping patterns reflects also their relative profitability.

3.3.2 Cropped areas

The main factors which determine cropping intensity and cropped areas are water availability, management practices, and labour supply. Double crop combinations, seasonal cropping intensities and cropped areas for both smallholders and mechanized farm are given in table 3-1. They are based on the following considerations :

Table 3 - 1 CROPS, CROPPING PATTERNS AND IRRIGATED AREAS (HA)

Type of farm and cropping pattern (W.S - D.S)	Total area (net)	Wet season crop	Dry season crop	Total	Crop		
					Rice	Maïze	Sorghum
Smallholder							
Rice - rice	7 210	6 850	4 687	11 537	11 537	-	-
Rice - diversified	3 410	3 240	2 217	5 457	3 240	739	1 478
Divers.- diversified	710	675	462	1 137	-	379	758
Total	11 330	10 765	7 366	18 131	14 777	1 118	2 236
Cropping intensity		95 %	65 %	160 %			
Mechanized farm							
Rice - rice	4 685	4 450	3 750	8 200	8 200	-	-
Divers.- diversified	250	250	250	500	-	500	-
Total	4 935	4 700	4 000	8 700	8 200	500	
Cropping intensity		95 %	80 %	175 %			
Total smallholder and mechanized farm	16 265	15 465	11 366	26 831	22 977	1 618	2 236
Overall cropping intensity		95 %	70 %	165 %			
Overall cropping pattern					86 %	6 %	8 %

- the land will be cropped to the maximum practical intensity in the wet season
- the average cropping intensity in the dry season, as determined by the availability of water supplies, is 70 percent. The predominance of rice, with its relatively high irrigation requirements, assures the project of ample water supplies and delivery capacity (accordingly precision in predicting future cropping patterns is not particularly essential)
- a fallow crop for at least one season every four years is desirable to inhibit weed growth. Maximum cropping intensity is therefore 175 percent, and maximum dry season intensity 80 percent
- the mechanized farm needs to operate at a high cropping intensity to justify the investments in farm machinery. Also the lower lying lands can more readily sustain a higher cropping intensity

The lands most suitable for irrigation are those of the alluvial terraces, which form a relatively extensive belt around the central floodplain and below the plateaux, some lower lying parts of which are included in the irrigation perimeters. The central floodplain itself has been excluded from agricultural development, the lowest lands which can be economically irrigated lying at 22,0 m. Development of lands below this elevation would create the need for additional pumping capacity and involve higher pumping costs. It would also, and equally importantly, reduce the storage capacity of the bottom lands and thereby considerably reduce the proportion of Anambe Basin runoff which could be used for irrigation. As planned, most of the central floodplain will provide a valuable source of grazing land, particularly towards the end of the dry season.

The irrigation perimeters (figure 3-2) comprise 16 265 net ha. Rice will be grown over 96 percent of the irrigated area in the wet season and 75 percent in the dry season. Cropping intensities adopted are 175 percent for the mechanized farm and 160 percent for smallholders, giving 165 percent for the project as a whole. The 65 percent dry season intensity for smallholders is an average value ; it allows for higher cropping intensities (occasionally zero) when dry season water supplies are scarcer.

3.3.3 Farming systems

The present farming population, which numbers around 38 000 persons, will not be capable of undertaking the management of over 16 000 hectares of irrigated land in addition to their present farm holdings. Therefore parallel development of smallholder agriculture and commercial mechanized rice farming is envisaged.

The mechanized farming operations have been limited to a maximum area of 5 000 ha located in the heavy soils of the lower terraces. These lands are both least accessible to present villages and least suitable for cultivation by draught animals. Large contiguous areas have been selected to simplify mechanized operations. The mechanized farm will be divided into four sectors or units of about 1 200 ha, this size being indicated primarily by the distribution of suitable lands and their development by phases, but also being a convenient size from a farm management viewpoint (see figure 5-1).

The remaining area, about 70 percent of the total, will be developed for irrigated smallholder agriculture under rice and diversified crops. Rice lands will initially be brought into cultivation under mechanized farming by the project authority, being released for smallholder cultivation as the necessary institutional infrastructure and agricultural services are created.

The size of plots considerated suitable for smallholder irrigated farming averages about 2,5 hectares. This corresponds to the area which a typical farm family can cultivate. Actual farm sizes will be adapted to the capacities of each farm family.

3.3.4 Processing facilities

The Anambe Basin is destined to become an area of intense agricultural production. This offers the opportunity for the development of associated processing industries, utilizing the production of mechanized farms and smallholders. However, the distance of the project from the more populated areas of Senegal and the present lack of dependable infrastructure limits the immediate agro-industry opportunities to first stage processing. As development gets under way many of the existing constraints will be lifted and more advanced processing may become possible in the area.

The initial emphasis will therefore be placed on establishing the rice milling facilities to process the marketable surplus of rice produced by the mechanized farm and smallholders.Rice seed treatment facilities will also be provided. Other schemes with potential, such as pulse cleaning and packaging and root crop and onion storage and marketing, should be evaluated once the project is under way.

With the exception of the Kedougou mill, the operation of large rice mills in Senegal has been characterized by poor utilisation and excess capacity. A rice milling programme must be carefuly planned to avoid these pitfalls. With this in mind, two types of rice mills are proposed. Industrial-type mills capable of bulk handling on a 24 hour production basis will be established for the mechanized farm units ; and multi-unit mills designed for handling paddy both in bags and in bulk, on day shift only, will be established for small farmers (see figure 5-1).

3.4. Project formulation

3.4.1 Selection of site of storage dam

Various possible storage schemes have been considered (refer to report 8, Project Planning), including :

- storage in the Anambe exit channel

- a dam and reservoir in the Kayanga valley downstream of the confluence
- a reservoir in the centre of the Anambe basin, contained by a peripheral dyke and a dam in the exit channel
- storage in the Kayanga valley upstream of the confluence, the most suitable dam site being near the village of Niandouba

The first three storage schemes were all found to have numerous disadvantages, including major costs of earthworks, limited storage capacity, high pumping costs and the need for drainage pumping stations. Construction of a storage dam and reservoir on the Kayanga river upstream of the Anambe confluence is therefore the only feasible means of providing a sufficient water supply for dry season cropping of large areas in the Anambe basin.

3.4.2 System of water delivery to irrigation service area

The system of water delivery to the heads of the left and right bank irrigation service areas is shown in plan in figure 3-2 and schematically in figure 3-3.

Kayanga runoff will be stored behind Niandouba dam and released to the Kayanga river through turbines housed in a power station located at the downstream toe of the dam. A small dam located just downstream of the Anambe-Kayanga confluence, and 25 km downstream of Niandouba dam, will divert Kayanga flows up the Anambe River to the main pumping stations. The two main pumping stations are disposed on either side of the Anambe river at the left and right extremities of a flood protection dam. The latter serves both to prevent Kayanga floods from entering the Anambe Basin and to help maintain a pool level in the Anambe channel.

The main right bank pumping station is electrically driven, receiving its energy supply from the power station at Niandouba dam. The main left bank pumping station is diesel driven.

A number of alternative water delivery schemes was studied, involving different types and dispositions of pumping stations and routes of conveyance works. These are described in report 8. Cost studies enabled all alternatives to be eliminated except for the alternative replacing the hydroelectric supply with diesel energy to drive the main right bank pumping station.

3.4.3 Energy supply

The major consumers of energy in the project are the two main pumping stations and the auxiliary pumping station. As the volume and security of supplies of diesel fuel are an important concern a number of different sources of energy have been examined as follows :

Table 3 - 2 ALTERNATIVE ENERGY SUPPLY FOR PUMPING STATIONS

Alternative	Pumping station			Remarks
	Main right bank	Auxiliary	Main left bank	
1	Diesel	Diesel	Diesel	Least costly solution now
2	Hydro-electric	Diesel	Diesel	Energy from Niandouba dam. Selected alternative
3	Hydro-electric	Diesel	Hydro-electric	Right bank P.S. supplied from Niandouba. Left bank development deferred until hydroenergy available from dams on Gambia River or Manantali
4	Hydro-electric	Thermal electric	Thermal electric	Thermal wood-fired generating station to supply two pumping stations plus ancillary facilities
5	Thermal electric	Thermal electric	Thermal electric	As 4, but all energy supplied from thermal generating station

The timing of development of hydroelectric facilities on the Gambia and Senegal rivers is presently uncertain, as is the cost of such energy delivered to the project area. This source has therefore not been considered further.

A more promising possibility is the production of electricity at a wood-fired thermal generating station, to serve not only the pumping stations but other project facilities and local towns and villages. Preliminary studies presented in report 7 indicate that the savings in diesel fuel cost are approximately balanced by the additional capital investment required for the power station and plantation plus the operating costs of these. Further studies will be carried out to obtain a better evaluation of the technical and economic feasibility of developing this energy source (see chapter 12). Until these issues are settled project planning will continue to be based on more certain energy sources. Nevertheless the possibility of complete independence in energy supply is a powerful positive factor in favour of the project.

Hydroenergy from Niandouba will be sufficient only to satisfy the demand of the main right bank pumping station, the first to be built. A diesel-driven right bank pumping station permits a substantial reduction in capital cost but increases annual operating costs. For the increase in annual operating costs to offset fully the reduction in capital cost the price of fuel would have to rise to about 100 FCFA per litre (equivalent to about US $ 45 per barrel) at 6 % discount rate or 150 FCFA per litre at 10 % discount rate. The first price will almost certainly be reached by the time that the hydroelectric station at Niandouba will be sending out energy.

With due consideration of these aspects, and in view of the fact that foreign exchange savings are a main objective, the solution with hydroelectric station at Niandouba is preferred. The choice of energy supply will be reviewed at detailed design but will not affect the main conclusions of this report.

3.5. Water demand and supply

3.5.1 Irrigation water requirements

Potential evapotranspiration, ETO, was calculated by the Blaney Criddle method for the nearest climate stations of Basse and Kolda, and the results modified to allow for the increase in humidity which will accompany large scale develoment of irrigation in the Anambe Basin. Values of ETo for the project area are given in table 3-3. The table also shows the calculation of farmgate irrigation water requirements, taking into account the following :

- a crop coefficient varying with the growth stage of the crop
- effective rainfall equalled or exceeded 4 years in 5 on average
- pre-irrigation water requirements to replenish the soil moisture reservoir and permit timely land preparation and planting
- percolation losses from paddy fields
- farm application efficiencies of 75 % for rice and 65 % for maïze and sorghum

The spatial distribution of rain during the wet season is more important to crop maturation and yield than annual or even monthly totals. A study of daily rainfalls showed that to achieve full security of water supplies 4 years in 5,two supplementary irrigations are required for rice between July and September. For other cereal crops a single irrigation is sufficient. Irrigation water requirements have been adjusted to reflect this need.

Monthly irrigation water requirements per ha and total requirements by development phase are given in table 3-4. Conveyance losses between Niandouba dam and the main pumping station are estimated at 10 percent. Overall irrigation distribution system losses between the dam and the farmgate are estimated at 25 %. Irrigation efficiencies may be summarised as follows :

	Rice	Diversified crops
Distribution system conveyance efficiency	75 %	75 %
Farm application efficiency	75 %	65 %
Overall irrigation efficiency	56 %	49 %

Table 3 - 3 CROP AND FARMGATE WATER REQUIREMENTS

	January		February		March		April		May		June		July		August		September		October		November		December		Total: Wet season	Total: Dry season
1. Potential evapotranspiration ETo (half monthly)	69	71	68	75	84	90	93	96	100	98	94	89	81	71	59	53	51	54	64	72	67	65	67	69		
2. Effective rainfall 4 years out of 5											18	37	46	62	77	90	85	57	29	0						
Mechanised and peasant rice	15/1			110-120 days							14/5	6/7			110 days						23/10					
3. Crop coefficient Kc		0,62	0,93	1,01	1,11	1,16	1,16	0,92	0,60				0,50	0,80	1,00	1,09	1,15	1,16	1,00	0,65						
4. Crop water requirement Kc x ETo		44	63	76	93	104	108	84	23[1]				27	57	59	58	59	63	64	24[1]					411	595
5. Pre-irrigation												60												60	60	60
6. Percolation 2 mm/day		0	20	28	31	31	30	28	0				0	16	31	31	30	30	22	0					160	168
7. Net water requirement 4 + 5 + 6 - 2		44	83	104	124	135	138	112	23			60[3]	0	11	13	0	4	36	57	24				60	205	823
8. Submersion			50	50				-100																		
9. Total water requirement 7+8		44	133	154	124	135	138	12	23			60	0	11	13	0	4	36	57	24				60	205	823
10. Farmgate requirement[4]		59	177	205	165	180	184	12	0[2]			75	0	50[5]	0	0	50[5]	0	75	0[2]				80	250	1 062
Mechanized maize and peasant maize/sorghum (1 : 2)	15/1			110 days					4/5			6/7			110 days						23/10					
3. Crop coefficient Kc		0,51	0,63	0,76	0,98	1,11	1,11	0,69					0,50	0,60	0,71	0,92	1,10	1,13	0,85	0,50						
4. Crop water requirement Kc x ETo		36	43	57	82	100	103	66					41	43	42	49	56	61	54	18[1]					364	487
5. Pre-irrigation												40												50	40	50
6. Total water requirement 4+5-2		36	43	57	82	100	103	66				40	0	0	0	0	0	4	25	18				50	87	537
7. Farmgate requirement[4]		55	66	88	126	154	158	102				62	0	50[7]	0	0	0	0	38	0[2]				77	150	826

NOTES
(1) Represents a part of the period
(2) Requirements supplied from residual soil moisture
(3) Effective rainfall not considered
(4) Farm application efficiency 75 % in dry season for rice
65 % in dry season for maize and sorghum
(5) Two irrigations necessary in mid-season one year out of five ; date of irrigation varies
(6) Maize 90 days, sorghum 120 days with ratio 1 ha maize : 2 ha sorghum
(7) One irrigation necessary in mid-season one year out of five : date of irrigation varies

Table 3 - 4 IRRIGATION WATER REQUIREMENTS

1. Per hectare

	At farmgate				At main pumping stations		At Niandouba dam	
	Rice		Diversified crops		Rice	Diversified crops	Rice	Diversified crops
	mm	m^3/ha	mm	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha
JANUARY	59	590	55	550	708	660	787	733
FEBRUARY	382	3 820	154	1 540	4 584	1 848	5 093	2 053
MARCH	345	3 450	280	2 800	4 140	3 360	4 600	3 733
APRIL	196	1 960	260	2 600	2 352	3 120	2 613	3 467
MAY								
JUNE	75	750	62	620	900	744	1 000	827
JULY	50	500	50	500	600	600	667	667
AUGUST								
SEPTEMBER	50	500			600		667	
OCTOBER	75	750	38	380	900	456	1 000	507
NOVEMBER								
DECEMBER	80	800	77	770	960	924	1 067	1 027
Wet season	250	2 500	150	1 500	3 000	1 800	3 334	2 001
Dry season	1 062	10 620	826	8 260	12 744	9 912	14 160	11 013
Total	1 312	13 120	976	9 760	15 744	11 712	17 494	13 014

2. At main pumping stations (10^6 m^3)

	PHASE I 1 490 ha			PHASE II 4 440 ha			PHASE III 7 490 ha			PHASE IV 11 485 ha			PHASE V 16 265 ha		
	rice	div. crops	total	rice	div. crops	total	rice	div. crops	total	rice	div. crops	total	rice	div. crops	total
Cultivated area															
Wet season (ha)	1249	95	1344	3976	242	4218	6688	428	7116	10298	613	10911	14777	675	15452
Dry season (ha)	1052	84	1136	3180	372	3552	4800	1192	5992	6640	2548	9188	9716	3296	13012
JANUARY	0,74	0,06	0,80	2,25	0,25	2,50	3,40	0,79	4,19	4,70	1,68	6,38	6,88	2,18	9,06
FEBRUARY	4,82	0,16	4,98	14,58	0,69	15,27	22,00	2,20	24,20	30,44	4,71	35,15	44,54	6,09	50,63
MARCH	4,36	0,28	4,64	13,17	1,25	14,42	19,87	4,01	23,88	27,49	8,56	36,05	40,22	11,07	51,29
APRIL	2,47	0,26	2,73	7,48	1,16	8,64	11,29	3,72	15,01	15,62	7,95	23,57	22,85	10,28	33,13
MAY															
JUNE	1,12	0,07	1,19	3,58	0,18	3,76	6,02	0,32	6,34	9,27	0,37	9,64	13,30	0,58	13,88
JULY	0,75	0,06	0,81	2,39	0,15	2,54	4,01	0,26	4,27	6,18	0,30	6,48	8,87	0,47	9,34
AUGUST															
SEPTEMBER	0,75		0,75	2,39		2,39	4,01		4,01	6,18		6,18	8,87		8,87
OCTOBER	1,12	0,04	1,16	3,58	0,11	3,69	6,02	0,20	6,22	9,27	0,23	9,50	13,30	0,36	13,66
NOVEMBER															
DECEMBER	1,01	0,08	1,09	3,05	0,34	3,39	4,61	1,10	5,71	6,37	2,35	8,72	9,33	3,05	12,38
Wet season	3,75	0,17	3,92	11,94	0,44	12,38	20,06	0,78	20,84	30,90	0,90	31,80	44,34	1,41	45,75
Dry season	13,40	0,80	14,20	40,53	3,69	44,22	61,17	11,82	72,99	84,62	25,25	109,87	123,82	32,67	156,49
Total	17,15	0,97	18,12	52,47	4,13	56,60	81,23	12,60	93,83	115,52	26,15	141,67	168,16	34,08	202,24

3.5.2 Downstream demand

There is little information available on abstraction of Kayanga runoff downstream of the dam, either present or proposed. Dry season discharge at Niapo Bridge falls to below 1 m^3/s at the end of the dry season in May. The average discharge over December to June, the period of lowest flow, is 1,6 m^3/s. To allow for downstream users and to maintain the ecology of the river, a continuous discharge of 2 m^3/s has been adopted as the minimum flow to be maintained in the Kayanga below the Anambe confluence, thereby providing both higher volume and higher security of supply.

3.5.3 Return flows from irrigation

Irrigation losses average about 45 percent of headworks releases and about 40 percent of the pumped water supply. A proportion of these losses will escape by evaporation or subsurface flow, but a large part will drain towards the centre of the Basin to be re-utilised or released as required, thereby reducing the demand on Niandouba reservoir by a corresponding amount. It is assumed that 50 percent of all irrigation losses may be redistributed in this manner. At full development return flows about equal compensation releases.

3.5.4 Reservoir operation

Reservoir operation involved carrying out a straightforward water balance among inflows, losses and releases. These computations were made for 61 years of the synthetically extended streamflow record, covering two wet and dry cycles. The routine calculations were carried out by computer.

Monthly computations stopped each year at the end of the wet season to determine the volume of water available for dry season cropping. The model predicted dry season runoff and reservoir evaporation, the first bein a function of annual runoff and the second of the reservoir storage level at the end of the wet season. The volume available for dry season irrigation use allowed for compensation releases and also for a storage reserve to be carried over for use during June and July of the following wet season. Thus supplementary wet season requirements were accorded priorit

The volume of water available for dry season use enabled the irrigable area to be determined. Figure 3-4 shows the area irrigated year by year following development of the right bank perimeter (phase III) and left bank perimeter (phase V) as determined by the water balance model. Table 3-5 gives the full water balance.

3.5.5 Optimization of storage requirements and irrigation service area

The model described was used to study a range of different combinations of irrigation service area and reservoir maximum storage level. Benefits from additional storage exceeded the cost of raising the dam up to the selected maximum storage level of 37,0 m IGN but not beyond.

Marginal cost studies (report 8) also showed that the irrigation service area could economically be increased until the marginal dry season cropping intensity fell below 50 percent. The results of reservoir operation studies give an average dry season cropping intensity of 71 percent at phase III and 60 percent at phase V. A mean dry season cropping intensity over the project area as a whole of 70 percent is considered appropriate on farm management grounds (cf. para 3.3.2).

Reservoir operation studies took into account Kayanga runoff and irrigation return flows but not Anambe runoff, for which data are extremely scarce. To achieve the proposed 70 percent dry season cropping intensity over the 16 265 ha service area at full development requires an additional supply of :

$$\frac{156{,}49 \times 10^6 \ m^3}{80 \ \%} \times 10 \ \% = 20 \times 10^6 \ m^3 \text{ (cf. table 3-4)}$$

This amount will readily be contributed by Anambe runoff as shown in the next paragraph.

3.5.6 Anambe supplementary supply

Mean annual runoff from the Anambe Basin is estimated at 55 million m^3. Following development three factors will contribute to a significant

Table 3 - 5 OPERATION OF NIANDOUBA RESERVOIR
WATER BALANCE

YEAR	VOLUME BEGIN NOV (M M3)	INFLOW NOV - OCT (M M3)	SPILL (M M3)	IRRIGATION RELEASES (M M3)	COMP. REL. (M M3)	EVAP. (M M3)	VOLUME END OCT (M M3)
1918/1919	420.0	190.3	0.0	223.1	2.0	112.0	273.2
1919/1920	273.2	301.2	0.0	205.2	2.0	72.4	294.8
1920/1921	294.8	101.4	0.0	221.9	2.0	79.0	93.2
1921/1922	93.2	524.5	107.7	35.4	2.0	52.6	420.0
1922/1923	420.0	322.5	1.3	206.9	2.0	112.4	420.0
1923/1924	420.0	555.0	217.6	223.0	2.0	112.4	420.0
1924/1925	420.0	365.4	54.7	199.6	2.0	109.1	420.0
1925/1926	420.0	140.8	0.0	221.5	2.0	110.3	226.9
1926/1927	226.9	488.8	67.2	161.4	2.0	65.1	420.0
1927/1928	420.0	397.8	82.1	205.5	2.0	108.3	420.0
1928/1929	420.0	377.4	48.6	217.6	2.0	109.1	420.0
1929/1930	420.0	349.4	46.7	200.6	2.0	100.1	420.0
1930/1931	420.0	295.2	0.0	225.8	2.0	116.7	370.7
1931/1932	370.7	231.6	0.0	231.9	2.0	100.5	267.9
1932/1933	267.9	370.3	0.0	227.6	2.0	76.7	331.8
1933/1934	331.8	315.5	0.0	215.1	2.0	83.6	346.6
1934/1935	346.6	583.8	196.4	222.3	2.0	89.7	420.0
1935/1936	420.0	544.3	220.4	217.1	2.0	104.8	420.0
1936/1937	420.0	286.4	0.0	209.8	2.0	114.3	380.3
1937/1938	380.3	347.2	0.0	230.8	2.0	105.2	389.5
1938/1939	389.5	214.8	0.0	202.1	2.0	95.0	305.2
1939/1940	305.2	123.3	0.0	199.6	2.0	75.6	151.3
1940/1941	151.3	112.4	0.0	111.9	2.0	52.5	97.3
1941/1942	97.3	74.8	0.0	40.4	2.0	48.2	81.5
1942/1943	81.5	200.2	0.0	29.6	2.0	46.9	203.2
1943/1944	203.2	58.0	0.0	155.8	2.0	59.8	43.5
1944/1945	43.5	358.8	0.0	45.0	2.0	42.4	312.9
1945/1946	312.9	300.6	0.0	211.6	2.0	80.8	319.2
1946/1947	319.2	232.9	0.0	217.0	2.0	83.9	249.2
1947/1948	249.2	168.2	0.0	193.8	2.0	67.1	154.6
1948/1949	154.6	100.1	0.0	114.1	2.0	56.7	82.0
1949/1950	82.0	490.6	77.9	25.8	2.0	47.0	420.0
1950/1951	420.0	426.5	118.9	199.6	2.0	106.0	420.0
1951/1952	420.0	371.2	67.2	199.6	2.0	102.5	420.0
1952/1953	420.0	193.9	0.0	212.2	2.0	109.4	290.4
1953/1954	290.4	418.5	0.0	225.6	2.0	82.3	399.0
1954/1955	399.0	480.7	140.3	213.4	2.0	103.9	420.0
1955/1956	420.0	451.0	118.9	219.3	2.0	110.8	420.0
1956/1957	420.0	395.5	88.0	199.6	2.0	105.9	420.0
1957/1958	420.0	360.5	25.4	224.3	2.0	108.7	420.0
1958/1959	420.0	331.2	0.0	224.2	2.0	112.4	412.5
1959/1960	412.5	215.6	0.0	224.2	2.0	107.6	294.4
1960/1961	294.4	392.3	0.0	216.1	2.0	77.8	390.7
1961/1962	390.7	418.8	82.4	207.6	2.0	97.6	420.0
1962/1963	420.0	264.7	0.0	199.6	2.0	108.2	374.8
1963/1964	374.8	444.0	85.0	221.0	2.0	90.9	420.0
1964/1965	420.0	298.4	0.0	213.6	2.0	114.3	388.5
1965/1966	388.5	465.4	140.6	199.6	2.0	91.6	420.0
1966/1967	420.0	439.9	113.8	216.6	2.0	107.5	420.0
1967/1968	420.0	156.5	0.0	223.1	2.0	110.5	240.8
1968/1969	240.8	127.7	0.0	160.2	2.0	69.0	137.3
1969/1970	137.3	155.2	0.0	101.0	2.0	56.7	132.8
1970/1971	132.8	201.9	0.0	104.0	2.0	56.4	172.3
1971/1972	172.3	49.0	0.0	129.9	2.0	58.5	30.9
1972/1973	30.9	40.6	0.0	52.1	2.0	35.9	0.0
1973/1974	0.0	211.7	0.0	47.3	2.0	31.2	147.7
1974/1975	147.7	195.4	0.0	128.7	2.0	60.2	152.3
1975/1976	152.3	72.3	0.0	116.3	2.0	56.7	49.6
1976/1977	49.6	33.2	0.0	50.4	2.0	41.5	0.0
1977/1978	0.0	186.1	0.0	38.9	2.0	29.9	136.9
1978/1979	136.9	37.8	0.0	118.3	2.0	64.6	0.0

increase in runoff :

- the higher water table will reduce infiltration and raise the runoff coefficient for the central part of the Basin

- collector drains and main drains will reduce the amount of standing water and hence the evaporation loss

- over the irrigated area the evapotranspiration which occurs presently, ie before development, may be credited to the project as an additional water resource

None of these influences on the water balance is readily quantifiable except perhaps the last. The actual annual evapotranspiration of the forest vegetation was estimated at 581 mm in an earlier study (SODAGRI, 1978),which is close to the average annual effective rainfall. If only 75 % of this amount were credited to the water balance this would make available an additional 71 million m^3 in an average year.

The influence of the project on the hydrological balance will only become clear after the early developments are completed ; it can already be confidently predicted, however, that Anambe runoff will be more than sufficient to supply the additional 20 million m^3 required at full development.

3.5.7 Conclusions

Water supplies are sufficient to provide supplementary wet season irrigation and full dry season irrigation to 16 265 ha at average cropping intensities of 95 % and 70 % in wet and dry seasons respectively, assuming that the long term runoff sequence of the Kayanga may be approximated by the sequence of the past 61 years.

3.6. Development programme

Financial and socio-economic considerations dictate phased development of the project. Full development of the project in a single phase would require capital expenditures representing an inordinate proportion of planned annual expenditures for agricultural development in the next development plan period. Moreover the restraints on the rate of development imposed by socio-demographic factors produce an unacceptable economic forecast for single phase development. It follows that the project must be implemented in phases to ensure a favourable cash flow.

Other considerations which favour phased development are :

- the earlier phases permit large scale testing of cultural techniques and farm management practices, providing the justification and guidelines for subsequent development

- the project as it develops can be more readily adapted to a changing economic, social and physical environment

In view of the magnitude of investments required for the main works, including Niandouba dam, the first phase of the project shall be limited to the development of an irrigated mechanized farm of 665 ha and smallholder plots encompassing 755 ha. These will serve as pilot schemes for the development of the project. They will be located on lands which cover a fairly typical range of soils suitable for irrigated agriculture

Following development and operation of the pilot schemes and the first phase of the Anambe project, land development will be continued during four subsequent phases, comprising two on either bank of the Anambe river (figures 3-2 and 3-5).The areas developed under each phase are as follows :

Table 3-6 DEVELOPMENT AREAS BY PHASE

Phase	Location	Mechanized farm	Smallholder farms				Total
		Rice-rice	Rice-rice	Rice-diver.	Divers.-div.	Total	
I	Right bank	665	650		105	755	1 420
II	Right bank	1 445	1 215	210	150	1 575	3 020
III	Right bank		2 025	830	195	3 050	3 050
IV	Left bank	1 485	815	1 500	195	2 510	3 995
V	Left bank	1 340	2 505	870	65	3 440	4 780
	TOTAL	4 935	7 210	3 410	710	11 330	16 265

Land will be developed for irrigation at a nearly constant rate from the start of phase II in 1984 to the completion of phase IV in 1991, averaging about 1250 net ha or 1500 gross ha per year. By the end of this period the mechanized farm will attain its final size of almost 5000 ha. Thereafter the rate of growth of the irrigated area will be limited to the rate of increase in smallholder farming, assumed not to exceed 1000 ha per year on any one bank. The project area will reach full land development (though not full production) in 1996. The phased development of the Anambe Basin is illustrated in figure 3-5, and the programme of land development, giving the rate of development of lands under smallholder and mechanized cultivation, is given in table 3-7.

The construction programme shown in table 3-8 is based on the foregoing land development programme.The main works for the pilot phase (phase I) are to be constructed during the period end 1980 to end 1981, permitting irrigation of the first dry season crop in 1982. Land development will continue for a further two years. The major construction period runs from 1984 to 1987 and includes the main storage works (Niandouba dam), flood protection works (Anambe dam) and the main right bank pumping and distribution works. The construction period starting in late 1987 will see construction of the main left bank pumping and distribution facilities. Land development, including secondary canals, drainage network, land clearance and levelling and tertiary works is phased according to the expansion in cultivated area.

3.7. Project description

3.7.1 Phase I

Storage of wet season runoff to supply the Phase I irrigation perimeter including the pilot farm will created by the confluence dam. At the maximum pool level of 22,30 m the dam will form a reservoir in the Anambe basin and the Anambe exit channel covering an area of 55 km^2 and providing a live storage volume of 48 million m^3.

The irrigation perimeter will be supplied by a diesel driven pumping station situated between the villages of Soutoure and Anambe. An excavated approach channel will lead water from the reservoir to the pumping station. In subsequent phases this channel will form part of one of the main drains. The pumping station has a rated capacity of 3,75 m^3/s at 13 m head.

Table 3 - 7 PROGRAMME OF LAND DEVELOPMENT

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001 - 2030
INCREASE IN IRRIGABLE AREA			PHASE I				PHASE II		PHASE III		PHASE IV			PHASE V								
Mechanized farm	ha		665				1 050	395				790	695		740	300	300					
Smallholder lands																						
Rice - rice	ha			175	475		180	1 035	750	1 275	350	165	300	1 005	300	500	700					
Rice - diversified	ha						165	45	555	275	740	300	460	130	160	400	180					
Diversified - diversified	ha						105	45	195		110	45	40	65								
Total smallholder	ha			280	475		450	1 125	1 500	1 550	1 200	510	800	1 200	460	900	880					
Total annual increase in area	ha		665	280	475		1 500	1 520	1 500	1 550	1 200	1 300	1 495	1 200	1 200	1 200	1 180					
SMALLHOLDER LANDS DEVELOPED																						
Under improvement (1)	ha			175	475		180	1 035	750	1 275	350	165	300	1 005	300	500	700					
Farmed by smallholders	ha			105	280	755	1 025	1 295	3 080	4 105	6 230	6 925	7 560	8 085	9 250	9 950	10 630	11 330	→	→	→	11 330
Total	ha			280	755	755	1 205	2 330	3 830	5 380	6 580	7 090	7 890	9 090	9 550	10 450	11 330	11 330	→	→	→	11 330
LANDS TRANSFERRED TO SMALLHOLDERS																						
Right bank	ha			105	175	475	270	270	550	800	800	600	400	400	400	135						
Left bank	ha										400	600	800	800	800	865	985	700				
Total	ha			105	175	475	270	270	550	800	1 200	1 200	1 200	1 200	1 200	1 000	985	700				
TOTAL IRRIGABLE AREA																						
Mechanized farm	ha		665	665	665	665	1 715	2 110	2 110	2 110	2 110	2 900	3 595	3 595	4 335	4 635	4 935	4 935	→	→	→	4 935
Interim lands (1)	ha			175	475		180	1 035	1 985	2 735	2 735	2 045	1 635	1 645	905	805	700					
Smallholder farms	ha			105	280	755	1 025	1 295	1 845	2 645	3 845	5 045	6 245	7 445	8 645	9 645	10 630	11 330	→	→	→	11 330
Total	ha		665	945	1 420	1 420	2 920	4 440	5 940	7 490	8 690	9 990	11 485	12 685	13 885	15 085	16 265	16 265	→	→	→	16 265

(1) Farmed by production division of project authority

Table 3 - 8 CONSTRUCTION PROGRAMME

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
PHASE I (incl. pilot farm)																	
Detailed design																	
Tender																	
Construction of confluence dam and pumping station																	
Distribution network and on-farm works																	
Area developed (ha)		665	280	475													
PHASE II/III Right bank																	
Detailed design																	
Tender																	
Construction :																	
Niandouba dam and H/E plant																	
Anambé flood protection dam and modifications to confluence dam																	
Main right bank pumping station and ancillary works																	
Installation of pumpsets																	
Foundations of left bank pumping station																	
Move of Phase I pumping plant																	
Auxiliary pumping station																	
Main canals																	
Secondary and tertiary canals drainage network, on farm works																	
Area developed (ha)						1 500	1 520	1 500	1 550								
PHASE IV / V left bank																	
Main left bank pumping station and ancillary works																	
Installation of pumpsets																	
Main canals																	
Secondary and tertiary canals drainage network and on-farm works																	
Area developed (ha)										1 200	1 300	1 495	1 200	1 200	1 200	1 180	
Total area developed (ha)		665	945	1 420		2 920	4 440	5 940	7 490	8 690	9 990	11 485	12 685	13 885	15 085	16 265	

The canal serving the pilot farm and smallholder plots follows the same alignment as the main canal in phase II. In order that construction of phase II does not disrupt irrigation of the pilot farm it will be necessary to construct the canal over the first reach of 3,4 km to its dimensions at full development, complete with concrete lining.

Without the protection afforded by the Anambe flood exclusion dam, a one in ten year flood would inundate all lands below elevation 23,2 IGN. The irrigation perimeter has therefore been located above elevation 23,0 m IGN.

Phase I lands comprise 1420 net hectares, including 665 hectares of mechanized rice farm and 755 hectares assigned to smallholders. The irrigation perimeter lies east of Awataba on lands which slope towards the central basin initially at a gradient of around 1,0 %, reducing to 0,1 %. The lower lying lands are some of the most suitable for extensive mechanized farming to be found in the basin. Double cropped rice will be the crop rotation on 650 hectares of smallholder farms, the remaining 105 hectares being suitable for diversified crops in both seasons.

An industrial rice mill will be established near to the pilot farm.

The irrigation water demands of the phase I area can be satisfied in 9 years out of 10 as shown in the water balance for the design year, table 3-9. The water balance starts at the beginning of June assuming the reservoir to be at its minimum level of 20,5 IGN. During June the level falls slightly before rising again as Kayanga runoff increases. The Waîma reservoir reaches its maximum level of 22,3 IGN in October. Thereafter irrigation demands, downstream releases and evaporation losses result in the reservoir level being drawn down steadily until the end of May, when it is just above its level at the start of the water balance. The water balance takes no account either of Anambe runoff or of drainage flows from irrigated lands. It assumes a continuous compensation release of 0,5 m^3/s, corresponding to the minimum dry season discharge of the Kayanga. The compensation release of 2 m^3/s to be provided following construction of Niandouba dam cannot be secured 9 years in 10 during Phase I.

Table 3 - 9 WATER BALANCE IN PHASE I

	June	July	August	Sept.	Oct.	Nov.	December I	December II	January I	January II	February I	February II	March I	March II	April I	April II	May I	May II
Evaporation-precipitation(1) (mm)	134	23	- 41	- 66	124	152	78	78	80	80	82	82	100	100	108	108	114	114
Water level (start) (m IGN)	20,5	20,4	20,8	21,2	21,9	22,3	22,3	22,2	22,1	22,0	21,9	21,8	21,6	21,4	21,2	21,0	20,9	20,8
Water surface area (km^2)	8	18	12	18	38	55	53	50	47	44	41	36	32	27	20	14	13	12
Storage volume (start) (10^6 m^3)	11	10,1	14,7	21,4	42,3	60,2	58,0	55	51,0	47,9	44,2	38,7	33,1	27,8	22,8	18,0	16,4	15,2
Inflow(2) (10^6 m^3)	2,8	7,0	7,5	21,8	25,2	7,5	1,7	1,8	1,3	1,4	1,1	1,1	1,0	1,1	0,9	0,9	0,9	0,9
Water requirements 3) (10^6 m^3)	1,3	0,9	-	0,8	1,3	-	-	1,2	-	0,9	2,6	3,0	2,5	2,7	2,9	0,3	-	-
Evaporation losses (10^6 m^3)	1,1	0,2	-0,5	- 1,2	4,7	8,4	4,1	3,9	3,8	3,5	3,4	3,0	3,2	2,7	2,2	1,5	1,5	1,4
Compensation releases(4) (10^6 m^3)	1,3	1,3	1,3	1,3	1,3	1,3	0,6	0,7	0,6	0,7	0,6	0,7	0,6	0,7	0,6	0,7	0,6	0,7
Storage volume (end) (10^6 m^3)	10,1	14,7	21,4	42,3	60,2	58,0	55	51,0	47,9	44,2	38,7	33,1	27,8	22,8	18,0	16,4	15,2	14
Water level (end) (m IGN)	20,4	20,8	21,2	21,9	22,3	22,3	22,2	22,1	22,0	21,9	21,8	21,6	21,4	21,2	21,0	20,9	20,8	20,7

(1) Precipitation for Velingara with frequency 90 %

(2) Inflow exceeded with frequency 90 %. Excludes contribution of the Anambé Basin

(3) For cropping intensity of 95 % in the wet season and 80 % in the dry season on 1420 ha

(4) 500 l/s

The water balance calculation confirms that the phase I area can be fully served with irrigation supplies in nine years out of ten by operating the Waïma reservoir between the levels of 22,30 and 20,50 m IGN. In exceptionally dry years the dry season irrigated area would be reduced according to anticipated water availability. In such years the potential for exploiting Anambe runoff and return flows would also be greatly reduced.

3.7.2 Phase II

The main works to be carried out for phase II are :

- Niandouba dam and power station
- Anambe flood protection dam
- Right bank main pumping station and ancillary works ; foundations for left bank main pumping station
- Channel improvements in the Kayanga and Anambe rivers
- Raising of overflow sections at confluence dam
- Main canals 19,0 km
- Main roads 13,6 km
- Main drains 19,2 km
- Secondary canals 40,6 km
- Land development 3 020 ha
- Industrial rice mills 1 No
- Multi-unit rice mills 2 No
- Seed treatment plant
- Livestock feed centre

Construction of Niandouba dam will be completed in two years starting in late 1983. The main right bank pumping station will be started at the same time. The construction schedule is organized so that irrigation of phase I areas can continue during construction of phase II. This affects in particular the Anambe flood protection dam. The "windows" between irrigation seasons of about 2 months during November and December and 2 1/2 months from mid April to end June are not long enough to permit the dam to be raised to its final height. It will therefore be necessary to start work on the Anambe dam in 1985 once irrigation of the dry season crop has been completed, raising it to a level of around 21,5 metres before the wet season halts construction. During the 1985 wet season Niandouba reservoir fills and can release water in a controlled manner for supplementary irrigation needs as required. Following the 1985 wet season construction of Anambe dam would be resumed, the dam being completed before the 1986 wet season. At the same time the diesel pumping station serving the phase I perimeter would be dismounted and the pumps and motors rehoused in the main right bank pumping station. Both the phase I area and the newly developed lands of phase II would be supplied by the right bank main pumping station from the 1986 dry season onwards.

The foundations for the main left bank pumping station would be laid as part of the phase II construction programme. Delaying these works until phase IV would either involve their construction while simultaneously maintaining a pool level in the Anambe exit channel to supply the right bank pumping station or involve disrupting irrigation. The first alternative is technically feasible but would be extremely costly. Advancing construction of these works to phase II proves the more attractive solution.

Channel improvements will consist of clearance of the Kayanga river bed from Niandouba dam to just downstream of the confluence dam, lowering of the Kayanga river bed over the first 3 km downstream of Niandouba dam and clearance and minor channel excavation in the Anambe River between Kounkane and the confluence.

Two mechanized farms will be established in the phase II irrigation perimeter. The first lying east of Awataba, is an extension of the phase I farm to the 22,0 metre contour (flood protection now being afforded by the Anambe dam) to include a total of 1 325 hectares. The second farm, located east of the village of Anambe, will cover 785 hectares of land, including some of the land presently cleared and farmed under rainfed conditions by SODAGRI. The remaining 1 575 ha will be transferred to small farmers.

During the peak irrigation period small farmers would be irrigating their fields for 14 hours per day on a seven day rotation. For mechanized farms irrigation would continue for about 16 hours daily, resulting in a need for two shifts. Flow control gates at the head of the secondary and tertiary canals control withdrawals from the main and secondary distribution systems. The main canal system is divided into reaches by constant downstream level control gates wich function automatically to maintain water levels downstream. Thus changes in demand due to opening or closing of the flow control gates at the head of the secondary system are signalled by level changes which are translated into changes in discharge by movement of the level control gates on the main canals. The signal is thereby sent progressively upstream to the first canal reach. The canal section in the first reach is dimensioned to provide a storage band for regulation of the main pumping station. Within this band falling water levels activate one or more pumps in turn, rising water levels causing pumps to stop in a similar manner.

As the right bank pumping station receives its energy supply predominantly from the hydroelectric plant at Niandouba, the decision to start and stop one or more pumps must first be transmitted to the Niandouba station so that the turbines can be started and stopped accordingly, in advance of the change in pumped discharge. These operations would be automated.

Intakes have been provided on either side of the Anambe dam to enable the main pumping stations to operate with maximum flexibility. In their normal irrigation function they can pump from either the Kayanga or the Waîma sides of the dam into the distribution system ; in their drainage function they can pump from the Waîma lake into the pool on the Kayanga side. Normally, however, water accumulating in the Waîma reservoir would be drained by gravity by opening the pumping station twin intake gates at either extremity of the Anambe dam.

3.7.3 Phase III

The main works to be carried out for phase III are :

- Installation of two additional groups in the main right bank pumping station
- Auxiliary pumping station and ancillary works between Anambe and Awataba
- Extension of low level main canal P-1 — 1,4 km
- High level main canal P-2 and branch, — 16,9 km
- Main roads — 19,0 km

- Main drains	27,2 km
- Secondary canals	36,5 km
- Land development	3 050 ha
- Multi-unit rice mills	3 No

The phase III service area of 3 050 hectares forms two perimeters, one close to Dialakegni being a natural extension of phase II, the other located in an arc covering from north-west to south-east of Awataba. Both areas have numerous small villages on their fringes and this factor plus the absence of large contiguous areas suitable for a mechanized farm, indicates development for smallholder agriculture.

In most years sufficient hydroenergy can be produced to meet the phase III pumping energy demand in full. In drier years the water stored in the Kayanga reservoir may be sufficient to meet irrigation water requirements yet insufficient to provide the necessary energy at the pumps. This situation is explained by the fact that about two cubic metres of water must be released from the reservoir on average to generate the energy to pump one cubic metre into the distribution system. During such drier years the standby diesel driven pumps would provide part or all of the energy balance (see figures 3-6 and 3-7).

It has been assumed on the basis of operation studies that the additional two pumping groups installed would be electrically driven, relying on the hydroenergy supply from Niandouba. Should it later emerge that the second of these groups be changed to a diesel driven one, this possibility has been allowed for in the design of the pumping station.

3.7.4 Phase IV

The main works for phase IV comprise :

- Construction of the main left bank pumping station on the foundations in place from phase II
- Ancillary works for pumping station, including regulating reservoir
- Main canal P-3 and branches P-3/1 and P-3/2, 18,8 km
- Main roads 24,0 km
- Main drains 27,1 km

- Secondary canals 42,5 km
- Land development 3 995 ha
- Industrial rice mills 1 No
- Multi-unit rice mills 3 No
- Extension of livestock feed centre

The main pumping station on the left bank will be diesel-driven. It discharges via twin 1800 mm diameter penstocks into a service reservoir of 400 000 m^3 capacity. This acts as a night storage reservoir, enabling pumping to continue for 24 hours at peak periods and resulting in reduced overall costs compared with pumping only during hours of irrigation.

The irrigation service area of 3 995 hectares includes the third mechanized farm of 1 485 hectares which occupies the extensive area of gently sloping land north to west of Koulinto village. The remaining lands are well located for farmers in the surrounding villages.

The system of water distribution to the left bank perimeter is the same as that already describes for the right bank. Demand is signalled automatically along the main canal and a constant level control gate at the service reservoir outlet ensures that the latter releases water according to demand. The service reservoir, as well as having a night storage function, controls the operation of the main pumping station. Pumps are activated or stopped according to level signals received from the service reservoir.

As development of the left bank proceeds the rules governing operation of Niandouba reservoir will require revision. During phase II the reservoir is operated to meet energy demands for pumping, except in the driest years. During later phases the governing criterion for reservoir operation will increasingly become the irrigation water demand at the pumping stations. The release pattern will change, relatively more water being released at the beginning of the dry season cropping cycle when reservoir levels are high, and less being released nearer the end of the irrigation season. This in turn will increase the need for back-up diesel pumping capacity on the right bank unless an alternative source of electric energy becomes available.

Anambe runoff and irrigation return flows will become increasing important sources of supply as the left bank is developed, and will be used in conjunction with releases from Niandouba reservoir. In normal years, Anambe runoff will be stored behind the Anambe dam from August until the end of the irrigation season in October to provide a source of supplementary irrigation supply. If permissible levels in the Waïma reservoir are exceeded water will be evacuated by gravity or by pumping to the Kayanga side of the Anambe dam. During the dry season, irrigation return flows can be managed in a similar way.

3.7.5 Phase V

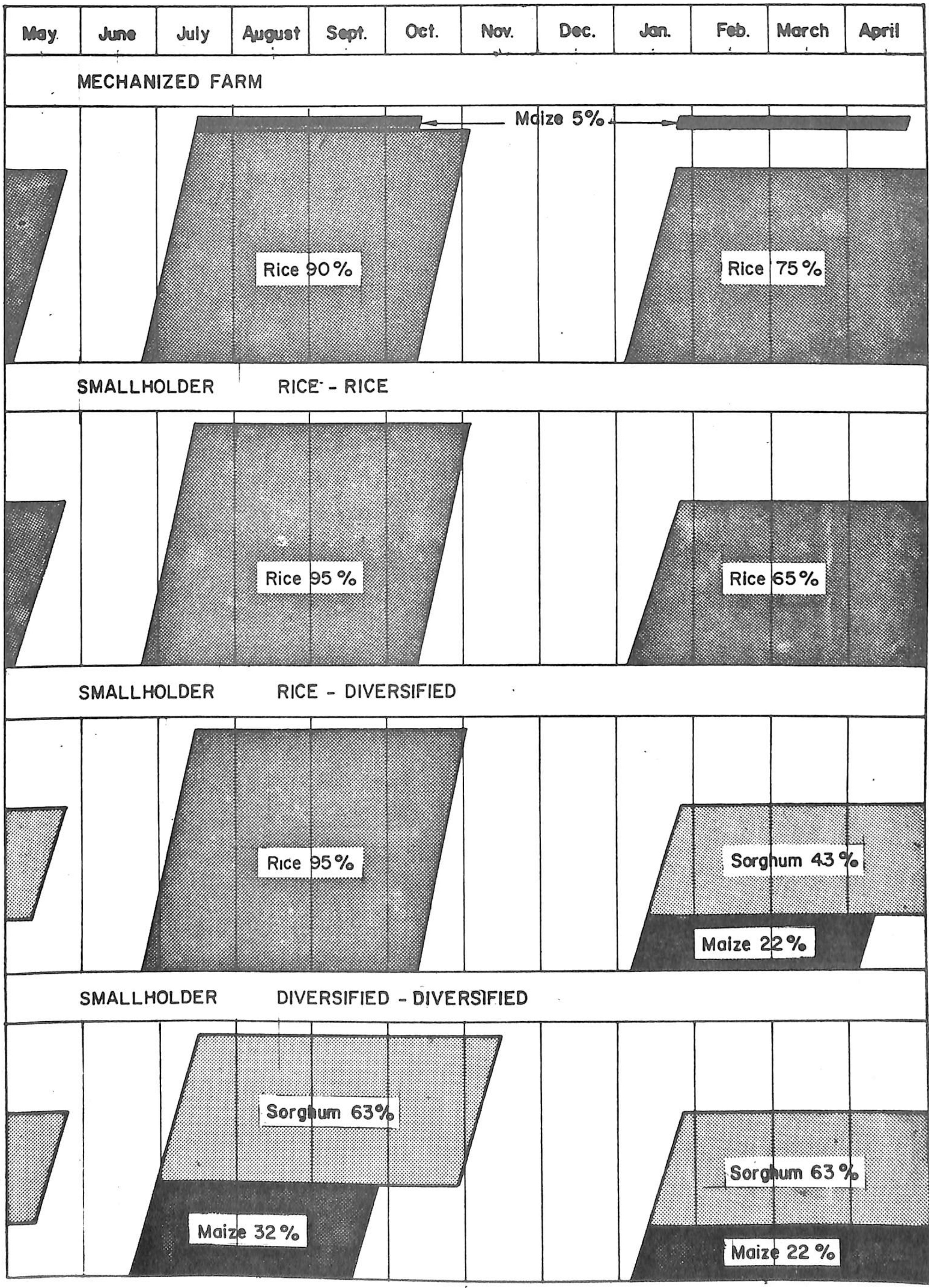
The main works for phase V comprise :

- Installation of groups 3 and 4 in the main left bank p.s.
- Extension of canal P-3, and branches P-3/3 and P-3/4, 29,5 km
- Main roads 24 km
- Main drains 26 km
- Secondary canals 45 km
- Land development 4 780 ha
- Industrial rice mills 1 N
- Multi-unit rice mills 4 N
- Extension of livestock feed centre

The 4 780 hectares of the service area include the fourth mechanized farm of 1 340 hectares.

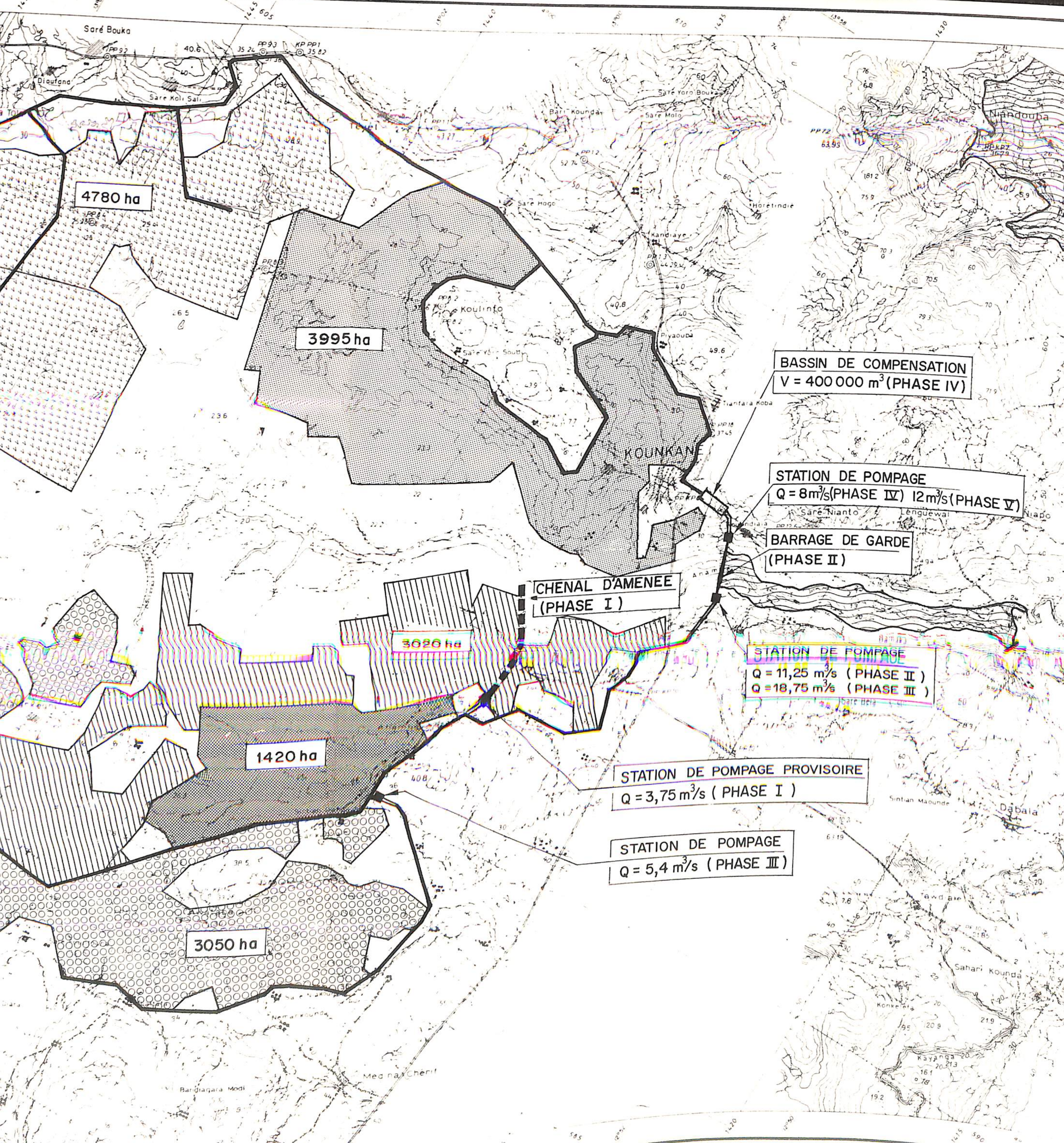
Water management in phase V remains essentially the same as for phase IV. When at some future date, an interconnected distribution system is established in the Upper Casamance, linked to main production and demand centres in other parts of the country and eventually also to neighbouring states, the energy produced at Niandouba dam can be fed into the network and the rules for reservoir operation will be determined by the irrigation water supply function only. This simplifies reservoir operation.

Water management can further be simplified by regulating reservoir releases according to the water level in the Kayanga river just downstream of Niandouba dam. Changes in pumping demand at the two main pumping stations located at the Anambe dam effect changes in the pool level in the Anambe exit channel which are translated hydraulically to Niandouba dam. These level variations will be controlled within predetermined limits by automatic opening and closing of the gated intake at the dam. This hydraulic transfer of information regarding demand changes will then replace the electric signals which were previously used to control reservoir releases on the basis of flows and levels at the head of the distribution systems. Figure 3-3 shows the system at full development in diagrammatic form.

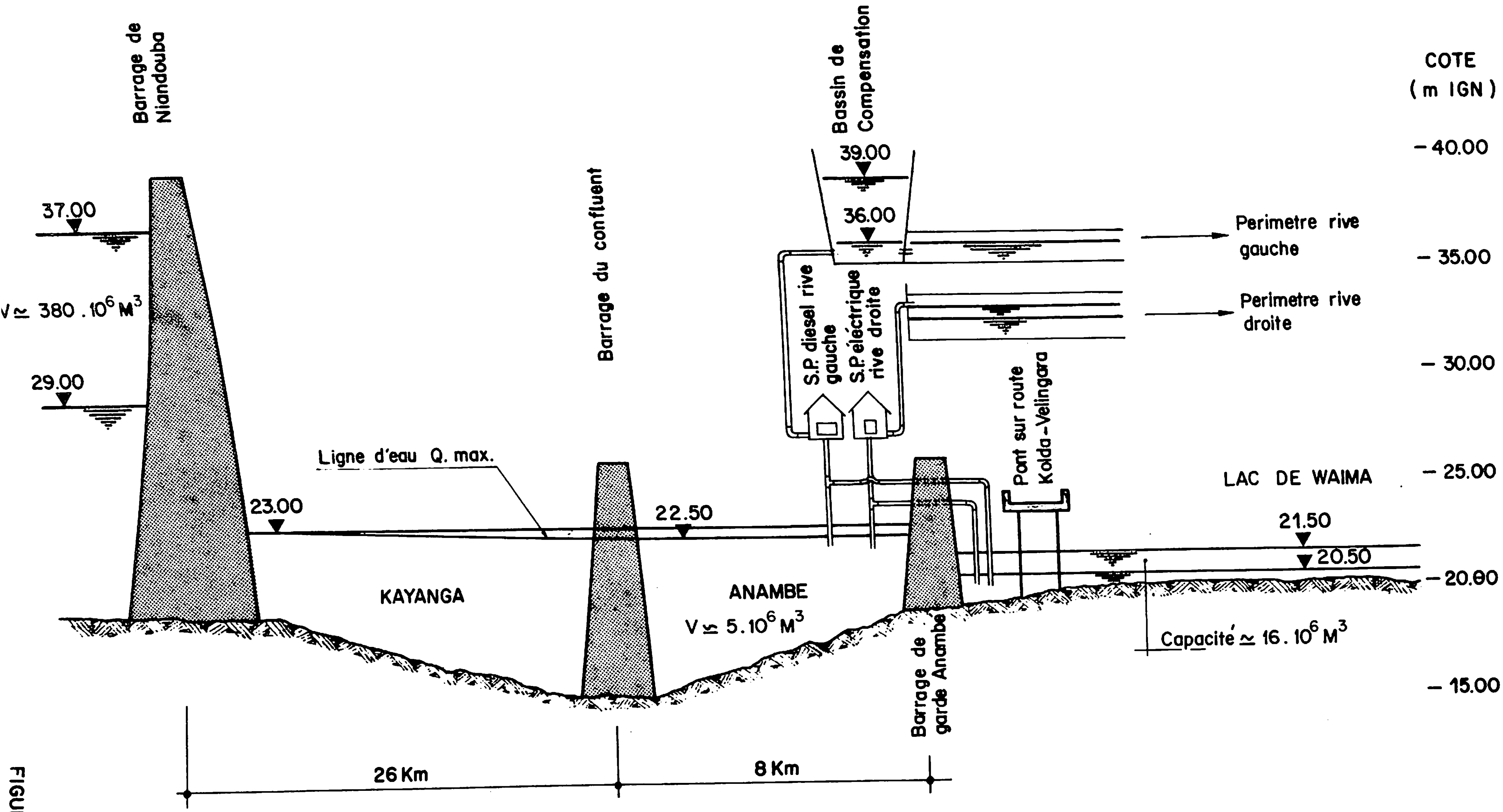


CROPPING PATTERNS

FIGURE 3-1

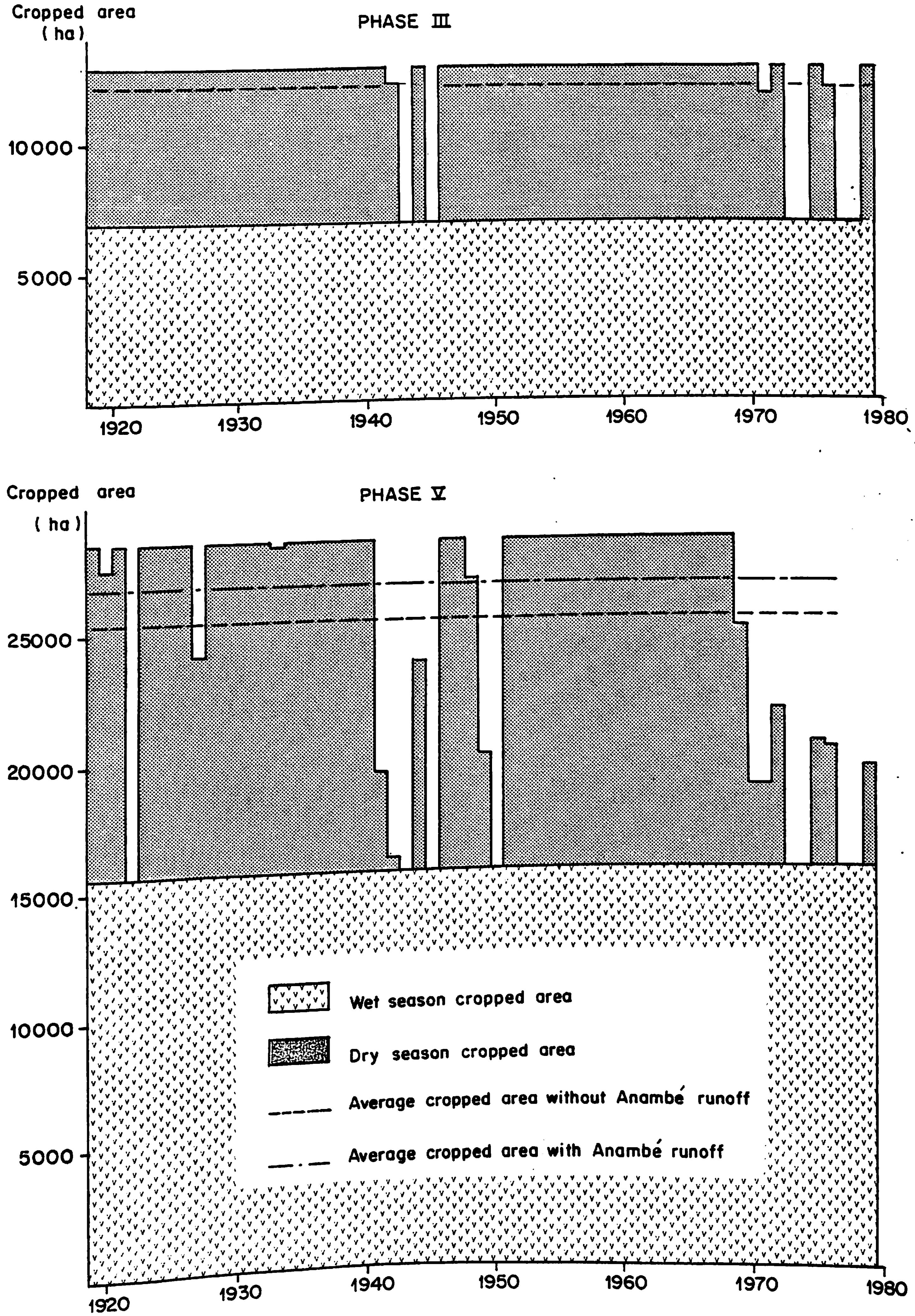

4780 ha
3995 ha
3020 ha
1420 ha
3050 ha
BASSIN DE COMPENSATION
V = 400 000 m³ (PHASE IV)
STATION DE POMPAGE
Q = 8m³/s(PHASE IV) 12m³/s(PHASE V)
BARRAGE DE GARDE
(PHASE II)
CHENAL D'AMENEE
(PHASE I)
STATION DE POMPAGE
Q = 11,25 m³/s (PHASE II)
Q = 18,75 m³/s (PHASE III)
STATION DE POMPAGE PROVISOIRE
Q = 3,75 m³/s (PHASE I)
STATION DE POMPAGE
Q = 5,4 m³/s (PHASE III)
KOUNKANE
Saré Bouka
Diaufana
Saré Koli Sali
Niandouba
Koulinto
Kandiaye
Piyaoupa
Dabala
Sahari Kounda
Kayanga
Medina Chérif
Bandiagara Modi
Sintian Maounde
Saré Nianto
Lenguewal

SCHEMA DES OUVRAGES D'ALIMENTATION DU PERIMETRE
(PHASE V)



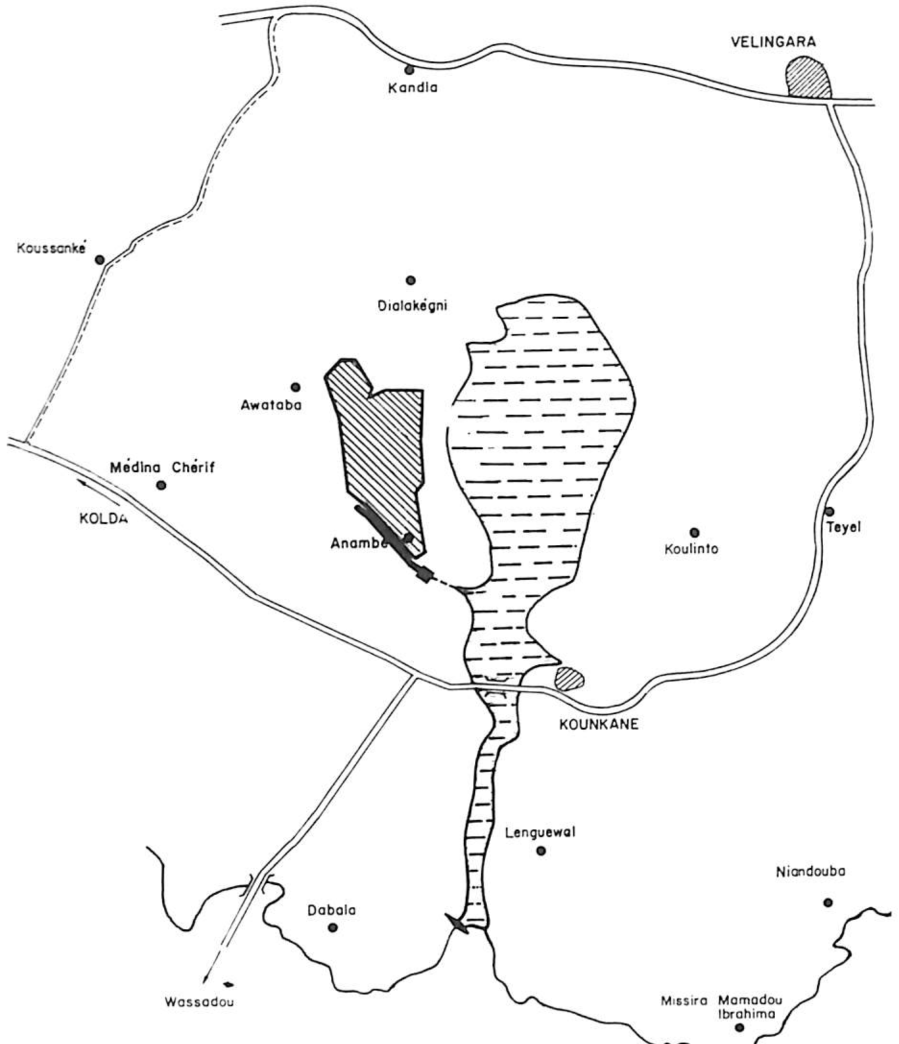
WATER DELIVERY SCHEME
(PHASE V)

FIGURE 3 - 3

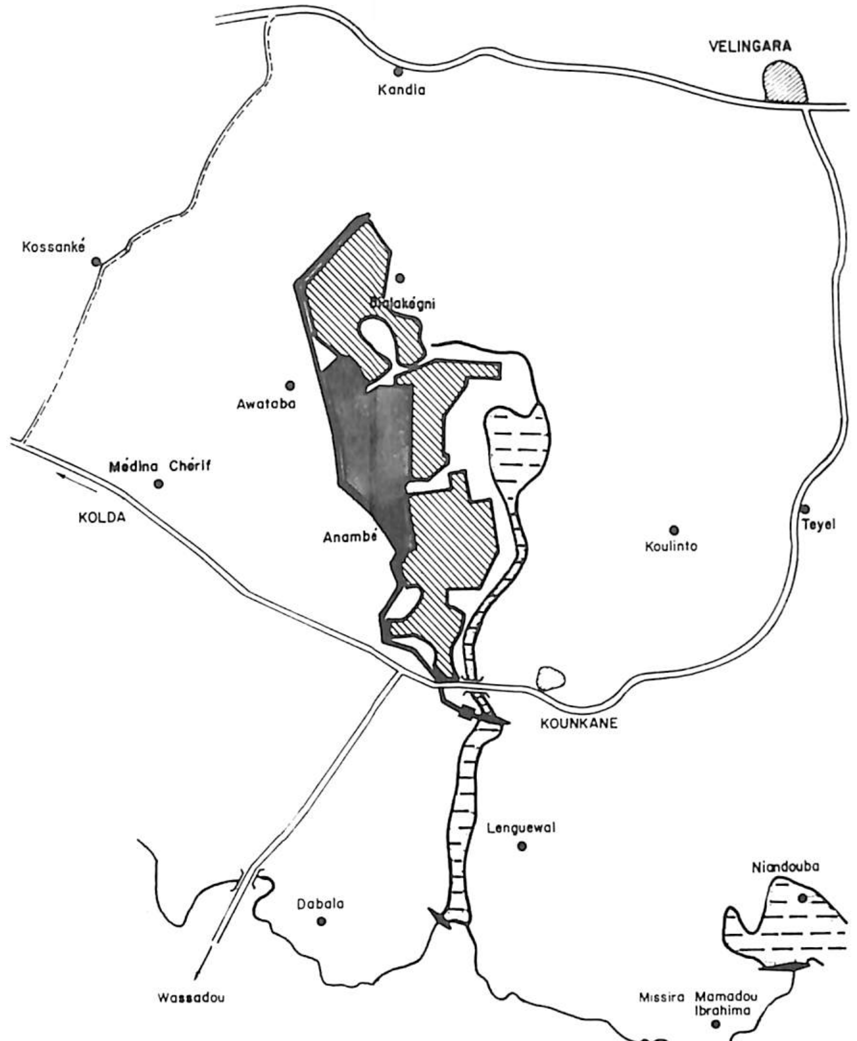


VARIATION IN CROPPED AREA OVER
61 YEAR STREAMFLOW SEQUENCE

FIGURE 3-4

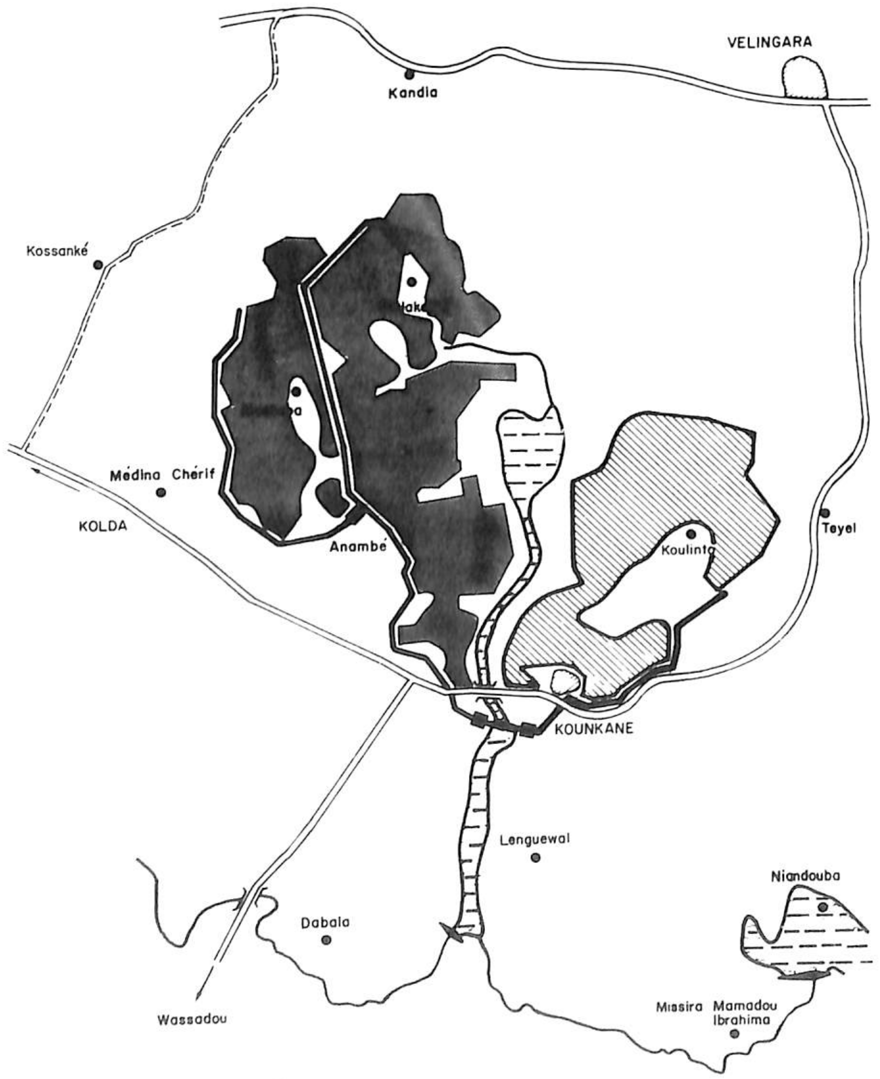


PHASE I

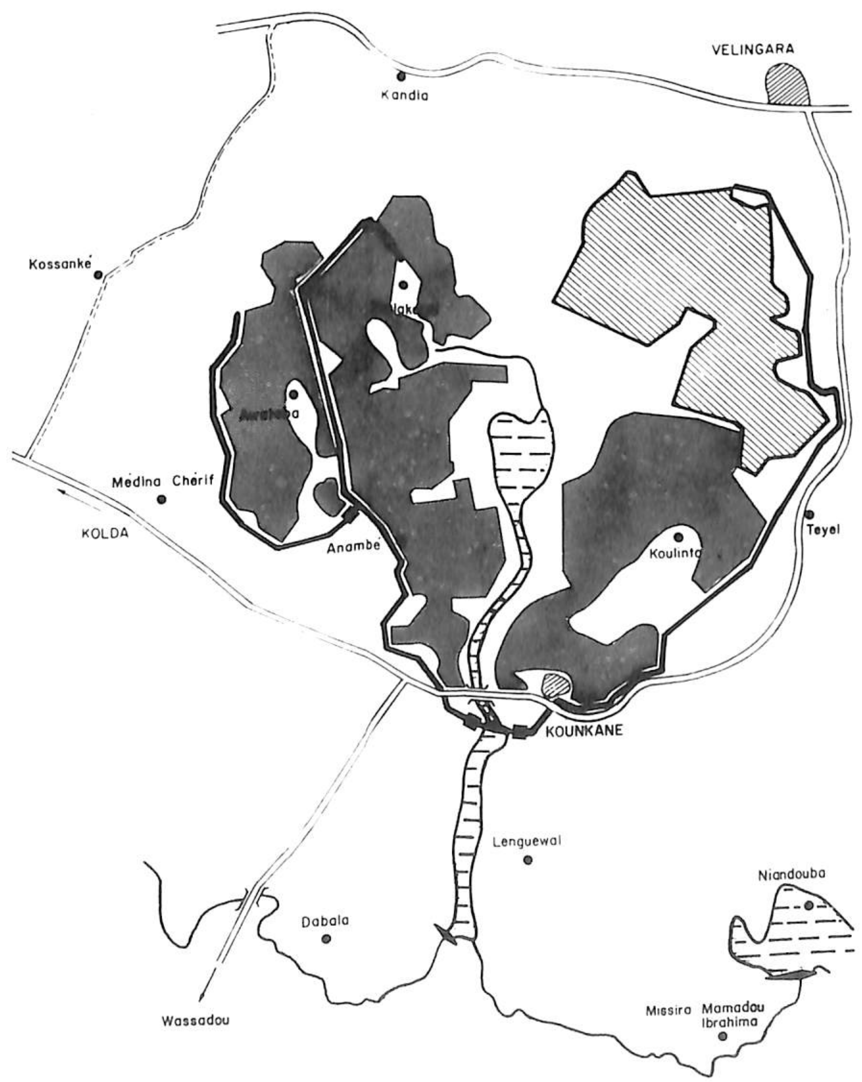


PHASE II

PHASE III



PHASE IV



PHASE V

LEGENDE

ZONE EN AMENAGEMENT

ZONE CULTIVEE

BARRAGE ET RETENUE

STATION DE POMPAGE

CANAL PRINCIPAL

ROUTE OU PISTE PRINCIPAL

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

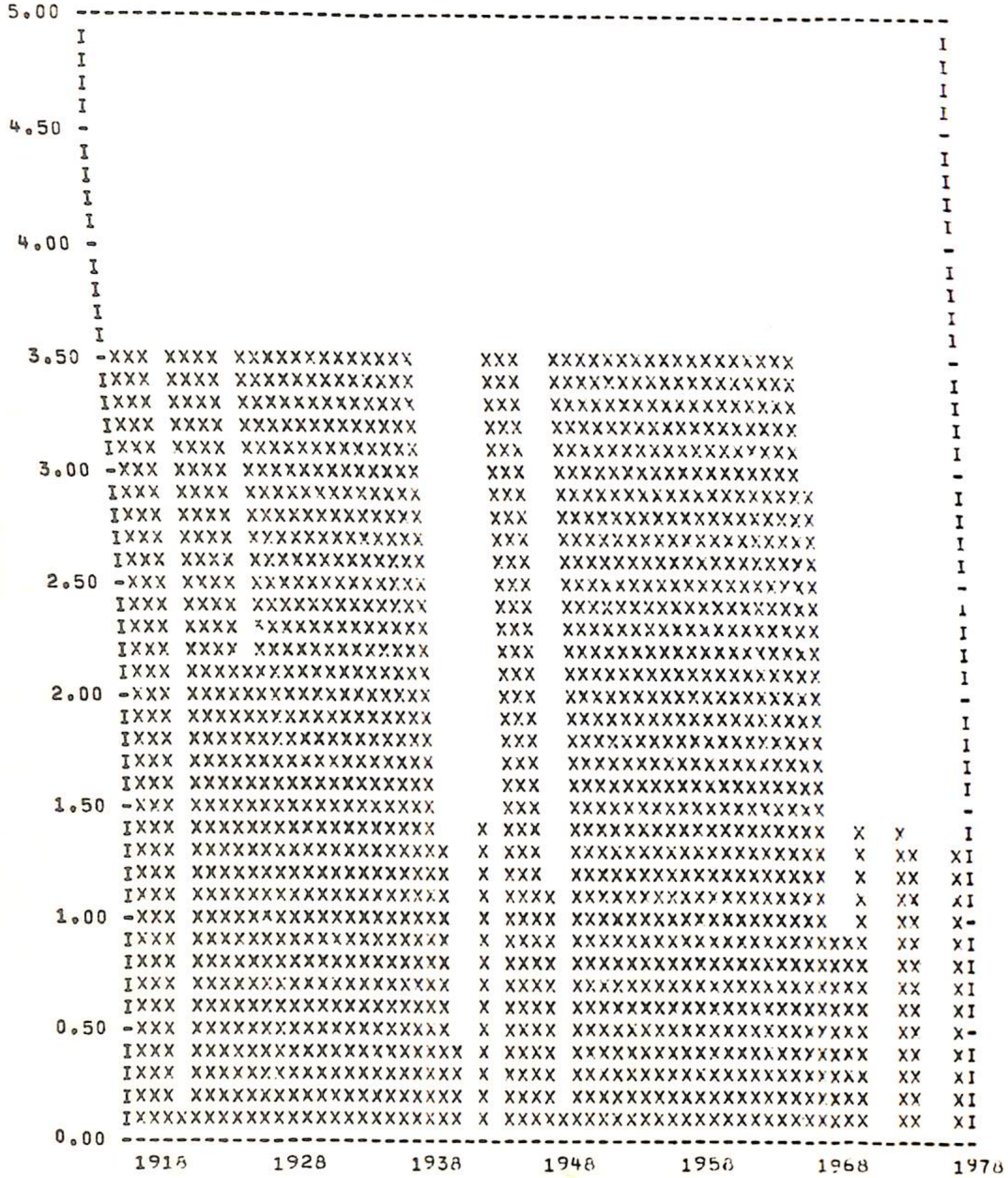
SCHEMA D'AMENAGEMENT PAR PHASE

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS. Niang
CONT.
VISA

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1/140.000	Avril 80	6158 - 214989	3 - 5

Electric energy dry season (GWH)



Diesel energy dry season (GWH)

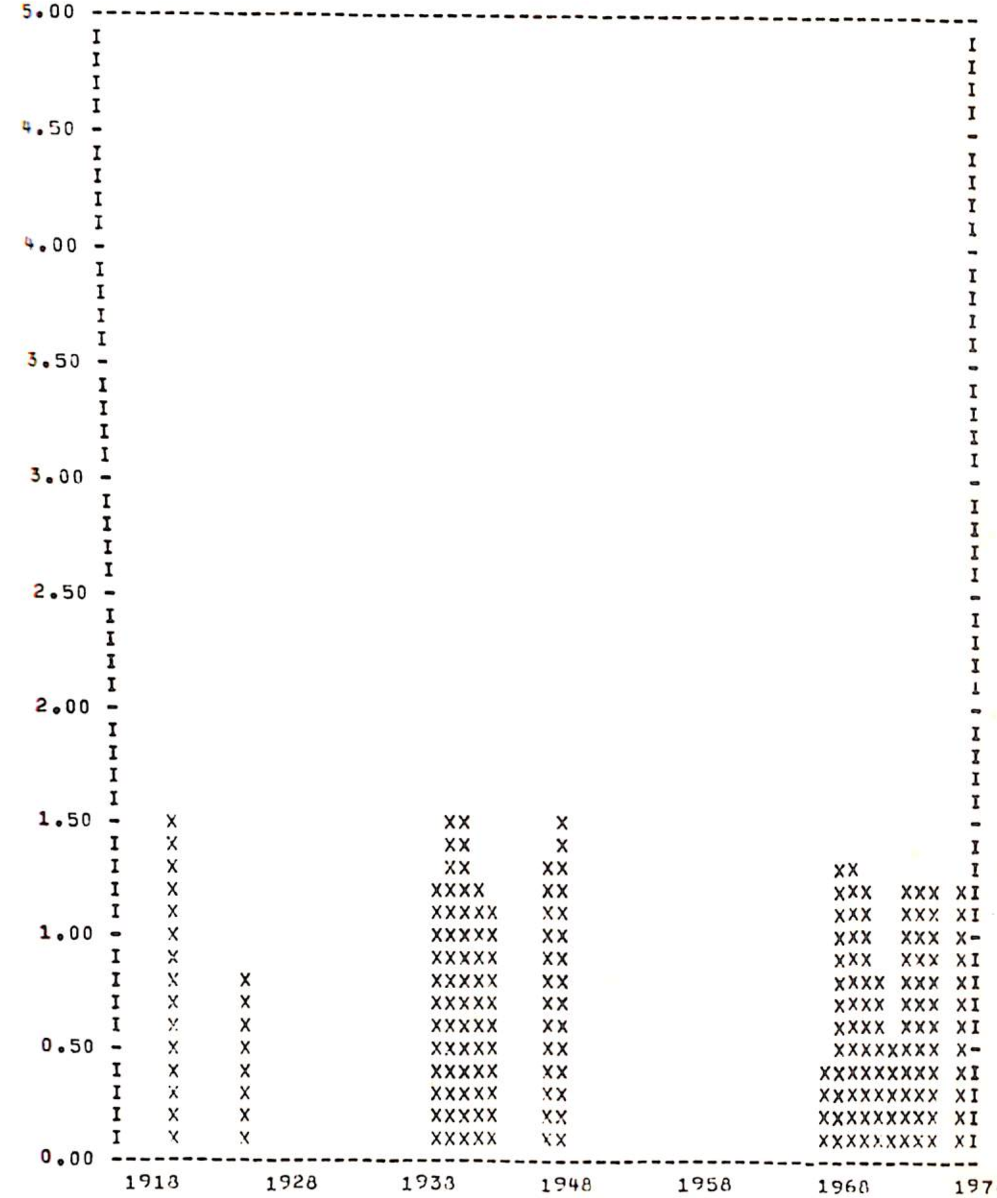
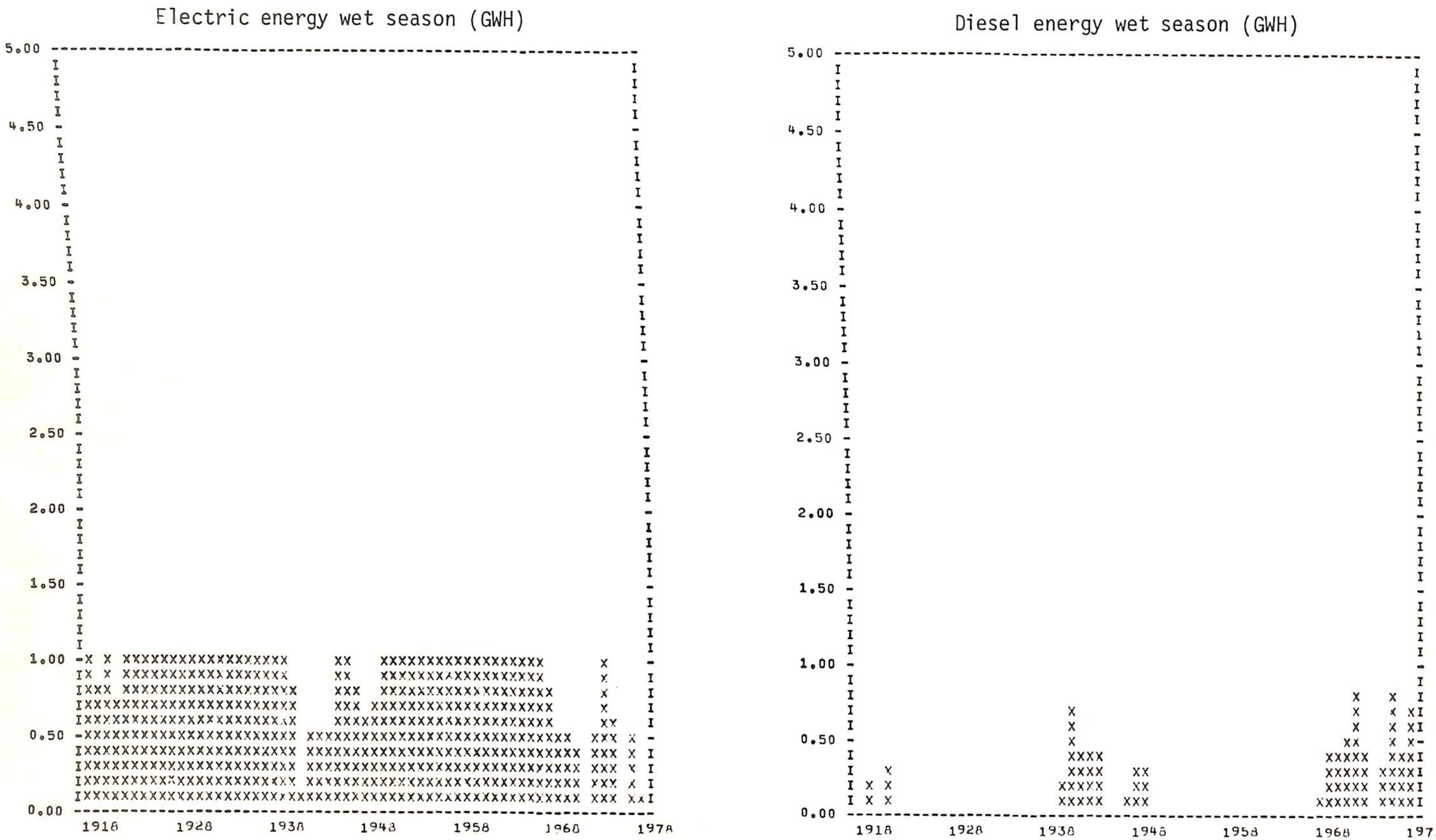


Figure 3-6

MAIN RIGHT BANK PUMPING STATION

ENERGY BALANCE, PHASE III, DRY SEASON



MAIN RIGHT BANK PUMPING STATION

ENERGY BALANCE, PHASE III, WET SEASON

Figure 3-7

4. IRRIGATION WORKS AND FACILITIES

4. IRRIGATION WORKS AND FACILITIES

4.1 Dams and power station

4.1.1 Niandouba dam and power station

Niandouba dam serves to store wet season runoff of the Kayanga river and to release it for irrigation use, both for full dry season irrigation and complementary wet season irrigation. A secondary purpose is the generation of hydro-electricity for supply of the right bank main pumping station.

The dam is located at the natural constriction in the Kayanga valley 2 km south of the village of Niandouba (figure 3-2). At the maximum pool level of 37,0 IGN the dam forms a reservoir with a stored volume of 420 million m^3 and a surface area of 85 km^2, extending upstream for 40 km, almost to the border with the Guinean Republic (figures 2-2 and 4-1).

The left bank of the dam site is formed from a ridge of developed laterite rock which extends almost to the river bank. The valley bottom heavily encumbered with tree growth, is filled with alluvial deposits of fine sands and silts with varying clay content which are lightly consolidated and relatively impermeable. On the right bank the laterite formation is found only above elevation 34,0 IGN.

Both site topography and foundation conditions indicate an earthfill dam. The absence of rock and aggregate material in the local region, and the availability of fine alluvial material in the immediate vicinity of the site, leads to selection of a homogeneous rolled-fill dam with a central chimney drain and upstream and downstream slopes of 1:3 and 1:2 respectively. The upstream face of the dam is protected by a 4 m (measured horizontally) layer of rip-rap, a 2 m gravel drainage layer and a non-woven synthetic membrane acting as a filter. The 2 m wide chimney drain is similarly protected by a synthetic membrane. A layer of lateritic gravel protects the downstream face of the dam. The dam cross section is shown on figure 4-2.

Cost studies were carried out to define the least costly configuration of dam and spillway. The selected solution is shown on figure 4-3. The spillway, located on the left bank, features a fixed overflow section, 100 m long with a duckbill crest profile, capable of passing the design flood of 400 m^3/s for a head over the spillway of 1,5 m. The length of the spillway channel has been shortened by curving the dam axis slightly upstream to the left bank.

The 5 m wide dam crest is at elevation 39,50 IGN - 19 m above existing river bed level - giving a freeboard of 2,5 m above maximum pool level. A line of gabions are added along the upstream side of the crest as an additional safeguard against wave action.

The storage level for power generation varies between a minimum of 29,0 IGN and a maximum of 37,0 IGN giving a live storage capacity of 380 million m^3. Irrigation releases are passed through turbines housed in a power station located at the downstream toe of the dam (figure 4-4). Two turbines develop the head between the reservoir pool and the downstream channel to generate 3,2 MW for a reservoir level of 34,5 IGN and 1,4 MW for 29,0 IGN as required by the main right bank pumping station. Two conduits traverse the dam, one serving as the bottom outlet, the other as power penstock. Operation of the conduits is commanded from a common intake tower set into the upstream face of the dam and reached by a walkway. A common tailrace channel discharges into the Kayanga river downstream.

The main features of Niandouba dam and power station are as follows :

<u>Reservoir</u>	maximum pool level	37,0 IGN
	minimum pool level for power generation	29,0 IGN
	minimum pool level for irrigation releases	26,0 IGN
	live storage between 29,0 and 38,0 IGN	380 $10^6 m^3$
<u>Dam</u>	crest elevation	39,5 IGN
	crest length	1 705 m
	maximum dam height	19 m
	embankment volume	587 400 m^3

Spillway	discharge capacity for 1,5 m head (elevation 38,5 IGN)	400 m^3/s
Bottom outlet	discharge capacity at minimum reservoir level	20 m^3/s
	sector gate dimensions	2,10 X 1,90 m
Power house	rated capacity	3,2 MW
	rated discharge	17,5 m^3/s
	capacity at minimum pool level	1,4 MW
	discharge at minimum pool level	17,5 m^3/s
Transmission line	length	20 km
	voltage	30 KV

4.1.2 Confluence dam

The confluence dam serves to divert the controlled releases from Niandouba dam to the two main pumping stations located on either side of the Anambé river 2-3 km south of Kounkané. During the first phase of development before construction of Niandouba dam, the confluence dam also serves to store Kayanga and Anambé runoff by creating a reservoir in the Anambé Basin and its exit channel with a live storage capacity of 48 million m^3.

The dam is sited 300 m downstream of the Anambé - Kayanga confluence. Here the Kayanga flows at the foot of a relatively steep hill on its right bank, formed by a spur of laterite rock. The left bank forms a plain rising in elevation from 22,0 IGN to 24,0 IGN underlain by lightly consolidated fine sandy and silty alluvial sediments, with varying proportions of the clay fraction. The general layout is shown in figure 4-5.

The topography, geology and availability of construction materials indicate a homogeneous earthfill dam. Both upstream and downstream faces slope at 1:3 and are protected by a 2,0 m layer of lateritic gravel. Additional rip-rap protection is provided on the upstream face below 24,0 IGN.

Spillway	discharge capacity for 1,5 m head (elevation 38,5 IGN)	400 m^3/s
Bottom outlet	discharge capacity at minimum reservoir level	20 m^3/s
	sector gate dimensions	2,10 X 1,90 m
Power house	rated capacity	3,2 MW
	rated discharge	17,5 m^3/s
	capacity at minimum pool level	1,4 MW
	discharge at minimum pool level	17,5 m^3/s
Transmission line	length	20 km
	voltage	30 KV

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Maximum pool level during the first phase of development is at elevation 22,3 IGN, increasing to 23,0 IGN after construction of Niandouba dam. These levels will be controlled with the help of a regulating weir which has an unlined approach channel and a concrete overflow section with a sill at maximum upstream pool level. The passage of floods is assured by a 200 m long spillway designed as a broad-crested weir formed from gabions. The spillway crest elevation is at 22,6 IGN during the first phase, subsequently being raised to 23,6 IGN. An earth embankment will contain the pool on the left bank.

The bottom outlet is controlled by an intake set into the upstream face of the dam housing a 2,0 m X 3,0 m sluice gate. A steel pipe provided with a control gate by-passes the bottom outlet and serves to carry the compensation releases to the Kayanga river downstream of the dam. The concrete bottom outlet traversing the dam discharges into a stilling basin.

The main features of the confluence dam are as follows :

Dam	crest elevation	26,0 IGN	
	crest length	210,0 m	
	maximum dam height	11 m	
	embankment volume	34 000 m^3	
Bottom outlet	discharge capacity under 3 m head		35 m^3/s
Spillway		Phase I	Phase II-V
	regulating weir crest el.	22,3 IGN	23,0 IGN
	flood spillway crest el.	22,6 IGN	23,6 IGN
	design discharge	510 m^3/s	510 m^3/s
	flood peak level	23,8 IGN	24,8 IGN

4.1.3 Anambé flood protection dam

The Anambé flood protection dam serves to protect the Basin against flooding from the Kayanga river at high stages. It also serves other times to control the movement of water into and out of the Anambé floodplain, supported in this role by the two pumping stations located at either extremity of the dam.

The dam is located 1,2 km south of the bridge carrying the N6 over the Anambé river. Selection of the alignment was based on two considerations - proximity to the irrigation service area and local topography influencing fill volume. The alluvial fine sands and silts, with varying clay content, on which the dam is founded are relatively impermeable and very suitable for construction of a homogeneous earthfill dam with the same cross section as that of the confluence dam.

The dam crest, at elevation 26,0 IGN, features a 100 m long emergency spillway in the central section designed to withstand overtopping and with its crest at 25,0 IGN. The spillway would only function in the case of an extreme flood in the Anambé Basin.

The general layout of the flood protection dam is shown in figure 4-6. Its main features are as follows :

crest elevation	26,0 IGN
maximum pool level on Kayanga side	23,0 IGN
peak flood level in Kayanga	25,0 IGN
maximum pool level on Anambé side	21,5 IGN
crest length	1 600 m
dam height	8 m
embankment volume	173 600 m^3

4.2 Pumping stations

Three pumping stations will be in operation at full development. The right and left bank irrigation perimeters are served independently by main pumping stations located respectively on the west and east extremities of the Anambé flood protection dam (see figure 4-6). The third pumping station, termed the auxiliary pumping station, is located south of Awataba on the main right bank irrigation canal (figure 3-2). It serves an area of 2 255 ha via the P-2 high level main canal.

The permanent pumping stations are a key element in the irrigation distribution system and their equipment has therefore been designed to be simple, reliable and robust. All have gravity intakes, and water levels in the supply channel above the pump impeller. Vertically mounted centrifugal pumps are driven either by electric or diesel motors according to the particular station. Electric motors are mounted on a floor at ground level and transmit energy to the pumps, housed at cellar floor level, via a vertical shaft. The same general configuration is maintained for diesel driven pumps except that the diesel motor must be horizontally mounted and therefore drives the pump through a gearbox and right angle drive gear.

Right and left bank main pumping stations can withdraw pooled water from either the Anambé or Kayanga sides of the flood protection dam via excavated approach channels and a bifurcated intake (figure 4-6) provided with trash screens and slide gates. Manipulation of the latter enables withdrawal of water by pumping from either side of the dam or alternatively the transfer of water by gravity from one side of the dam to the other. In the pumping mode, water may be pumped either into the irrigation network or else across the dam for drainage of the Anambé Basin toward the Kayanga River.

The pumping station building consists of a watertight reinforced concrete caisson foundation and a superstructure with a reinforced concrete frame and masonry infill. The superstructure houses the motors, electromechanical equipment, control panels, workshop/parts store, and offices. A travelling crane is provided for maintenance and replacement of heavy equipment.

The pipelines linking the pumping stations to the outlet works into the irrigation canal network are constructed of reinforced concrete and will be buried.

Operation of the pumps is regulated automatically according to level variation in either the first canal reach or the regulating reservoir.

Figure 4-7 shows the layout of the main right bank pumping station.

The three permanent pumping stations to which the above descriptions apply will be constructed and equipped during Phases II to V. During Phase I the irrigation perimeter will be temporarily supplied by a diesel driven pumping station situated between the villages of Soutouré and Anambé. An excavated approach channel will lead water to the pumping station from the reservoir in the Anambé central floodplain. The pumping station (figure 4-8) has two diesel groups of 3,75 m^3/s combined capacity. It delivers water via a 400 m penstock, 1 800 mm in diameter. The pump groups, fuel tank and penstock will be dismantled during construction of the Phase II works, the pumps and motors being rehoused in the main right bank pumping station where they will serve as a reserve group and the penstock being reutilized for the auxiliary pumping station to be constructed in Phase III. During its period of service the station will be manually controlled, operating according to a pre-determined schedule.

The main right bank pumping station will deliver a supply of 11,25 m^3/s to 4 440 ha in Phase II by means of three electrically driven pump groups. The number of groups is increased to five in Phase III, delivering 18,75 m^3/s to the 7 490 ha of the right bank irrigation perimeter. The station obtains its energy supply via a 20 km long 30 KV power line from the power house at Niandouba dam. The diesel groups transferred from the Phase I pumping station act as reserve in case of insufficient hydroenergy. During the peak of the irrigation season the station will operate about 16 hours each day.

All civil works for the main right bank pumping station will be constructed during Phase II. The layout permits the replacement of one or more electric motors by diesel motors, without major modifications, should this eventually prove necessary as a result of a deficient hydroenergy supply.

The auxiliary pumping station, constructed during Phase III, delivers 5,4 m^3/s to an irrigable area of 2 225 ha. The four pump groups are diesel driven and include one reserve group. The operation of the station is essentially similar to the main right bank pumping station.

The main left bank pumping station serves the Phase IV and V development areas, delivering 12 m^3/s to the 8 775 ha of the left bank perimeter. The four pumpsets include one reserve set and are installed over two phases. The station is designed to pump for 24 hours daily at peak periods, supplying the irrigation system via a regulating reservoir of 400 000 m^3 which serves as a night storage reservoir.

Pumping station characteristics may be summarised as follows :

Station designation	Phase I	Main right bank P.S.	Auxiliary P.S.	Main left bank P.S.
Area served (ha)	1 420	7 490	2 255	8 775
Dynamic head (m)	13	13	10	19
Design discharge (m^3/s)	3,75	18,75	5,4	12,0
Motors	Diesel	Electric	Diesel	Diesel
Installed capacity (kW)	1 800	3 225	1 050	4 500
Number of pumpsets	2	5 (excl.reserve)	4	4
Pipeline diameter (mm)	1 800	2 X 2350	1 800	2 X 1800
Pipeline length (m)	400	600	400	650

4.3 Distribution network

4.3.1 Design concept

The irrigation network serves to distribute irrigation water supplies in the correct amount at the required time and place. It consists of main canals and their branches, secondary canals, tertiary canals and farm ditches.

Main canals in general follow the contour to maintain command. Automatic downstream level control gates divide the main canals into reaches and ensure that water is delivered to the head of the secondary distribution system automatically according to demand.

Secondary canals may be aligned along the contour or down the contour. The area served by a secondary canal is termed an "operational unit". Within this unit the distribution of irrigation supplies both in time and in quantity may be decided autonomously and translated into independent action such as appropriate manipulation of flow control gates. The area served by a secondary canal is generally 300-400 ha for the mechanized farm and 80-250 ha for lands farmed by smallholders. This system has the advantage that whereas during the early years following development control of water delivery will be in the hands of the project authority, at some future time these responsibilities may be delegated to cooperatives or farmer groups based on the operational unit.

Tertiary canals are designed to carry a constant flow which is distributed in turn to each of the 2,5 ha farms forming the tertiary or rotational unit under smallholder farming. For mechanized farms, tertiary canal operation is similar, the tertiary block being appropriately subdivided to permit water delivery in turn to each of the subdivisions. The flow delivered to each smallholder farm is constant, different depths of irrigation at the field being applied by varying the duration of water delivery to the farm-gate. In this way the farmer always handles a constant stream, an essential requirement for efficient irrigation in view of the present lack of experience. This constant flow is termed a flow module. The flow module varies only according to the crop grown in the main irrigation season, whether rice or other cereal crops. For rice the flow module is 40 l/s ; for diversified crops, 30 l/s.

Tertiary canals carry flows of either one or two flow modules according to whether they serve 7 farms of 2,5 ha (one module), 14 farms of 2,5 ha or mechanized tertiary blocks (two modules in both cases). Secondary canals also carry discharges equal to a number of flow modules according to the number of farms and tertiary blocks served. Control of the correct discharge into both secondary and tertiary canals is simplified by the use of constant flow gates at their head. Once open, the discharge of these gates is virtually indifferent to small variations in water level upstream.

Two irrigation methods will be practised : basin and furrow irrigation. Basin irrigation is the technique to be used for both the rice-rice and the rice-diversified cropping patterns. It will therefore be much the more widely practised, these cropping patterns being adopted over all but 710 hectares of the 16 265 hectares to be developed for irrigation. Each basin will be level and bunded. The farmer progressively fills each of his basins either by means of on-farm distribution ditches or by letting water spill from one basin to the next. Under furrow irrigation water will be turned from the farm ditch into the furrows using siphons. Fields will typically be 100 m long the furrows following slopes varying generally from 0,2 % to 1,5 %.

Water rotation within the tertiary block will normally be the responsibility of the group of farmers forming the tertiary unit, though close supervision by trained project authority personnel will be required during the first seasons of operation.

Two standard layouts of the tertiary unit have been adopted, one for small farmers, the other for the mechanized farm. These are shown on figure 4-9.

Under smallholder cultivation water is distributed either to farms lying on both sides of the tertiary canal or on a single side only, the layout depending on the terrain. Each farm is equipped with a gated farm turnout which is either fully open or shut. A farm drain carries excess water to the tertiary drain. A laterite farm road runs along the drain providing all-weather access to each farm. For farms growing diversified crops in both seasons land forming will be limited to grading the land to the natural slope. Elsewhere land levelling will be required for basin irrigation. This wil be accomplished partly with the aid of heavy machinery during land development and partly by the farmers themselves during subsequent seasons.

The mechanized farm units are located on the lower terraces on heavy soils and gently sloping terrain. The fields have a net area of 37,5 ha, forming a tertiary block served by a canal carrying a flow of 80 l/s (2 modules). Seven turnout/division structures are located along the tertiary canal and enable 40 l/s to be withdrawn at each structure, two turnout gates being open during irrigation. The layout of the mechanized farm units is such that at some future date they can be readily subdivided into 14 farms of 2,5 ha each, thereby enabling their transfer to small farmers as the demand arises. A farm road would in this case be added along the centre of the tertiary unit to give access to each farm.

4.3.2 Layout of main distribution network

Two irrigation networks are planned serving the left and right bank perimeters respectively (see figures 4-10 and 4-11) and each supplied independently by a main pumping station. The right bank system will be developed during Phase I to III,the left bank during phases IV and V.

The right bank perimeter covers a net area of 7 490 ha. It is supplied via main canal P-1 which originates at the outlet works for the pipeline delivering water pumped by the main right bank pumping station. The canal carries 18,5 m^3/s at its head and is 23,8 km long. The first reach includes a flow control band which serves to regulate pump operation. At chainage 10,33 a discharge of 5,4 m^3/s is withdrawn from canal P-1 by the auxiliary pumping station to serve the "high level" main canal P-2. Over the first 15,4 km canal P-1 follows the flanks of the plateaux, traversing rather permeable silty sands initially and then the heavier soils lying in the plain between the villages of Awataba and Woloto.

Canal P-2 swings in an arc around the lowlands lying south and west of Awataba which include a high proportion of suitable ricelands. A branch canal originating at chainage 0,5 serves an area of lighter soils on the lower slopes of the plateaux, where irrigated diversified crops are planned on land already partly under cultivation. The higher level canal P-2 serves an area of 2 225 ha.

The left bank covers a net area of 8 775 ha. It is supplied by main canal P-3 which originates at the regulating reservoir. Over its length of 28,7 km canal P-3 feeds four branch canals, originating at chainages 6,68, 8,90, 20,88 and 24,80. These in turn serve irrigable areas of 1 805 ha, 1 580 ha, 1 185 ha and 1 750 ha. Over the major part of its length canal P-3 crosses permeable sandy soils.

4.3.3 Description of works

Canals (figure 4-12)

Main canals including branch main canals will be concrete lined and divided into reaches 3-4 km long in which level, and thereby flow, will be regulated automatically by hydraulically actuated constant downstream level gates. Wherever possible level control gates will be located immediately upstream of a secondary canal intake.

The selection of concrete lining for main canals is based on technical, economic and operational considerations. Cost comparison between concrete lined and unlined canals (report 11, annex 7) shows that cost differences are small. The lower initial investment cost of an unlined canal is almost entirely offset by costs due to substantially higher maintenance and pumping requirements, a longer canal route and greater seepage losses. In effect, to obtain command over lands at the tail of the main canal the unlined canal must start at higher elevation, thereby placing the canal in less favourable terrain from both route length and seepage aspects, as well as involving higher pumping costs. From an operational viewpoint, supply of the secondary canals within the required level tolerance is simpler to ensure with a lined main canal.

Secondary and tertiary canals will be unlined. To ensure proper compaction they will be constructed by first placing and compacting selected fill in the form of a trapezoidal embankment and then excavating the canal section within the compacted embankment.

Secondary offtakes from main canals are equipped with constant flow gates. Water distribution from the head of the secondary canals is of the "upstream control" type, water being allocated within the operational unit according to a predetermined schedule. Tertiary offtakes are also equipped with constant flow gates, the required level tolerance in the secondary canal being assured by the use of duckbill or diagonal weirs. These accommodate fluctuations in canal discharge for only minor variations in level. Tail escapes are provided at the end of each secondary canal. Drop structures will be provided as required by local topography, being located generally at intake structures and farm turnouts.

Roads

The road network provided will include main roads, secondary farm roads and service roads.

Main roads (figure 5-1) are 11 m wide with a 7 m wide laterite pavement and 2 m wide shoulders. They generally follow main or branch canals. A total length of 45 km on the right bank and 48 km on the left bank will be provided to carry a relatively dense traffic of farm machinery, trucks and other vehicles.

Main canals are provided with a service road restricted to use by project personnel. This is located on one bank and is 6 m wide with a 4 m laterite pavement. A 4 m wide road is provided on the opposite bank for canal maintenance.

Secondary roads follow secondary canals and drains and have a 4 m wide pavement and 50 m shoulders. Tertiary or farm roads are 4 m wide also with a laterite bearing surface. They run along tertiary drains. For the mechanized farm tertiary roads are omitted.

Corridors have been provided along main drains to allow cattle access to pasture in the central floodplain. They are generally 75 m wide.

Miscellaneous structures

Various other canal structures will be required including road and foot bridges, culverts and watering points for cattle.

4.3.4 Gross to net area conversion

Gross irrigable areas have been converted to net areas by making the reductions in the following table :

Table 4-1 CONVERSION OF GROSS TO NET IRRIGABLE AREA

	Smallholder lands	Mechanized farm
Tertiary and farm level canals, drains, roads, etc	10 %	5 %
Secondary canals, roads and drains	3 %	2,5 %
Land presently considered suitable but proving unsuitable when more detailed information available	2,5 %	2,5 %
Total	15 %	10 %

4.4 Drainage

4.4.1 Introduction

The central floodplain is presently subject to inundation during flood stages of the Kayanga River and from runoff from surrounding lands. Low gradients and slowly permeable strata result in slow surface and subsurface drainage. Evacuation by the Anambé River of runoff accumulating in the central floodplain is impeded by flat natural channel gradients and low ridges in the streambed which form a natural obstruction, creating a lake in the floodplain at the end of the wet season which gradually dries out during the dry season.

Drainage works will be designed to serve the following ends :

- to collect surface runoff originating outside the irrigation perimeter and to carry this flow through the irrigated lands to discharge into the central floodplain.

- to ensure removal of excess rainfall from cultivated lands within the irrigation perimeter, both ricelands and diversified crop lands

- to ensure an aerated root zone for diversified croplands

- to remove runoff accumulated in the control floodplain to the Kayanga river when levels exceed those which can be permitted.

4.4.2 Protection from external runoff

The alluvial terraces are presently subject to flooding due to the lack of well defined drainage channels. During the wet season runoff from higher lands fills local depressions and exceeds the capacities of natural drainage ways so that water moves across the land in the form of sheet flow.

This runoff will be intercepted by collector drains located above the main canals and guided into main drains traversing the irrigation perimeters. Main drains, often following natural drainage paths, will be excavated to a depth and section permitting the design flows from a 10 year storm to be confined within the drainage channel.

4.4.3 Drainage of irrigated lands

Ricelands have only a surface drainage requirement, drains providing for emptying of the paddies during the growing season when required and removal of excess water from storm rainfall so as to avoid damage to the crop.

A drainage modulus of 4,5 l/s/ha has been adopted for design of the secondary and tertiary drainage network. This permits removal of excess rainfall from ricelands in 4 days following a 1 in 5 year storm. The same modulus has been adopted for diversified croplands, resulting in some temporary ponding of excess runoff on the lower part of the fields. Crop damage would be infrequent and slight.

4.4.4 Drainage of central floodplain

Project implementation will influence Anambé runoff as described in paragraph 3.6.6. Natural removal of runoff to the Kayanga will be facilitated by reduced Kayanga discharges and the greater discharge capacity of the Anambé channel.

These changes will result in greater runoff volumes from the Anambé Basin, in runoff from rainfall reaching the central floodplain earlier in the wet season, and in a more evenly distributed runoff. All of these changes increase the volume of Anambé runoff which can be used for irrigation, mainly as a supplementary wet season supply. The useful storage capacity of the central floodplain is between 15 and 20 million m^3.

The way the drainage system is operated will vary, depending on the amount of wet season runoff both in the Kayanga and Anambé rivers. Wet season operation for dry, average and wet years is described in the following paragraphs.

In a dry year there will be little runoff from the Anambé Basin. To ensure supplementary irrigation requirements, the pool level of 23,00 m will be maintained until October in the Anambé exit channel by releases from Niandouba dam. Such runoff as accumulates in the Anambé central floodplain will either evaporate or could be used as required for additional irrigation supplies.

In an average year, pool level will be maintained in the Anambé exit channel until the central floodplain filled to about 21 m. The water in the exit channel will then be drawn down, initially by passing water into the Anambé Basin via the intakes at each pump station, and thereafter by opening the confluence dam sluice valve. The Anambé central floodplain (Waïma lake) will then provide the necessary reserve. The timing of this operation will vary, but will typically take place in August after full project development. If maximum storage levels in the Anambé central floodplain are exceeded then water will be released to the Kayanga through the gates at the pumping station intakes. At the end of the wet season, Anambé runoff may continue to be stored or may be released gradually to maintain flows in the Kayanga River.

In a wet year the pool level maintained in the Anambé exit channel will be drawn down early in the wet season. Excess water accumulating in the Anambé

Basin will be drained by gravity to the Kayanga. In exceptionally wet years the combination of higher Anambé runoff and spills from the Kayanga reservoir will cause the maximum storage level in Waīma lake to be exceeded. For a runoff occuring once in 20 years levels will rise to about 22 m for about ten days, a degree of flooding which can be to tolerated without significant loss of yield. In more extreme years the pumps will be used to maintain Anambé reservoir levels within tolerable limits(see figure 4 - 13).

4.5 Land development

About 13 percent of the area to be irrigated is presently under cultivation. The 16 400 ha of wooded savanna to be cleared represent a substantial resource which may be exploited for fuel wood, charcoal and quality timber (cf report 7). Land clearance will be carefully planned so as to obtain the maximum benefit from the wood removed. It is assumed herein that local contractors will remove most of the standing timber either in the form of charcoal (90 percent) or as quality timber (10 percent). They would pay a tax based on the amount removed.

Following primary clearance by local contractors, the main contractor will carry out destumping and derooting, piling, land grading and levelling and disc harrowing. This will be followed by burning and reworking with bulldozer and disc harrow. Hourly land clearance rates with D8 buldozers or equivalent are estimated at 6 hours per ha if the primary clearing is carried out together with secondary operations, or at 4 hours per ha if primary clearing is excluded.

The above procedure for land clearance should be reviewed after the Phase I area has been developed and after discussion with contractors and forestry authorities.

Following the operations described, further passes with a crawler tractor and disc harrow will be required to loosen the soil for the first three crops on heavy rice soils and the first crop in other areas. During this period of soil preparation the project authority will be responsible for farming smallholder lands, a mechanized production division being formed for this task. Thereafter they will be cultivated by wheeled tractors or oxen-drawn equipment by either the mechanized farm or small farmers.

On-farm development will follow rough grading and levelling under the main contract. The small farmer will be left to devise, with the help of project officials, the best means of providing irrigation water from his head ditch to each corner of his plot. This will involve creation of smaller basins including bunds and minor land levelling. Such works will be spread out over the first few seasons.

4.6 Buildings

Buildings to be constructed for the project include houses for senior personnel, living quarters for junior personnel, offices, workshops and stores.

The business department of the project authority (SODAGRI) and the Director General will be based in Vēlingara,where SODAGRI will have its registered offices after transfer from Dakar. Office space of 200 m^2 will be required following development of Phase II. The operational headquarters will be located near the pilot farm between Anambé and Awataba (figure 5 - 1) and will provide offices for staff of the engineering,mechanized farm and agri-culture/extension departments. The building will have an area of 200 m^2 at Phase I, being subsequently enlarged to 475 m^2 and 675 m^2 respectively in phases II and IV.

Office space will also be provided at the headquarters of the cooperative unions (see section 7.8). An area of 100 m^2 per building will be required. A further 40 m^2 is provided at each mechanized farm unit headquarters.

Central workshops are located at project headquarters for major repairs of farm machinery. The workshops will serve the mechanized farm,production division, operation and maintenance division and mechanization section of the project authority as well as service vehicles assigned to project personnel. A total area of 1 200 m^2 will be provided at full development. Each mechanized farm division will also be provided with service and repair workshops of 300 m^2 area at the division headquarters.

Storage of 200 m^2 will be provided at cooperative union headquarters and 400 m^2 at mechanized farm divisional headquarters for all seasonal agricultural inputs. A further storage area of 500 m^2 is provided at the project authority operational HQ for equipment, spare parts and lubricants.

A total of 64 hard furnished houses will be provided for senior project staff, including mechanized farm division personnel. Junior personnel will be housed in apartment blocks. A total of 100 apartment units will be required, including hard furnishings.

Tonguia
Koundiama
Maloyel
Bantan Kountou
Patim Kouta Pakane
Pakane
Kodionté
Mayel Lesso
Pourega
Saré Diaobé
Sahatou
Paroumba
Daharatou
Kayanga
LEGENDE
Surfaces cultivées
Limite de l'influence directe du rése
(définie par la cote maximale pend
une crue centennale)
REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI
AMENAGEMENT DU BASSIN DE L'AN
LA REGION DU RESERVOIR
ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR
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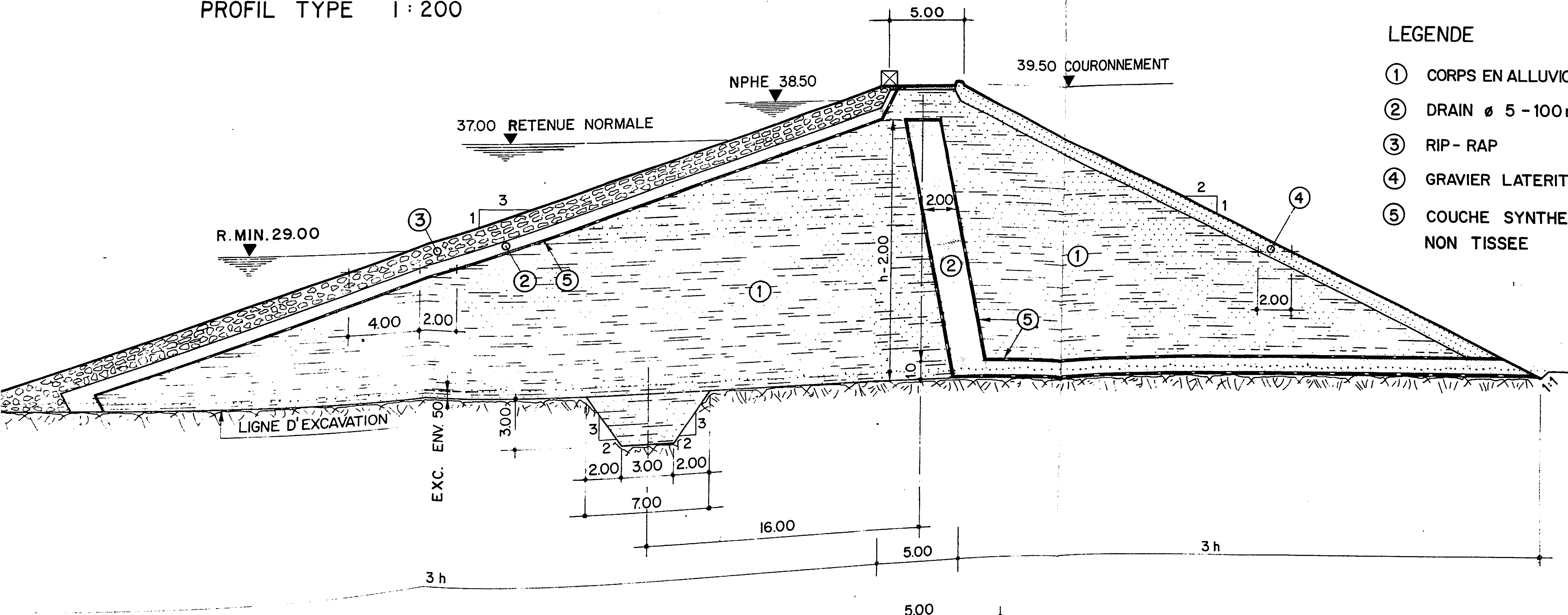

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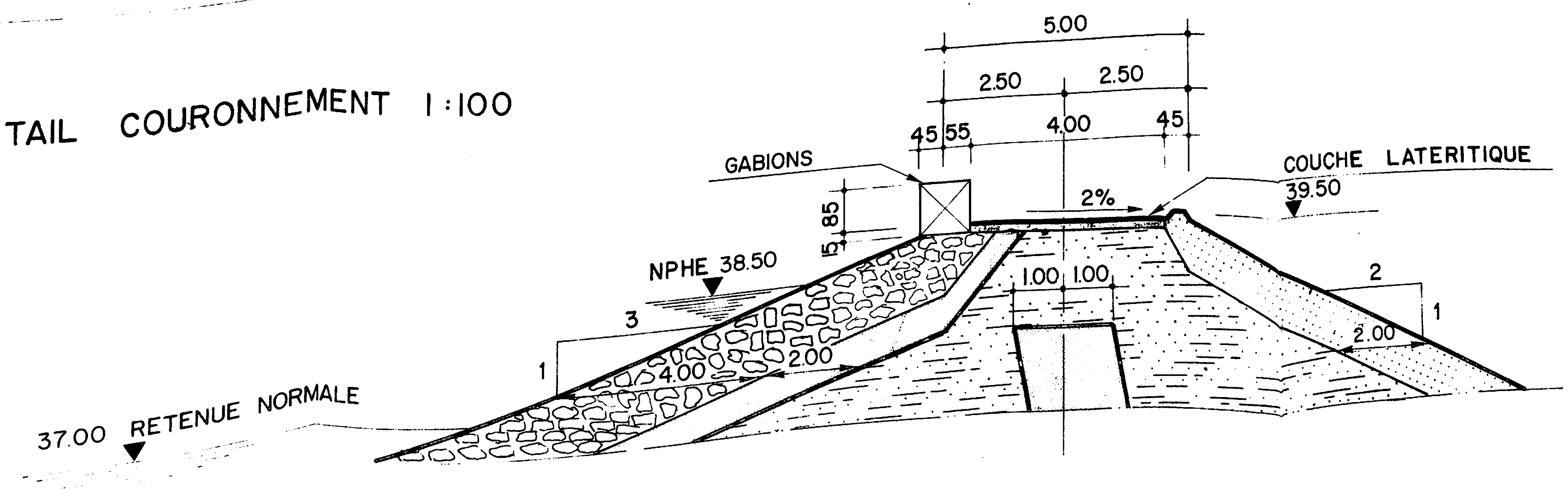
4. GRAVIER LATERITIQUE
5. COUCHE SYNTHETIQUE NON TISSEE

DETAIL COURONNEMENT 1 : 100



REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAM

BARRAGE DE NIANDOUBA
PROFIL TYPE
ET DETAIL COURONNEMENT

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

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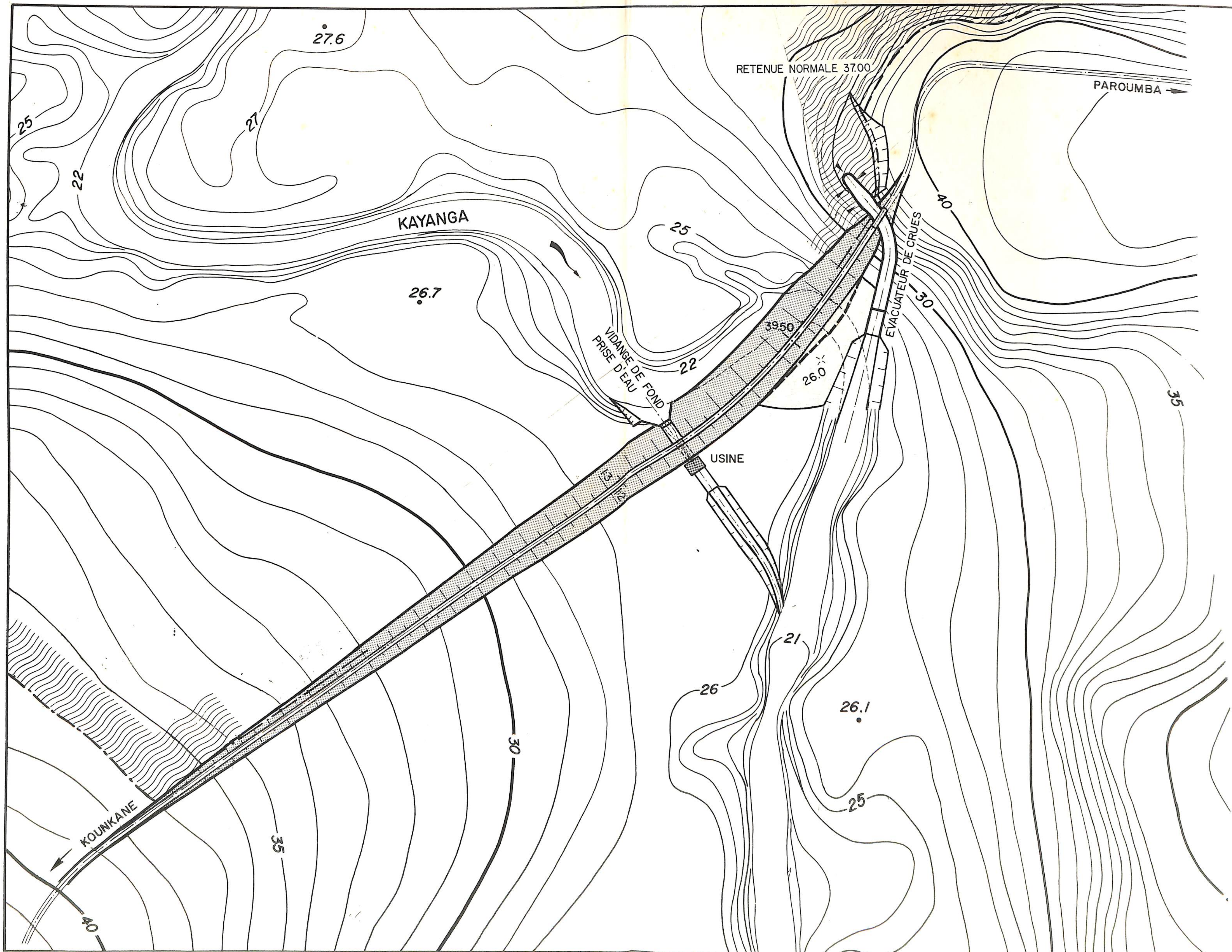
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PRISE D'EAU
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USINE
21
26
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30
25
35
KOUNKANE
40

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

BARRAGE DE NIANDOUBA

SITUATION DES OUVRAGES

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ZURICH - DAKAR

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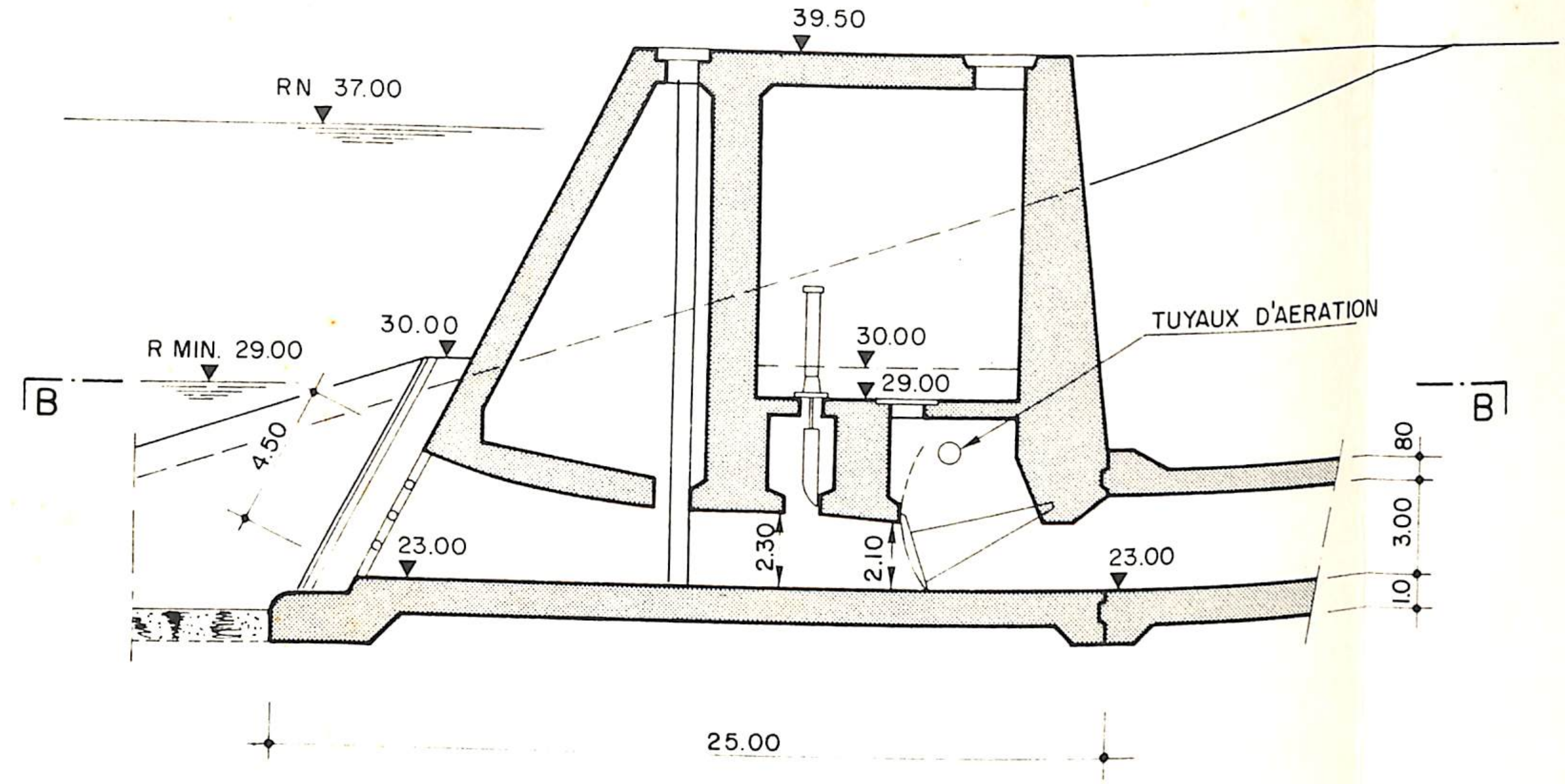
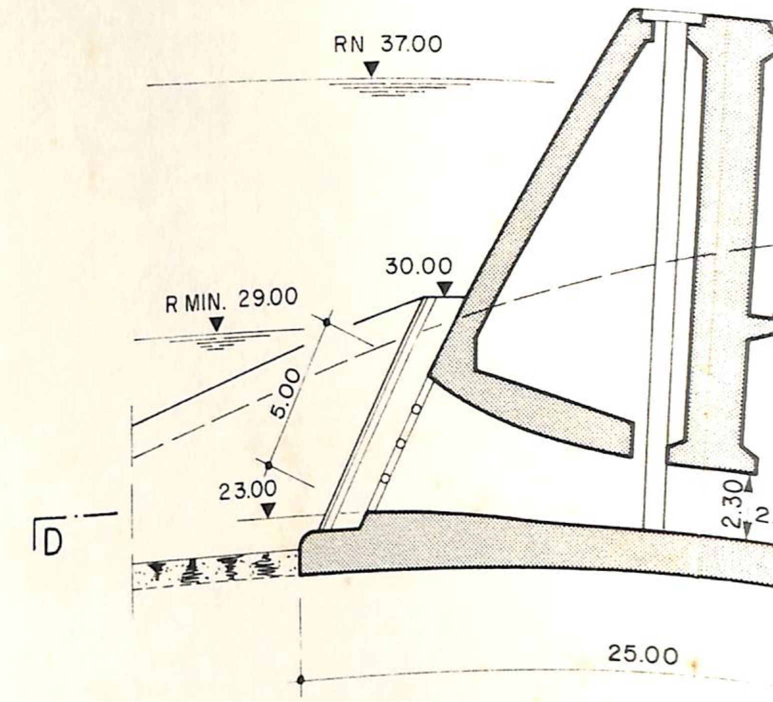
COUPE A-A





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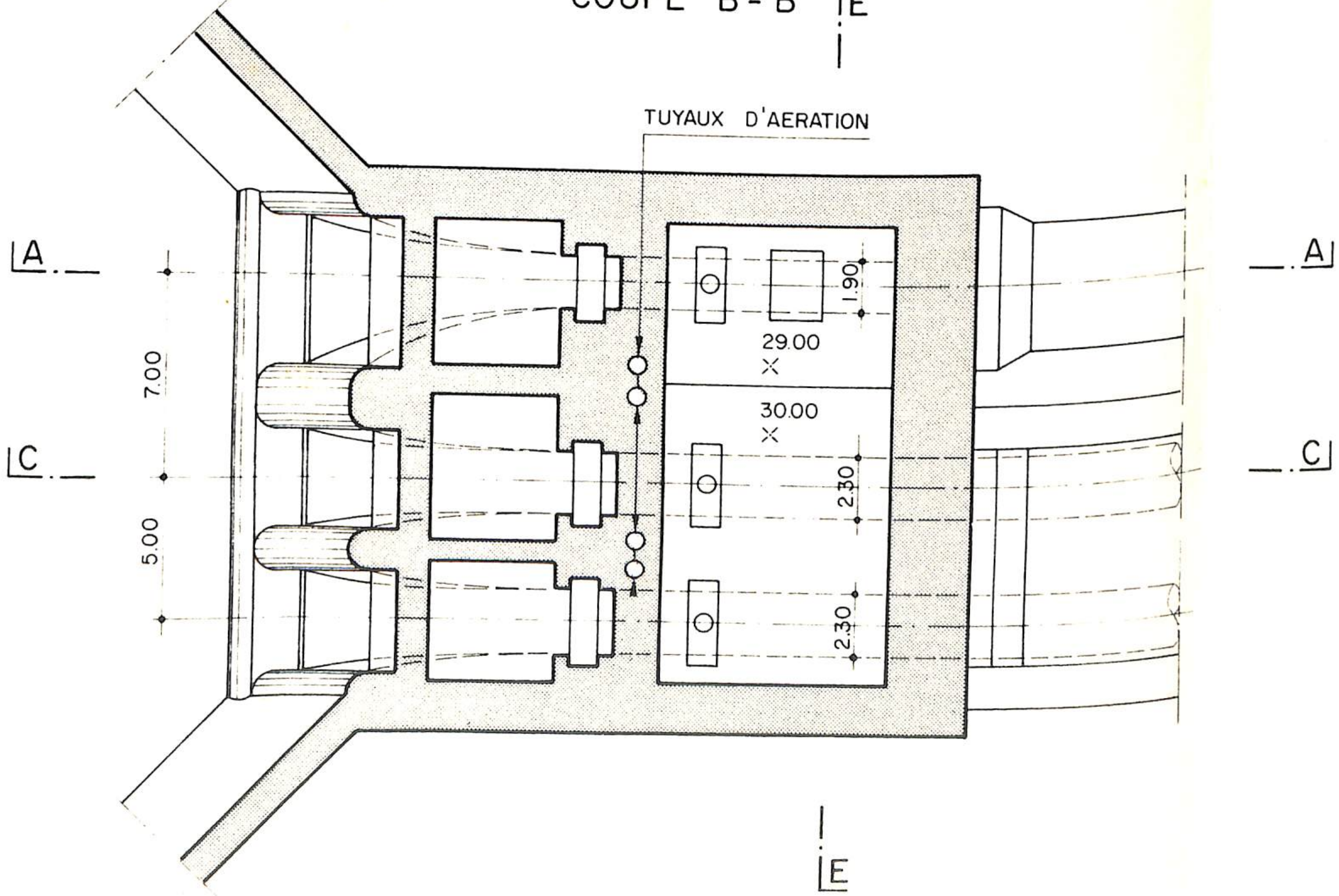

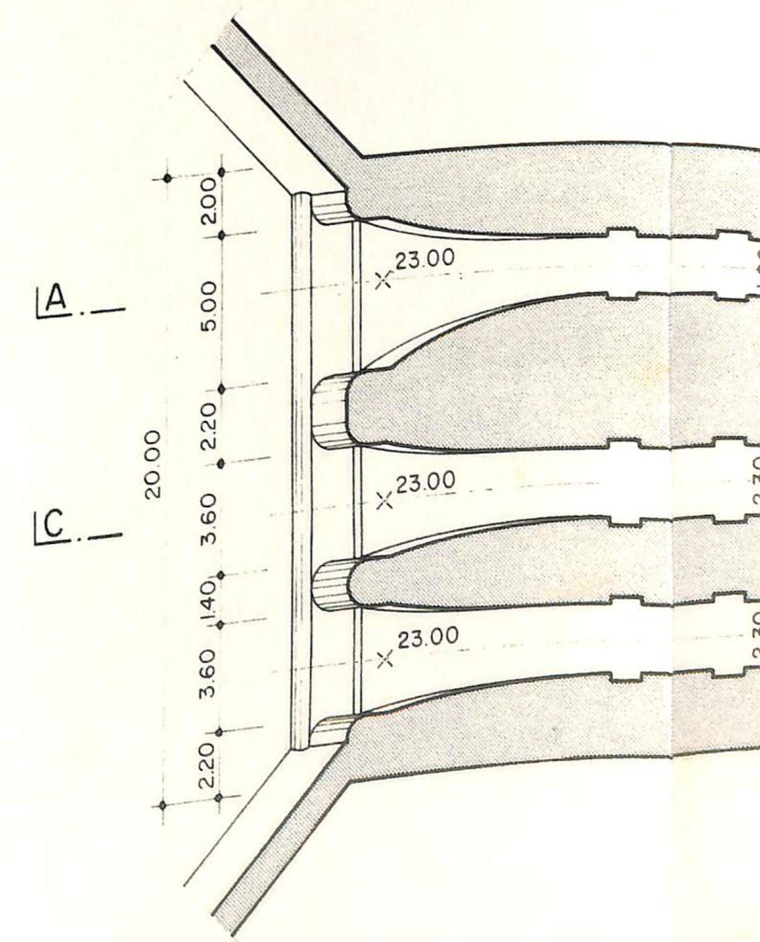

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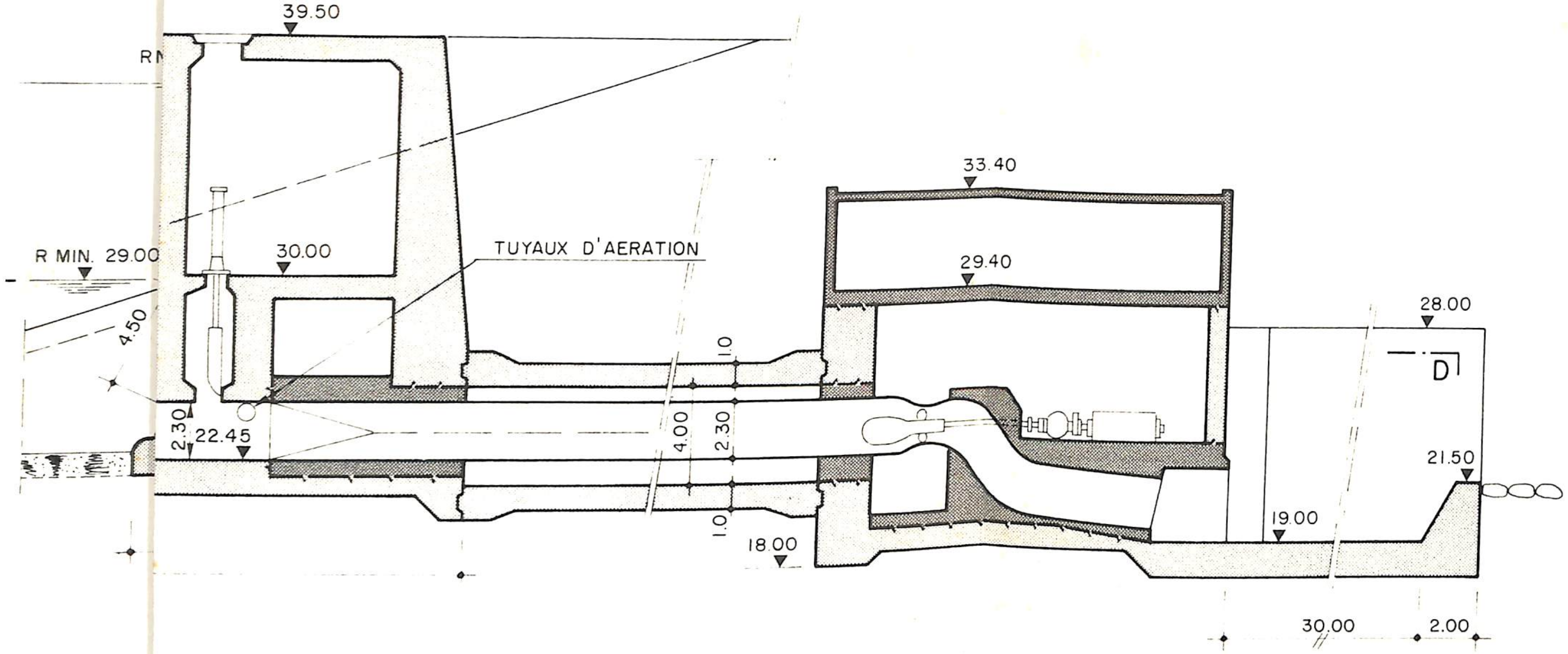

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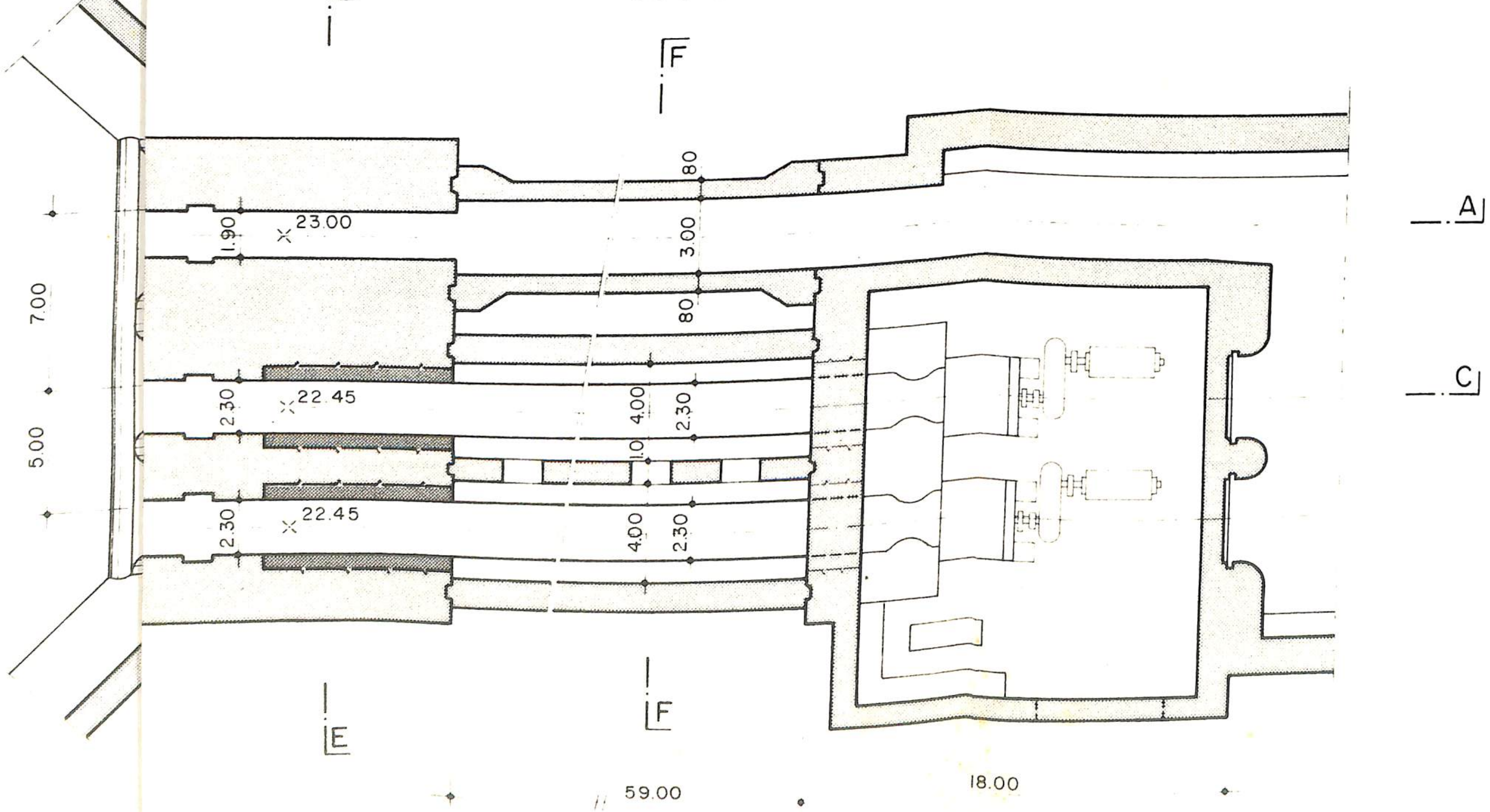

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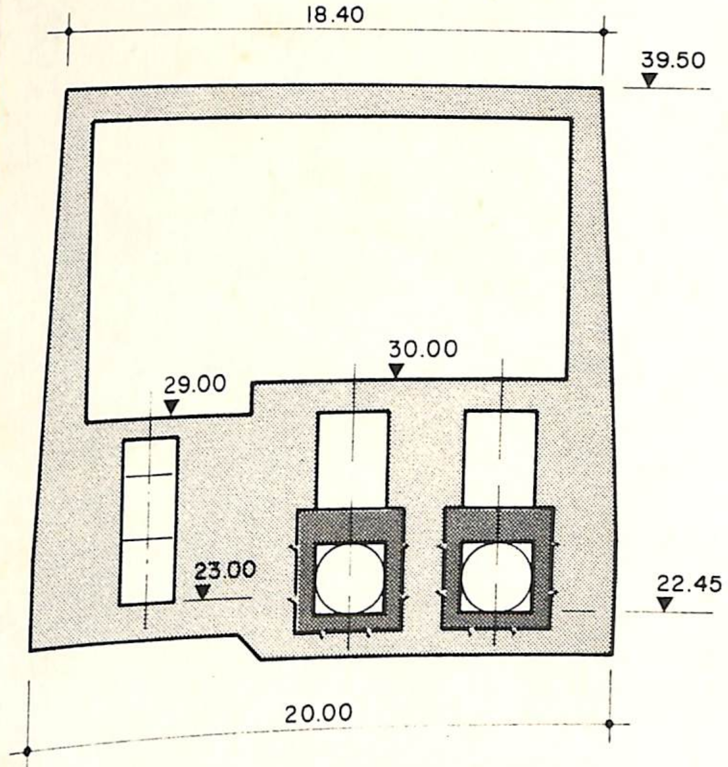

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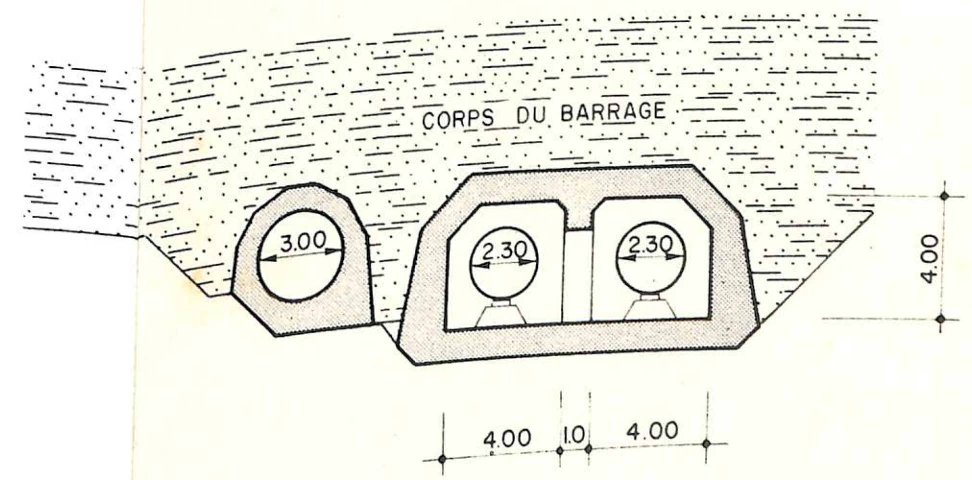


REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

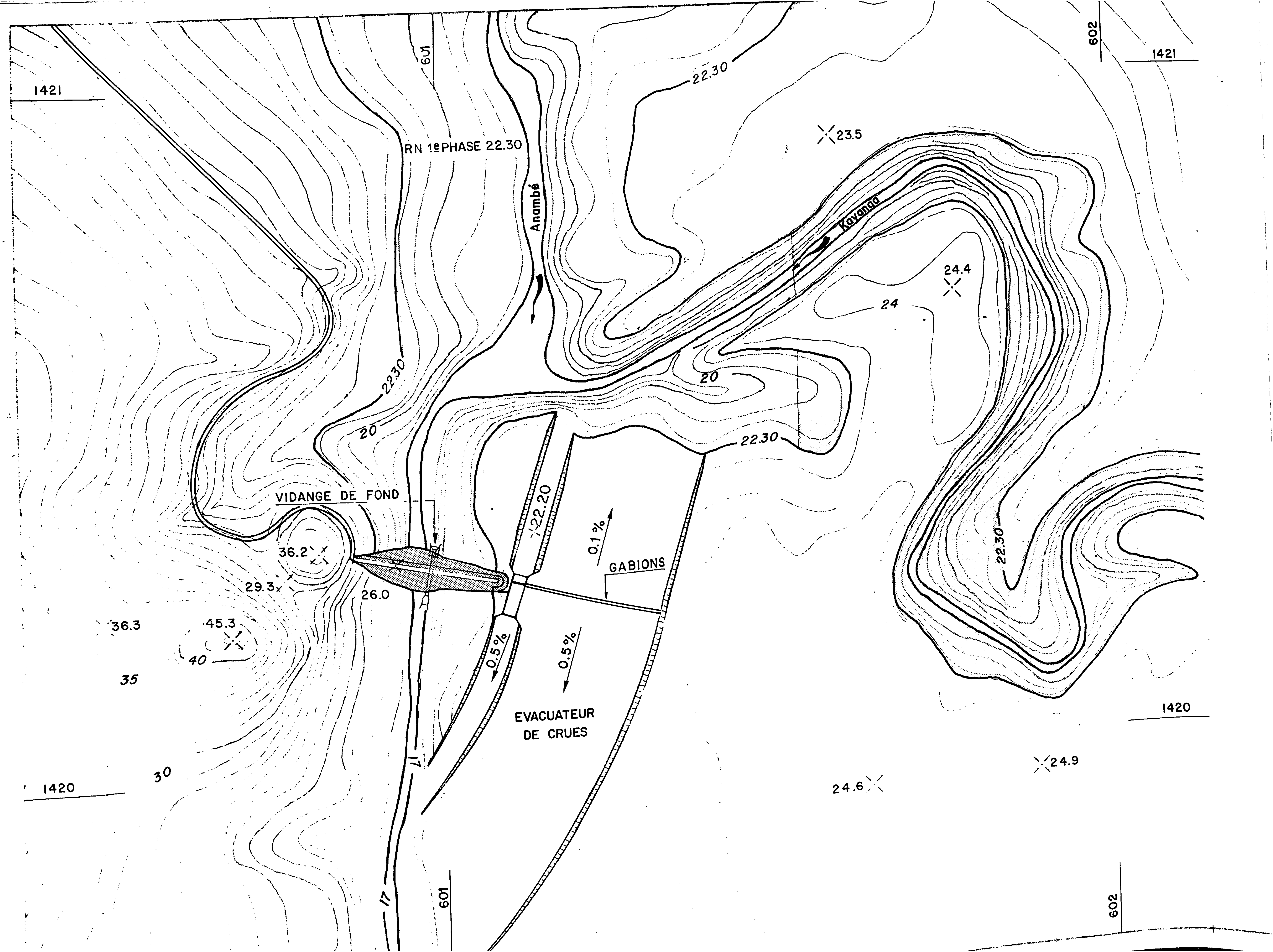
BARRAGE DE NIANDOUBA

USINE VARIANTE 2

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS
CONT
VISA

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:250	Mars 80	6158-2175 78	4-4



1421
1421
602
601
22.30
23.5
RN 1º PHASE 22.30
Anambé
Kavanaa
24.4
24
22.30
20
20
22.30
22.20
VIDANGE DE FOND
0.1%
GABIONS
22.30
36.2
29.3
26.0
36.3
45.3
40
35
0.5%
0.5%
EVACUATEUR
DE CRUES
1420
24.9
24.6
1420
30
17
17
601
602

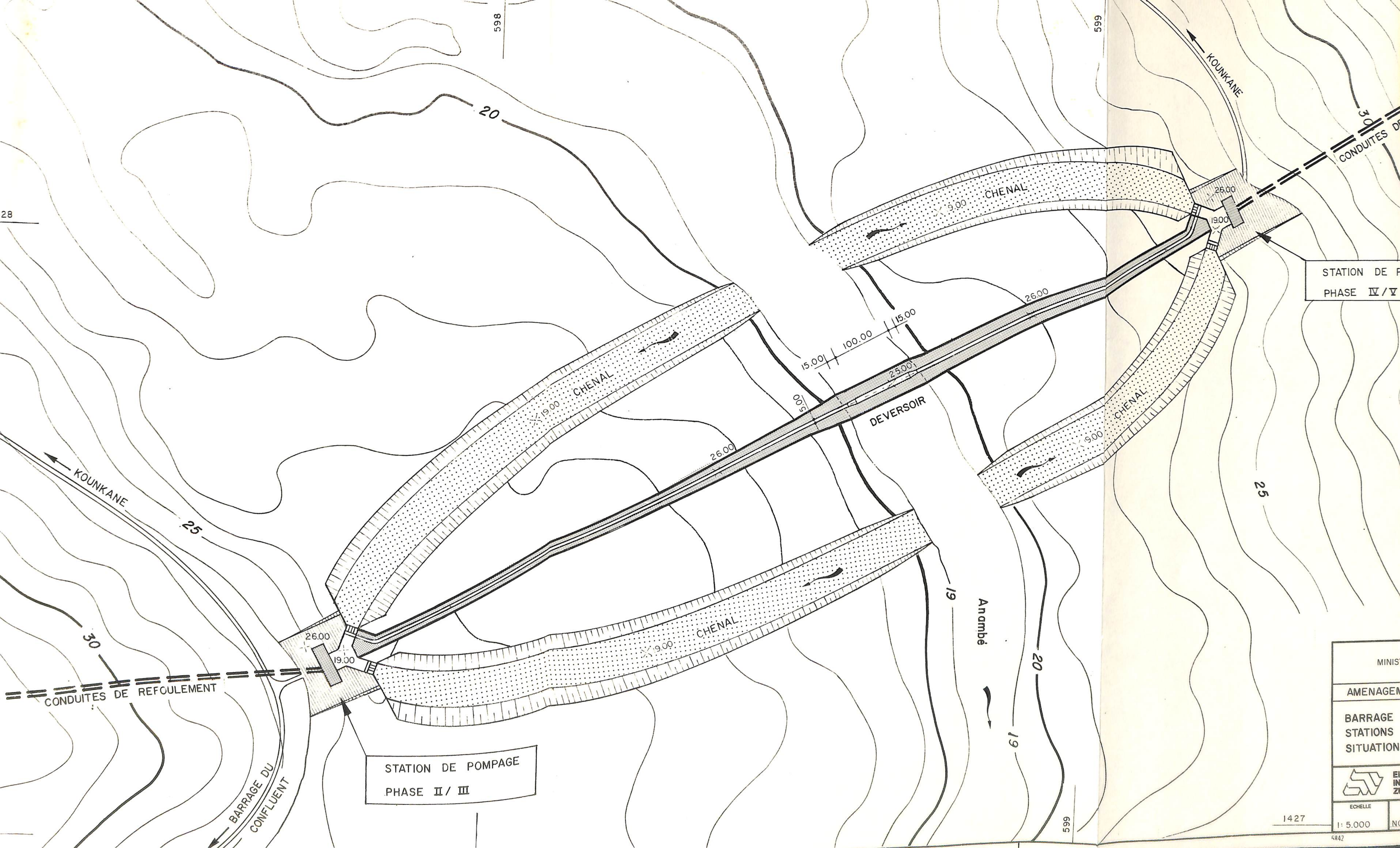
REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

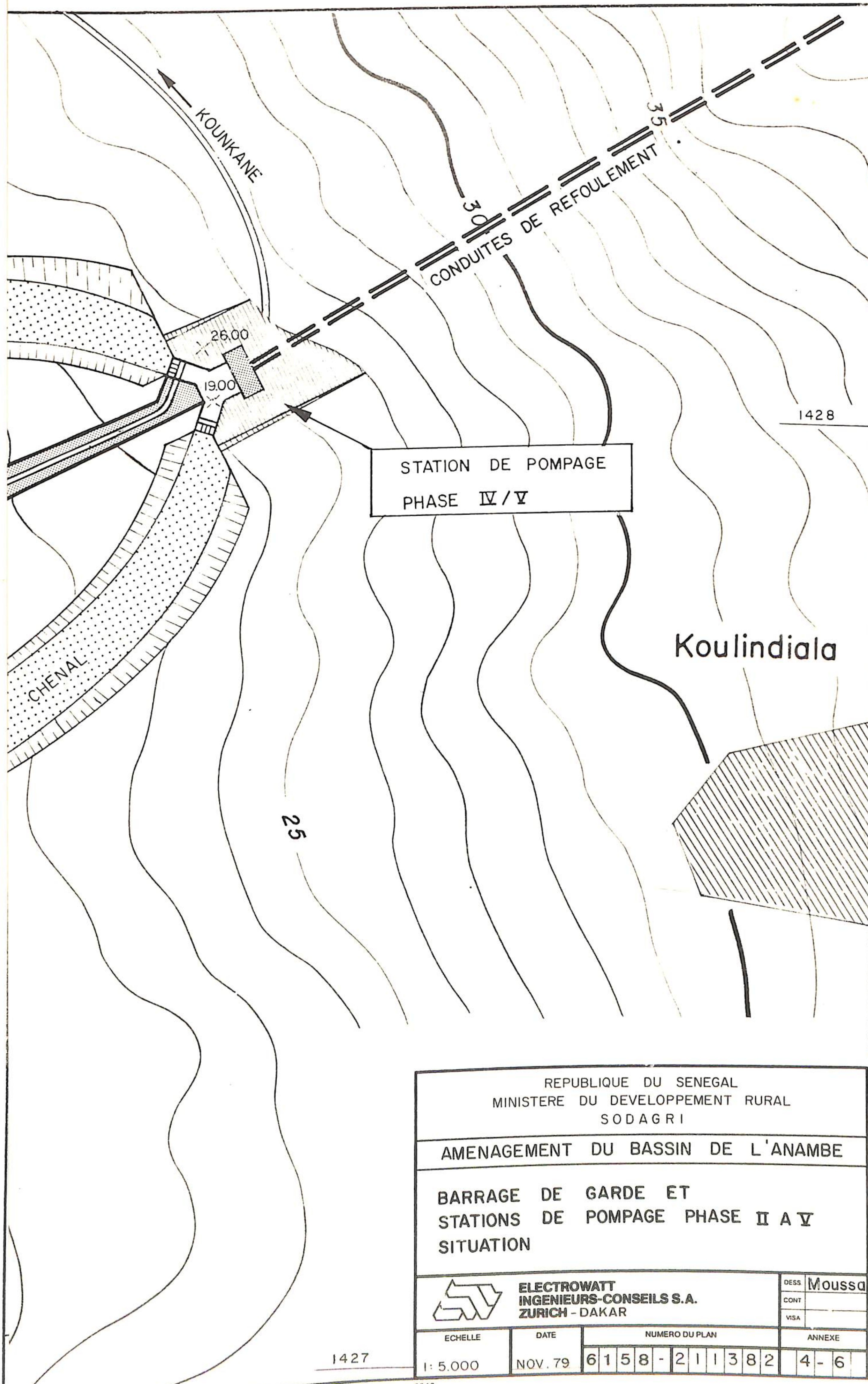
BARRAGE DU CONFLUENT

SITUATION

ELECTROWATT INGENIEURS-CONSEILS S.A. ZURICH - DAKAR		DESS	Moussa
		CONT	
		VISA	
ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:5000	NOV. 79	6158-211399	4-5



598
599
28
20
25
30
19
KOUNKANE
CONDUITES DE REFOULEMENT
CHENAL
DEVERSOIR
26.00
25.00
19.00
15.00
100.00
5.00
Anambé
STATION DE POMPAGE
PHASE II / III
STATION DE P
PHASE IV / V
BARRAGE DU CONFLUENT
MINIST
AMENAGEM
BARRAGE
STATIONS
SITUATION
ECHELLE
1: 5.000
1427
6842



REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

BARRAGE DE GARDE ET
STATIONS DE POMPAGE PHASE II A V
SITUATION

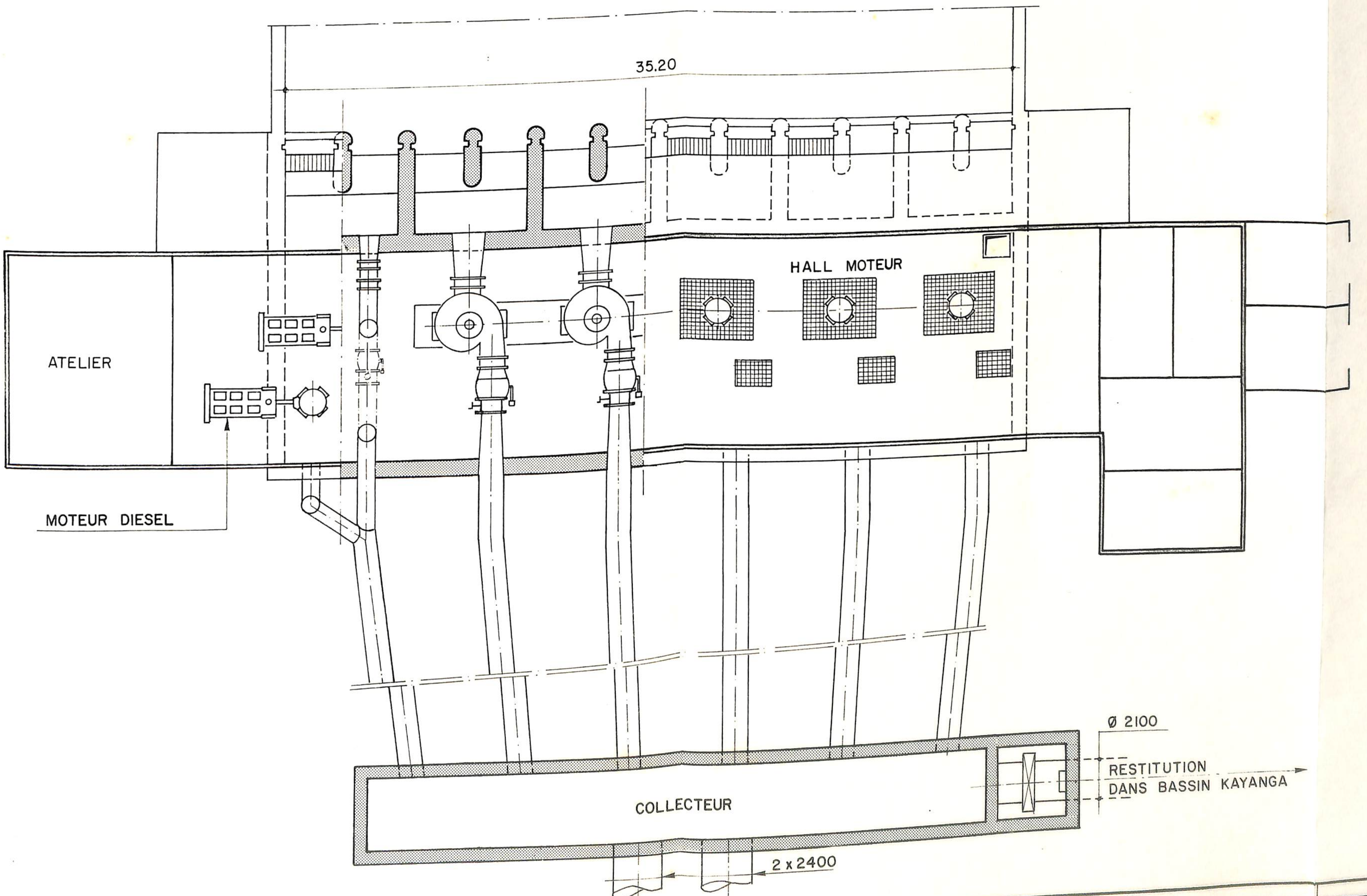
ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS Moussa
CONT
VISA

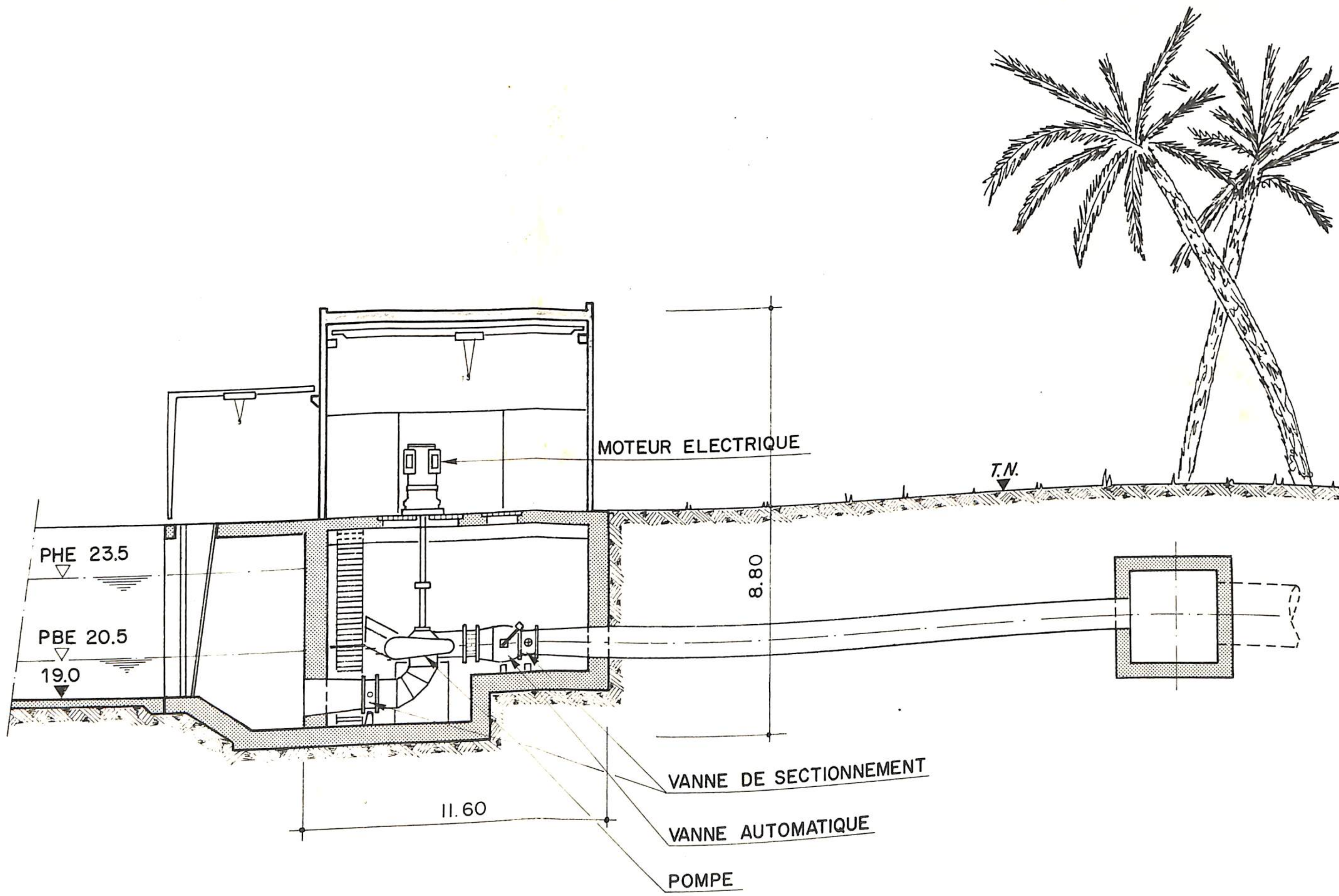
ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1: 5.000	NOV. 79	6158 - 211382	4 - 6

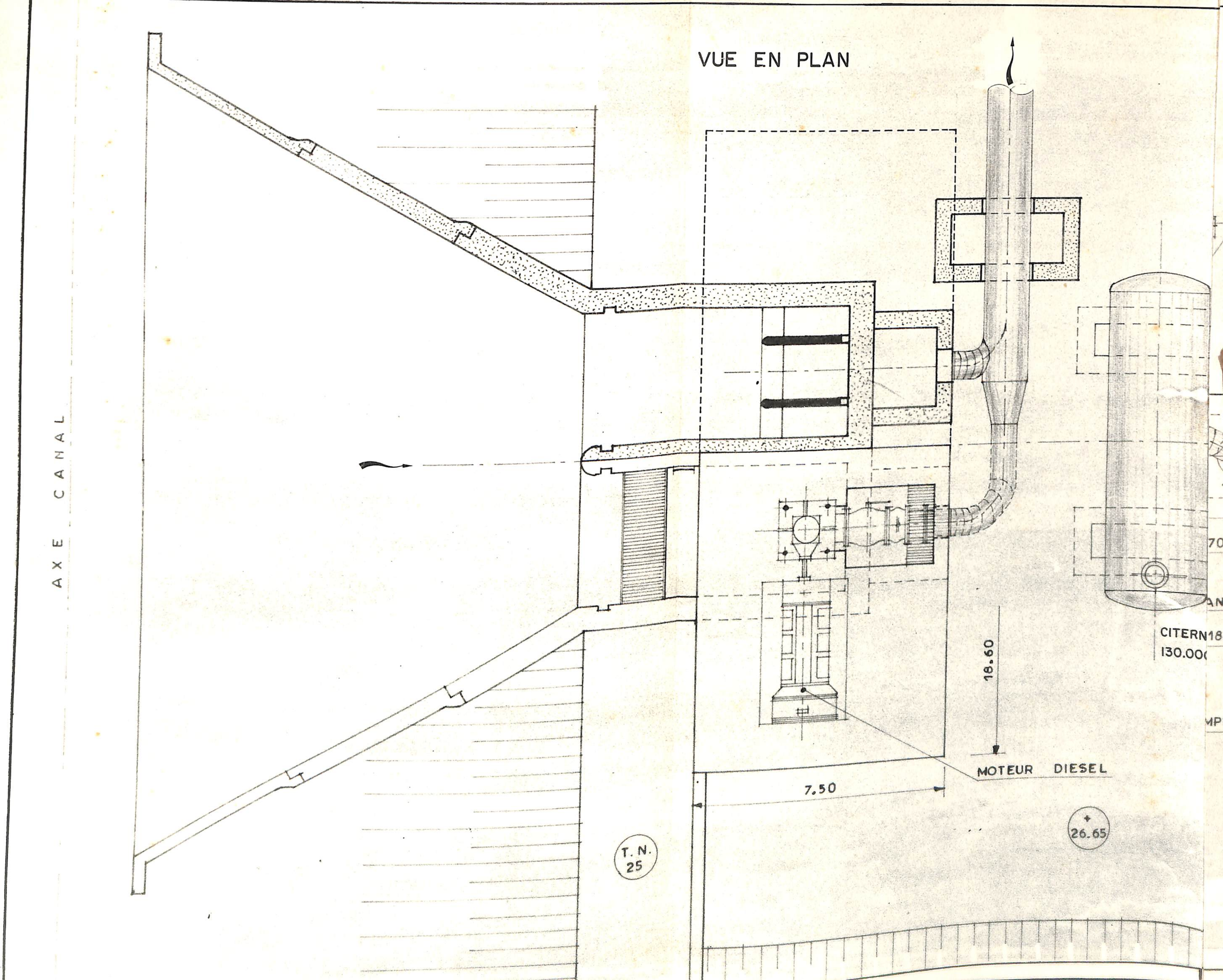
6842

VUE EN PLAN

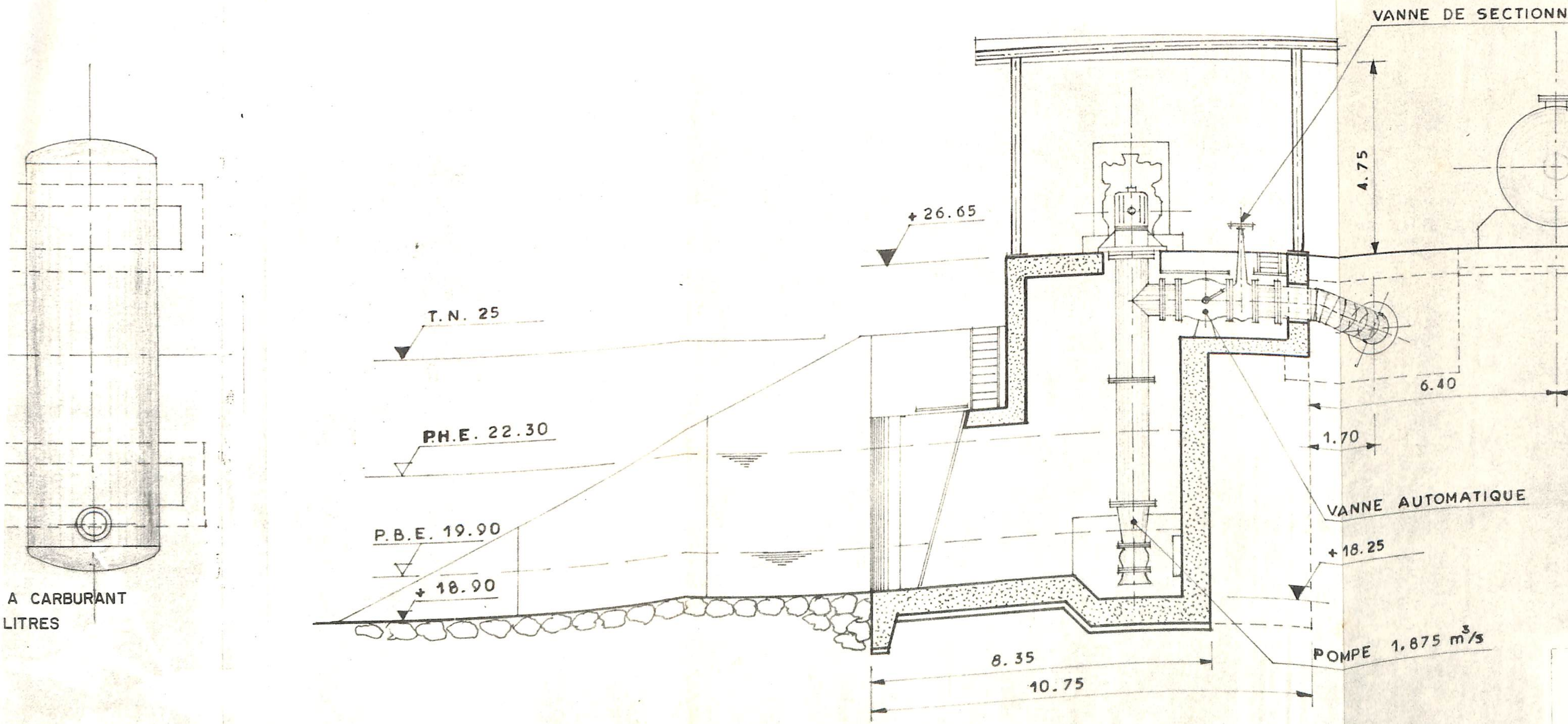

35.20
HALL MOTEUR
ATELIER
MOTEUR DIESEL
Ø 2100
RESTITUTION
DANS BASSIN KAYANGA
COLLECTEUR
2 x 2400

COUPE TRANSVERSALE




VUE EN PLAN
AXE CANAL
18.60
MOTEUR DIESEL
7.50
26.65
T. N.
25
CITERN18
130.00
70
AN
MP

COUPE TRANSVERSALE



REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

STATION DE POMPAGE PROVISOIRE
3,75 m^3/s (PHASE I)

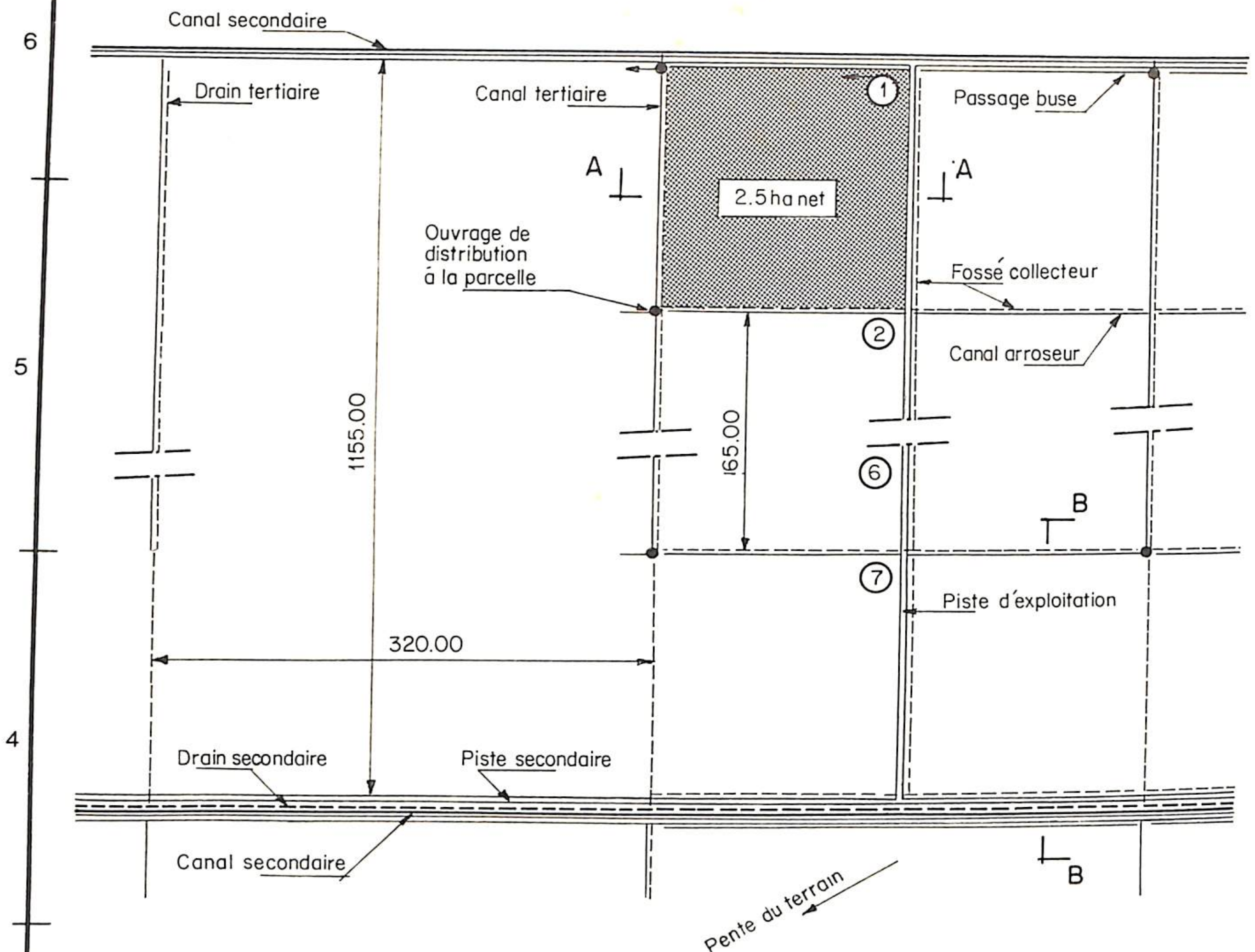
ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:100	DEC. 79	6158 - 209002	4 –

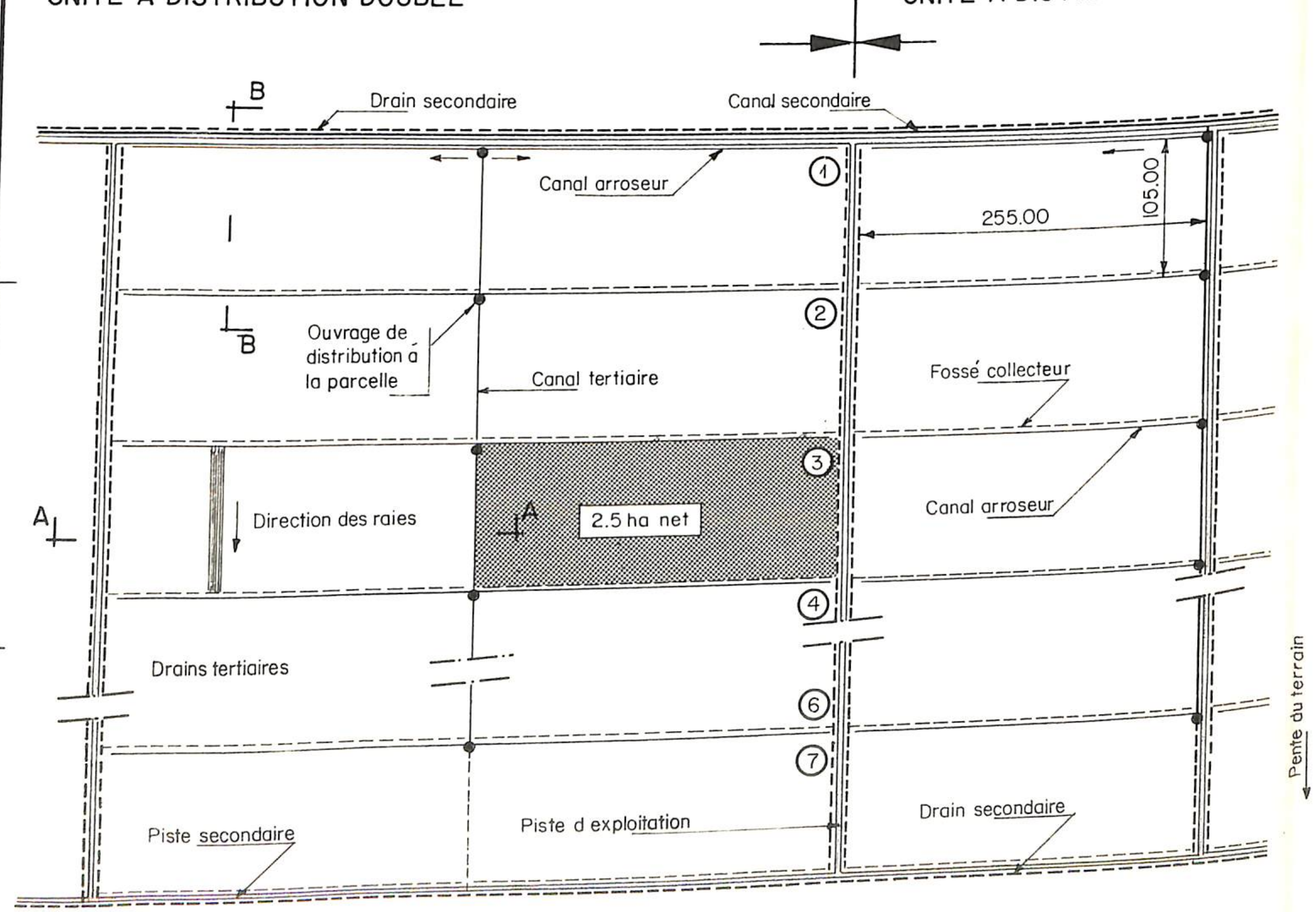
DESS. MB. MD
CONT.
VISA

5842

UNITE TYPE DE CULTURE MECANISEE — UNITE TYPE TRANSFORMEE EN CULTURE PAYSANNALE

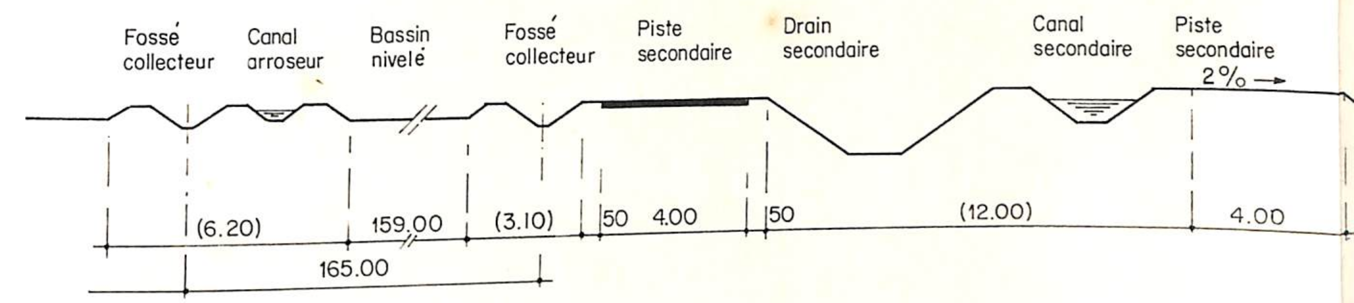


UNITE A DISTRIBUTION DOUBLE — UNITE A DISTRIBUTION SIMPLE

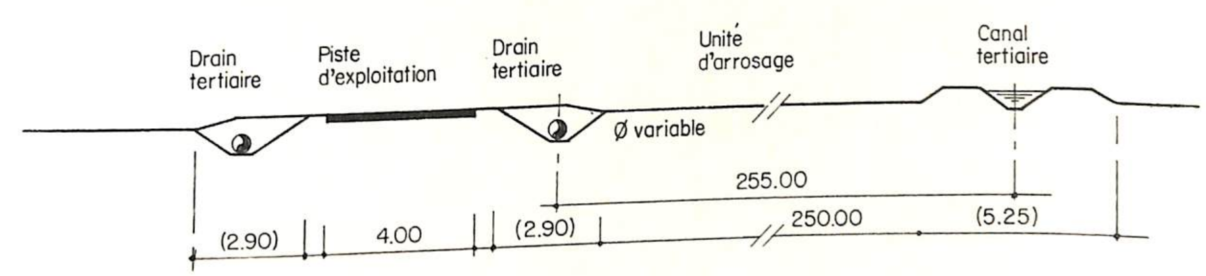


COUPE A-A

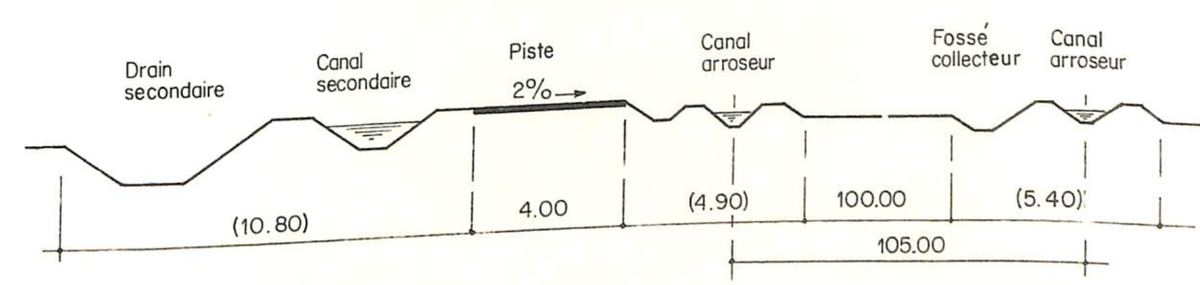
COUPE B-B



COUPE A–A

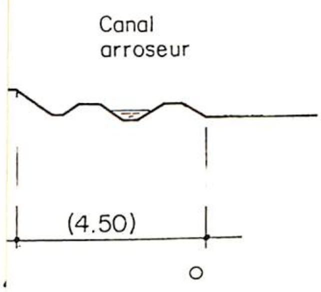


COUPE B – B



Les cotes en parentheses representent des cotes variables

ECHELLES Coupes 1 : 100
Plans 1 : 2500



REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

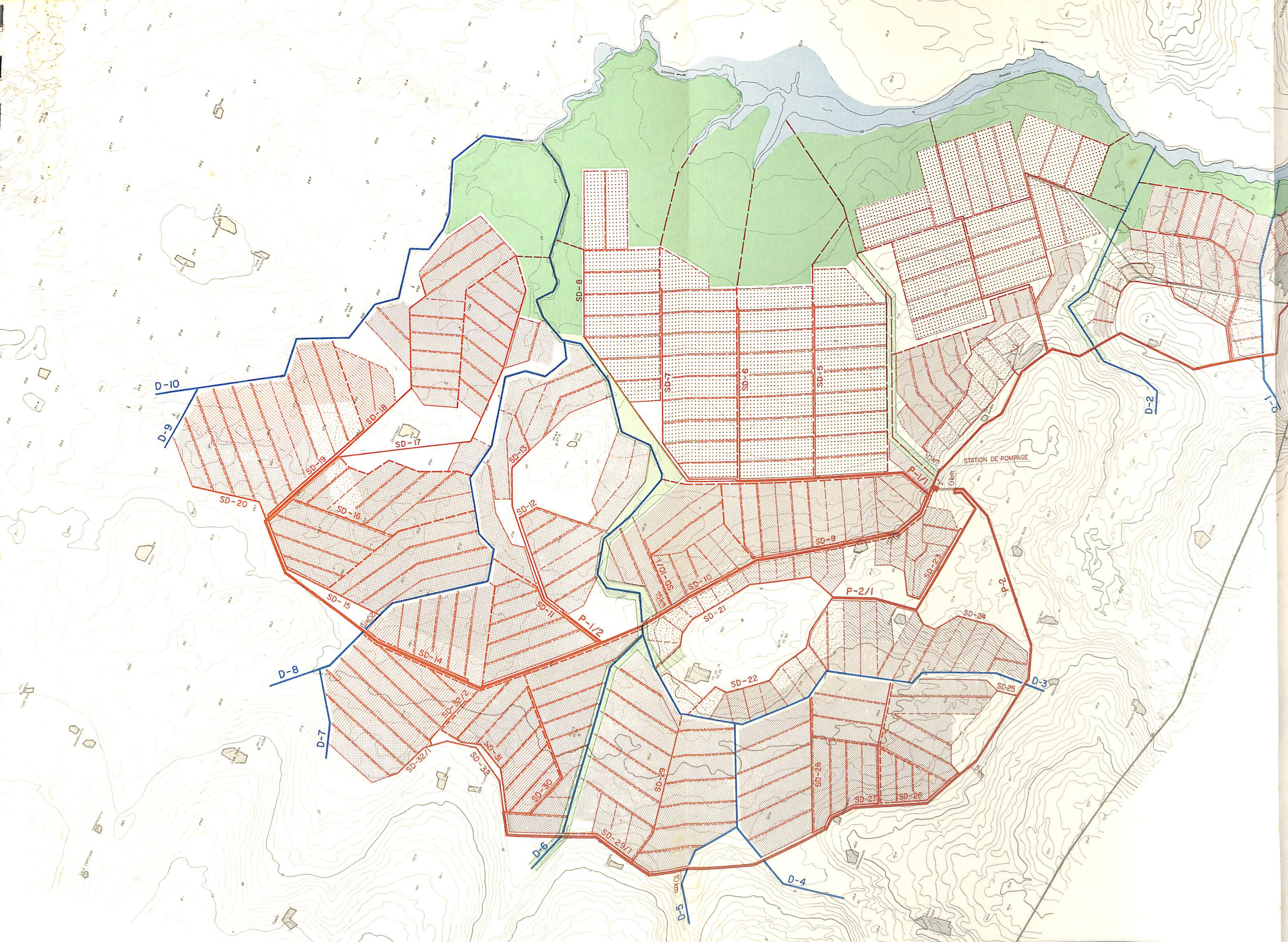
AMENAGEMENT DU BASSIN DE L'ANAMBE

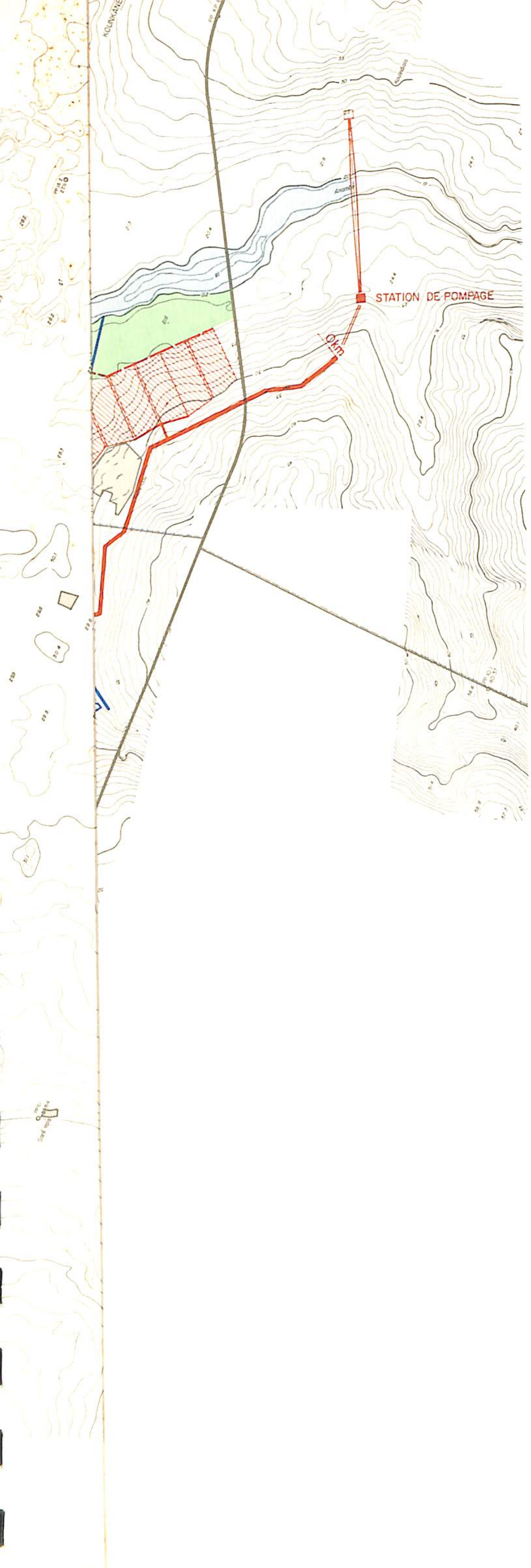
UNITES TYPES D'IRRIGATION

ELECTROWATT INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS	Niang
CONT	
VISA	

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:100 1:2500	Mai 1980	6158 - 209019	4 - 9


D-10
D-9
D-8
D-7
D-6
D-5
D-4
D-3
D-2
D-1
SD-5
SD-6
SD-7
SD-8
SD-9
SD-10
SD-11
SD-12
SD-13
SD-14
SD-15
SD-16
SD-17
SD-18
SD-19
SD-20
SD-21
SD-22
SD-23
SD-24
SD-25
SD-26
SD-27
SD-28
SD-29
SD-29/1
SD-30
SD-31
SD-32
SD-32/1
SD-32/2
P-1/1
P-1/2
P-2
P-2/1
STATION DE POMPAGE
0km
10km



LEGENDE

- ASSOLEMENT RIZ-RIZ EN CULTURE MECANISEE
- ASSOLEMENT RIZ-RIZ EN CULTURE PAYSANNALE
- ASSOLEMENT RIZ-DIVERS
- ASSOLEMENT DIVERS-DIVERS
- PATURAGES DE BAS-FONDS
- PISTE POUR BETAIL
- ZONE INONDEE DE LA WAIMA
- CANAL PRINCIPAL
- CANAL SECONDAIRE
- CANAL TERTIAIRE
- DRAIN PRINCIPAL
- DRAIN SECONDAIRE
- DRAIN TERTIAIRE

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI
(SOCIETE DE DEVELOPPEMENT AGRICOLE ET INDUSTRIEL DU SENEGAL)

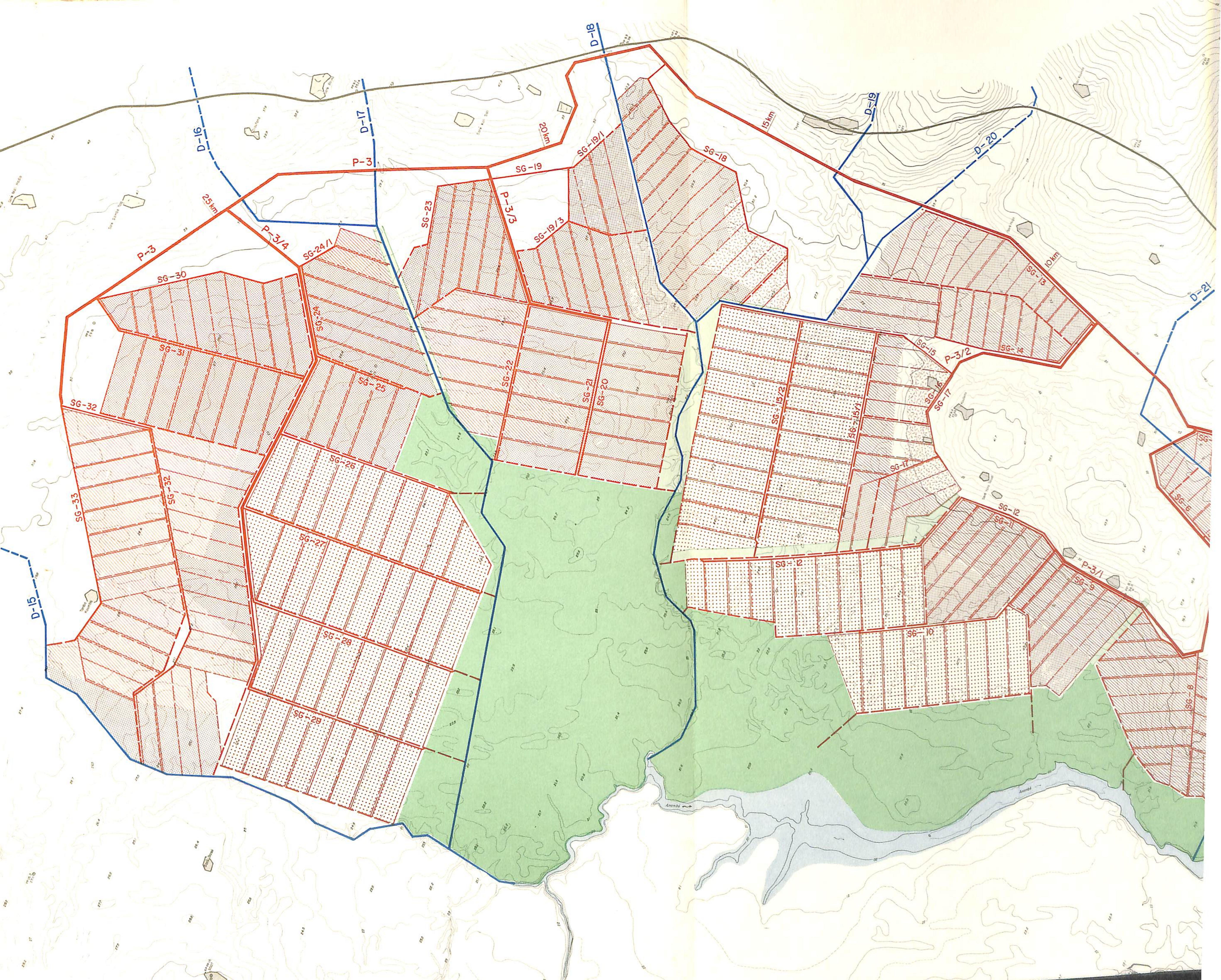
AMENAGEMENT DU BASSIN DE L'ANAMBE

PLAN D'AMENAGEMENT RIVE DROITE

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS
CONT
VISA RVB

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:50'000	DEC. 79	6158-211396	4-10



D-15
D-16
D-17
D-18
D-19
D-20
D-21
P-3
P-3/4
P-3/3
P-3/2
P-3/1
25 km
20 km
15 km
10 km
SG-19
SG-19/1
SG-19/3
SG-18
SG-23
SG-24/1
SG-24
SG-30
SG-31
SG-32
SG-33
SG-25
SG-26
SG-27
SG-28
SG-29
SG-22
SG-21
SG-20
SG-15/2
SG-15/1
SG-15
SG-16
SG-17
SG-14
SG-13
SG-12
SG-11
SG-10
SG-9
SG-8
SG-6

LEGENDE

- ASSOLEMENT RIZ-RIZ EN CULTURE MECANISEE
- ASSOLEMENT RIZ-RIZ EN CULTURE PAYSANNALE
- ASSOLEMENT RIZ-DIVERS
- ASSOLEMENT DIVERS-DIVERS
- PATURAGES DE BAS-FONDS
- PISTE POUR BETAIL
- ZONE INONDEE DE LA WAIMA
- CANAL PRINCIPAL
- CANAL SECONDAIRE
- CANAL TERTIAIRE
- DRAIN PRINCIPAL
- DRAIN SECONDAIRE
- DRAIN TERTIAIRE

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI
(SOCIETE DE DEVELOPPEMENT AGRICOLE ET INDUSTRIEL DU SENEGAL)

AMENAGEMENT DU BASSIN DE L'ANAMBE

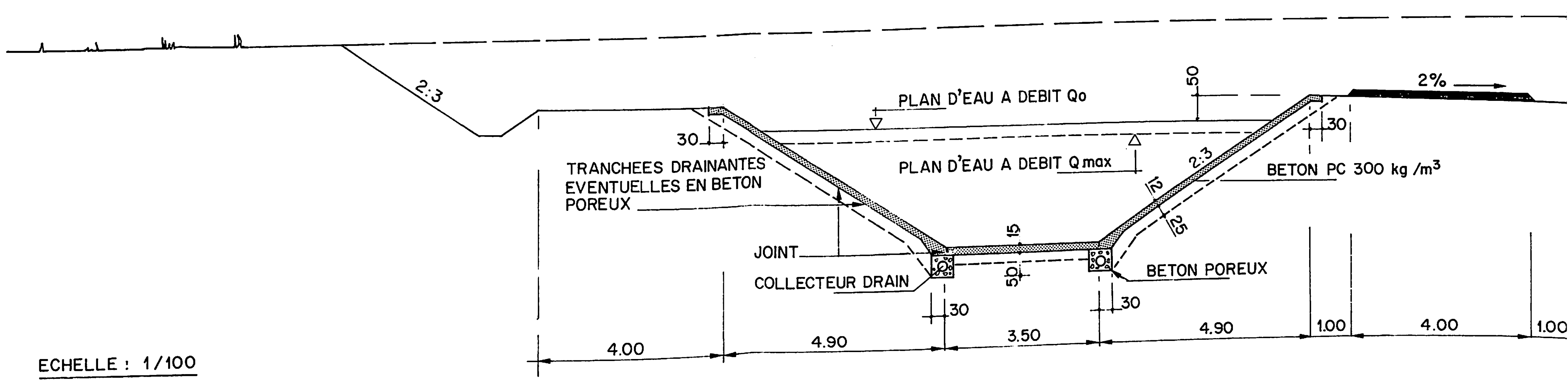
PLAN D'AMENAGEMENT RIVE GAUCHE

ELECTROWATT INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS.
CONT.
VISA RVB

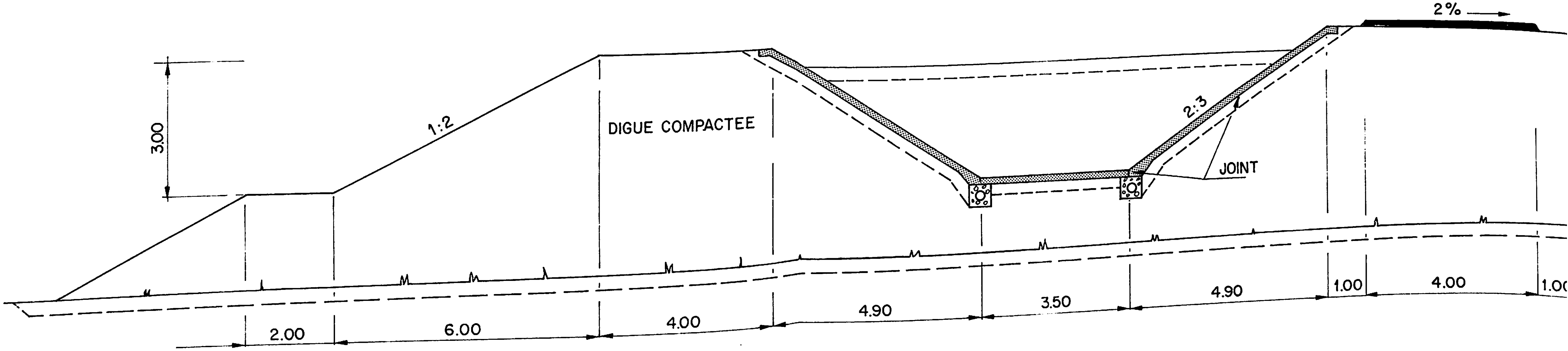
ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:50'000	DEC. 79	6158-211397	4-11

CANAL PRINCIPAL EN DEBLAI



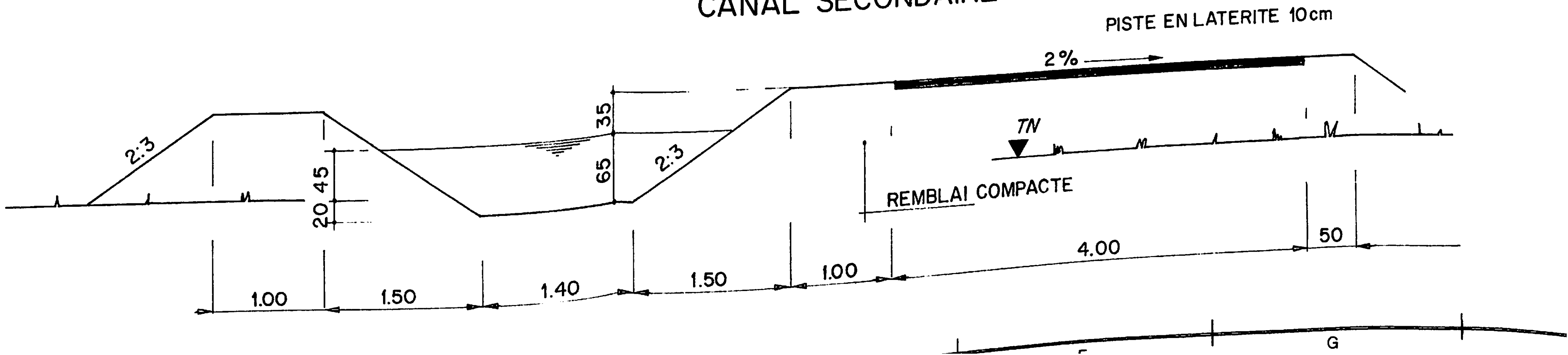
ECHELLE : 1/100

CANAL PRINCIPAL EN REMBLAI

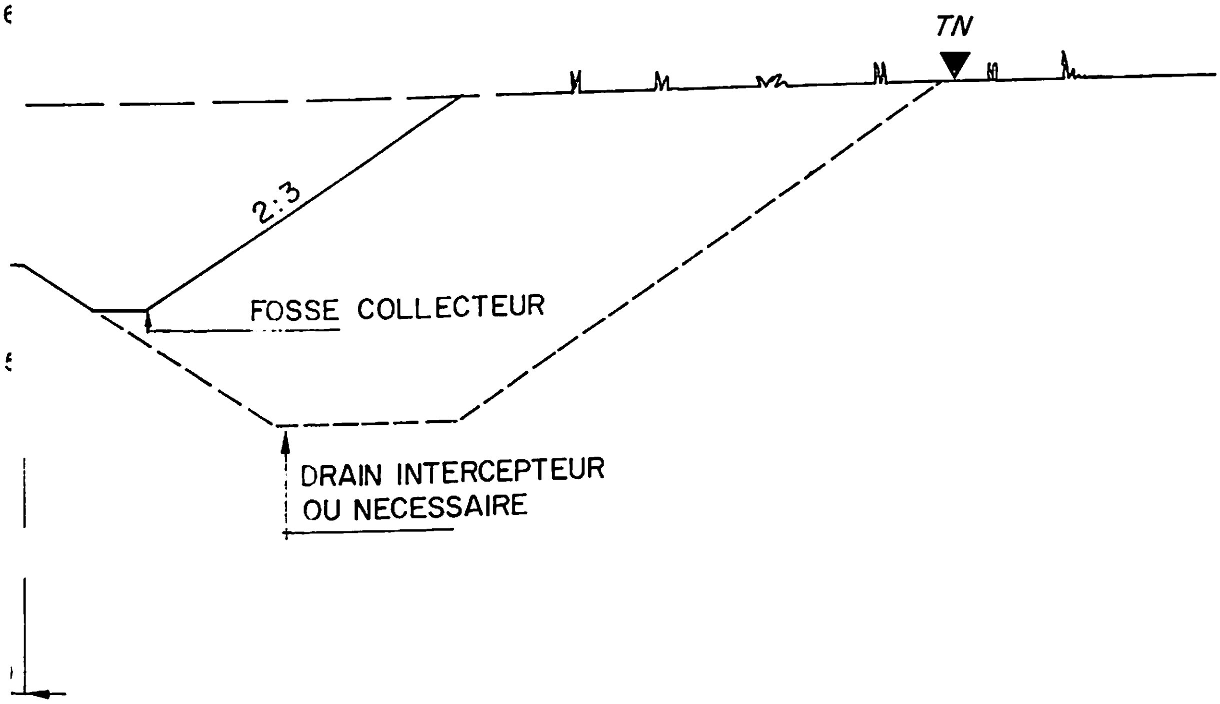


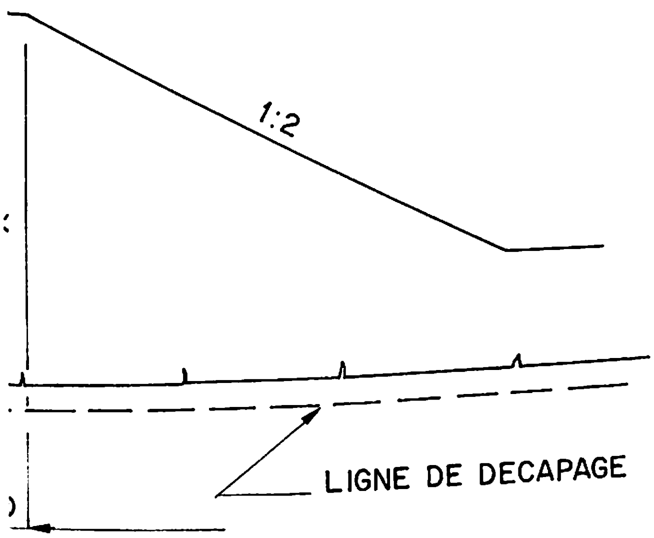
ECHELLE : 1/100

CANAL SECONDAIRE



ECHELLE : 1/50





CANAL PRINCIPAL
$Q = 20\ m^3/sec$
$J = 0,15$ ‰

CANAL SECONDAIRE
$Q = 0,5m^3/sec$
$J = 1,2$ ‰

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

CANAUX PRINCIPAUX ET SECONDAIRES

PROFILS TYPES

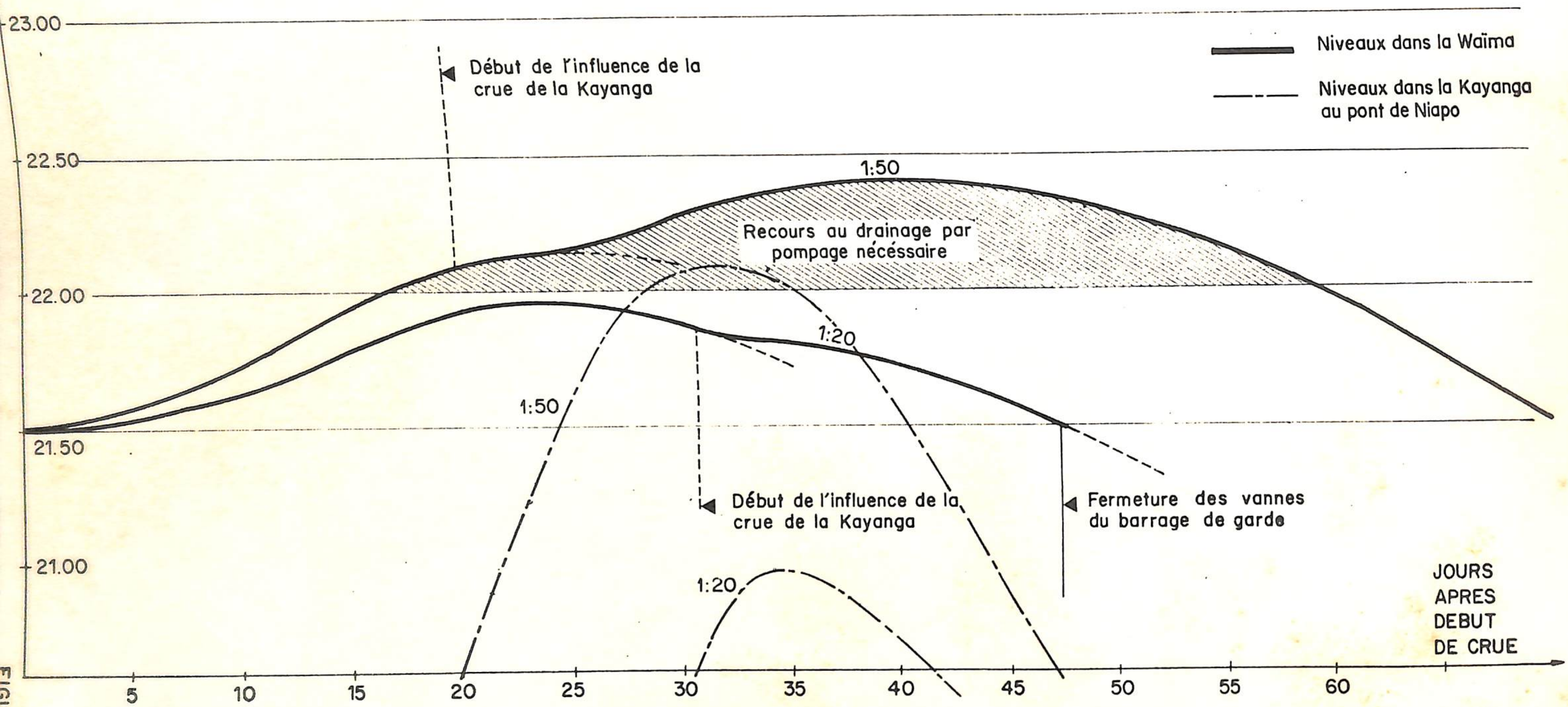
ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS. Niang
CONT.
VISA

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
1:100-1:50	Avril 80	6158 - 214986	4 - 12

NIVEAUX DES EAUX DANS LA ZONE CENTRALE DE LA WAIMA

ANNEES HUMIDES DE FREQUENCE 20 ET 50 ANS



FLOOD WATER LEVELS IN WAIMA LAKE

FIGURE 4.13

5. AGRICULTURAL ECONOMY

5. AGRICULTURAL ECONOMY

5.1 Crops and yields

For rice I Kong Pao is the variety which is presently best known in Upper Casamance and to which recommendations herein relate. It is resistant to blast (pericularia oryzae) a disease prevalent in the area. Its growth cycle of 110 days may be extended for the dry season crop by the cooler weather at the start of the cycle. A cycle of 120 days for the dry season is assumed.

White sorghum with a shorter cycle than presently cultivated varieties will be introduced, such as 51-69, a variety of 120 days. For maize SODEFITEX and SODAGRI have been introducing a white hybrid of 90 day growth cycle, which has been well accepted.

Under reasonably good farm management practices, and with effective agricultural support services, productivity will increase fairly rapidly to moderately high levels. Anticipated yields of crops are shown in table 5-1. They are estimates of yields reasonably attainable with application of available techniques and are well below the yield potential of these crops if grown under optimum conditions. The difference between potential and actual yields reflects the results obtained by farmers in Senegal with irrigated crops as well as general experience.

Table 5 - 1 CROP YIELDS

		Mechanized farm		Production division	Smallholders	
		First 4 years	Full development		First 4 years	Full development
Rice	- wet season	3,0	4,0	3,0	2,6	3,5
	- dry season	3,5	4,5	3,5	3,0	4,0
Maize	- wet season	3,0	4,5	-	2,2	3,0
	- dry season	4,0	5,5	4,5	2,8	3,7
Sorghum	- wet season	-	-	-	2,2	3,0
	- dry season	-	-	-	2,4	3,2

5.2 Cultural practices

5.2.1 Smallholders

Smallholders will gradually adopt improved cultural practices, advancing from present techniques to first a semi-intensive agriculture and then to an intensive agriculture. At neither level are any untried practices other than irrigation introduced. Improved varieties, split fertiliser application, use of herbicides and insecticides, incorporation of organic matter and use of draught animals for weeding and ridging, as proposed at the semi-intensive level, have all been introduced by SODEFITEX for cotton and have generally been applied successfully.

The intensive level corresponds to a more advanced level of farm management and greater use of inputs. Agricultural support services and farmer organisation will also have evolved to become increasingly effective. It has been assumed that the intensive level will be reached after four years at the semi-intensive level.

Cultural practices are based on the continued and intensified use of work oxen which will be supported by development of appropriate equipment and improvement of the breed. Harvesting will still be carried out by hand. Direct seeding will be adopted for rice. Basin and furrow methods of irrigation will be employed for rice and diversified crops respectively. Farmers growing rice followed by a diversified dry season crop will adopt a combination of the two methods, depending on soil type and the depth of the water table in the wet season.

Control of weeds is critical for high rice yields. Water management techniques and hand pulling will maintain weed control, with chemical weeding applied on the dry season crop. A periodic fallow is also envisaged. Maize and sorghum will be mechanically weeded. Introduction of these cultural practices requires the small farmer to purchase, individually or cooperatively, a variety of additional farm machinery, including reversible plough, seed drill, multi-purpose tool bar and sprayer. Small threshers and shellers will also be introduced. All equipment proposed is produced in Senegal by SISCOMA. Input requirements and costs are given in table 5-2, based on prices given in table 5-3. Costs are based on producer prices. Studies

Table 5 - 2 SMALLHOLDER PRODUCTION COSTS AND NET REVENUE PER HECTARE (1) (2)

CROP AND SEASON (3)		Seed (kg) 1	Seed (kg) 2	Compound fertilizer (kg) 14-7-7 1	Compound fertilizer (kg) 14-7-7 2	Urea (kg) 1	Urea (kg) 2	Herbicide (1) 1 & 2	Insecticide (1) 1 & 2	Seed and storage treatment (FCFA) 1	Seed and storage treatment (FCFA) 2	Farm equipment cost (FCFA) 1	Farm equipment cost (FCFA) 2	Total input costs (2) (FCFA) 1	Total input costs (2) (FCFA) 2	Gross revenue (FCFA) 1	Gross revenue (FCFA) 2	Net revenue (FCFA) 1	Net revenue (FCFA) 2	Farm labour required (m - d) 1	Farm labour required (m - d) 2	Net revenue per man day (FCFA) 1	Net revenue per man day (FCFA) 2
		← All values per hectare →																					
Rice : Wet season	A	100	120	100	200	80	120	-	5														
	B	4 500	5 400	2 500	5 000	2 000	3 000	-	4 500	1 900	2 500	14 264	14 264	29 664	34 664	107900	145250	78 236	110586	57,5	59,5	1 361	1 859
Dry season	A	100	120	100	200	100	120	8	2,5														
	B	4 500	5 400	2 500	5 000	2 500	2 500	6 000	2 250	2 100	2 750	14 264	14 264	34 114	38 164	124500	166000	90 386	127836	61	64	1 482	1 997
Maïze : Wet season	A	20	20	100	150	80	100	-	2,5														
	B	2 000	2 000	2 500	3 750	2 000	2 500	-	2 250	1 200	1 600	16 464	16 964	26 414	29 064	81400	111000	54 986	81936	64	65	859	1 261
Dry season	A	20	20	100	200	80	120	-	2,5														
	B	2 000	2 000	2 500	5 000	2 000	3 000	-	2 250	1 500	1 950	17 064	17 964	27 314	32 164	103600	136900	76 286	104736	66	68	1 156	1 540
Sorghum : Wet season	A	10	15	100	150	70	100	-	2,5														
	B	425	638	2 500	3 750	1 750	2 500	-	2 250	1 150	1 575	14 264	14 264	22 339	24 977	88000	120000	65 661	95023	61	62	1 076	1 533
Dry season	A	10	15	100	200	70	100	-	2,5														
	B	425	638	2 500	5 000	1 750	2 500	-	2 250	1 250	1 675	14 264	14 264	22 439	26 327	96000	128000	73 561	101673	64	65	1 149	1 564
FOR 2,5 HA FARM																							
Rice - rice	B	18 000	21 600	10 000	20 000	8 813	12 000	9 750	14 344	7 925	10 406	57 056	57 056	125973	144411	458600	614700	332627	470289	236	246	1 409	1 912
Rice - divers.	B	12 231	14 600	10 000	20 000	7 729	11 458	-	14 344	6 679	8 808	58 573	59 060	109558	128421	416400	557800	306842	429559	242	249	1 268	1 725
Rice - divers.	B	3 800	4 368	10 000	17 031	7 333	10 667	-	9 000	4 937	6 631	60 260	61 198	95420	108520	363900	490700	268480	382180	253	257	1 061	1 487

Note : (1) At producer prices

(2) Excluding water charges
Levels 1 and 2 correspond to semi-intensive and intensive respectively

(3) Input requirements shown under 'A' (units shown at head of column)
Input costs in FCFA shown under 'B'

Table 5 - 3 PRICES OF INPUTS, BUILDINGS AND PERSONNEL

(in FCFA)

	Unit	Producer price (1)	Economic price
Paddy rice	kg	41,5	54
Maize	kg	37	37
Sorghum	kg	40	40
Millet	kg	40	40
Groundnuts	kg	45,5	55
Cotton (seed)	kg	55	90
Meat	kg	200	200
Seed rice	kg	52	70
white maize	kg	100	75
yellow hybrid maize	kg	100	100
white sorghum	kg	50	70
groundnuts	kg	52	-
cotton	kg	-	-
Compound fertilizer 14-7-7	kg	25	57
Urea	kg	25	77
Herbicide for rice	l	750	750
Herbicide for maize	l	750	750
Insecticide	l	900	900
Seed treatment	kg	2 500	2 500
Storage treatment	kg	833	833
Fuel			
Petrol	l	130	75
Diesel	l	85	65
Buildings			
Storage shed	m^2	35 000	35 000
Store, workshop	m^2	50 000	50 000
Office	m^2	60 000	60 000
Housing	m^2	75 000	75 000
Salaries			
Labourer	month	30 000	400/day
Assistant mechanic	month	50 000	50 000
Mechanic	month	80 000	80 000
Tractor driver	month	55 000	55 000
Guard	month	30 000	30 000
Storekeeper	month	40 000	40 000
Assistant manager	month	150 000	150 000
Farm manager	month	250 000	250 000

1) financial price

show that with the proposed cultivation practices and cropping intensities one man can cultivate 1,25 ha either of rice or diversified crops in the wet season. A typical farm family are assumed to have a labour force equivalent to two men, resulting in a cultivable area per family of 2,5 ha. Table 5-2 also gives the annual input requirements and production costs for the typical 2,5 ha farms.

5.2.2 Mechanized farm

The introduction of mechanized farming requires trained personnel, skilled managers and the necessary physical and organisational infrastructure to operate the farm and maintain farm machinery. All of these elements musts be created by the project on the spot or be provided from outside the area.

Cultivation techniques follow accepted modern practice. Aerial application of urea fertiliser and insecticide in mid-cycle is required. Compound fertilizer as a base dressing can be applied by tractor drawn spreader. Weed killer is applied by tractor mounted sprayer at the time of sowing. Annual input requirements are given in table 5-4. Farm machinery requirements are given in the same table. Mechanized farm costs (in terms of producer prices) are based on the requirements of a hypothetical 1 200 ha mechanized farm unit. Each mechanized farm unit will have its own offices ; houses, storage hangars, workshops, power supply and vehicles for maintenance and for farm personnel. The unit will be run by a farm manager and an agricultural assistant. Personnel requirements are given in table 7-1. A seasonal labour force of about 70 is required for irrigation.

5.2.3 Production division

Following their development, all lands except those assigned to the mechanized farm will be held by the project authority until they can be transferred to small farmers. This transfer may take place immediately following development or after a few years, depending upon the need for soil improvement and upon the rate at which farmers are settled on new lands.

Table 5 - 4 MECHANIZED FARM
INPUT REQUIREMENTS AND COSTS (1)

	Per hectare				Per 1200 ha farm(2)		
	Rice		Maize				
	Quant. (kg or l)	Cost (FCFA)	Quant. (kg or l)	Cost (FCFA)	Quant. (t.or m^3)	Financial cost (10^6 FCFA)	Economic cost (10^6 FCFA)
ANNUAL INPUTS							
Seed	100	4 500	20	2 000	299	9,15	11,13
Compound fertilizer	200	5 000	200	5 000	420	10,50	23,94
Urea	120	3 000	200(3)	5 000	265	6,62	20,37
Herbicide	8	6 000	5	3 750	16,6	12,33	20,37
Insecticide	5	4 500	5	4 500	10,1	9,45	12,33
Seed treatment	0,3	750	0,04	100	0,6	1,50	9,45
							1,50
Total						49,55	78,72

FARM MACHINERY 1 200 ha farm	Unit price (10^6 FCFA)	Number	Cost (10^6 FCFA)
Crawler tractor 80 HP	13,20	1	13,20
Wheeled tractor 80 HP	7,5	5	37,50
Wheeled tractor 45 HP	3,60	5	18,00
Combine harvester	12,60	4	50,40
Disc harrow	1,80	2	3,60
Trailer	0,85	10	8,50
Boom sprayer	1,40	2	2,80
Seed drill	1,05	2	2,10
Fertiliser spreader	1,20	1	1,20
Miscellaneous equipment		LS	8,05
Spare parts		LS	21,80
Additional equipment for maize cultivation x 25 % (4)		LS	1,97
Total			169,12

1) All costs in financial terms (producer prices) unless otherwise stated
2) At cropping intensities given in table 3-1
3) Increased to 250 kg for dry season crop, costing 6250 FCFA
4) Divided equally over 4 farm units

Lands held by the project authority will be farmed by the production division of the agriculture department. To farm these lands the production division will equip itself with the same range of equipment as the mechanized farm and will benefit from the experience gained on the mechanized farm units. Requirements for farm machinery, buildings, equipment and personnel are related to those for the hypothetical 1 200 hectares farm. Allowance is made for the reduced efficiency of equipment utilisation, resulting from the changing area cultivated and the smaller fields, by reducing yields and increasing farm machinery needs. Details are given in report 12, annex 7.

The cost of initial land preparation by crawler tractors is estimated at 40 000 FCFA per ha for the heavier lands which are suitable for rice monoculture and 10 000 FCFA per ha for other irrigable lands.

5.3 Volume of agricultural production

5.3.1 Smallholders

The areas of land farmed each year of the development period to 1996 are given in table 3-7 and in table 5-5. Table 5-5 also gives the distribution of smallholder land according to cropping pattern, the average areas cultivated each year at each level of intensity, and the volumes of production of rice, sorghum and maize. These are summarized in table 5-6. At full development, smallholder production from 11 330 ha is forecast to reach 65 000 tons, including 54 000 tons of paddy (83 %), 7 000 tons of sorghum (11 %) and 4 000 tons of maize (6 %).

5.3.2 Mechanized farm

Mechanized farm production, based on 95 : 5 rice to maize cultivated area is given in table 5-6. At full development it reaches 37 000 tons of which 93 percent is rice and the remainder yellow maize.

5.3.3 Production division

The areas of land farmed by the production division are given in table 3-7. Most of these lands are ricelands but some are cultivated to diversified crops in the dry season. By 1997 all such lands are scheduled to have been transferred to small farmers.

Table 5 - 5 AREAS UNDER SMALLHOLDER CULTIVATION AND VOLUME OF PRODUCTION

Year	Irrigable area (ha)	Areas by cropping pattern (ha)			Areas cultivated (average) (ha)												Production (ton)								
					Rice				Sorghum				Maize				Rice			Sorghum			Maize		
					Wet season		Dry season		Wet season		Dry season		Wet season		Dry season										
		Rice-rice	Rice-divers.	Divers divers.	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Wet season	Dry season	Total	Wet season	Dry season	Total	Wet season	Dry season	Total
1980																									
1981																									
1982																									
1983	105			105					67		46		33		23					147	110	257	73	64	137
1984	280	175		105	166		114		67		46		33		23		432	342	774	147	110	257	73	64	137
1985	755	650		105	618		423		67		46		33		23		1 607	1 269	2 876	147	110	257	73	64	137
1986	1 025	650	165	210	774		423		133		163		67		82		2 012	1 269	3 281	293	391	684	147	230	377
1987	1 295	830	210	255	988		540		95	67	156	46	48	33	78	23	2 569	1 620	4 189	410	522	932	205	304	509
1988	1 845	935	460	450	1 159	166	494	114	219	67	349	46	109	33	175	23	3 594	1 938	5 532	683	985	1 668	341	575	916
1989	2 645	1 155	1 040	450	1 468	618	328	423	219	67	600	46	109	33	300	23	5 980	2 676	8 656	683	1 587	2 270	341	925	1 266
1990	3 845	1 955	1 330	560	2 347	774	848	423	222	133	656	163	111	67	328	82	8 811	4 236	13 047	887	2 096	2 983	443	1 222	1 665
1991	5 045	2 710	1 730	605	3 230	988	1 222	540	222	162	810	202	111	81	405	101	11 856	5 826	17 682	974	2 590	3 565	487	1 508	1 995
1992	6 245	3 370	2 230	645	3 995	1 325	1 583	608	124	285	851	397	62	143	426	198	15 025	7 181	22 205	1 128	3 313	4 441	564	1 925	2 489
1993	7 445	4 065	2 670	710	4 313	2 085	1 892	751	165	285	819	646	82	143	410	323	18 511	8 680	27 191	1 218	4 033	5 251	609	2 343	2 952
1994	8 645	5 105	2 830	710	4 418	3 121	2 048	1 271	95	355	715	819	48	178	358	410	22 410	11 228	33 638	1 274	4 337	5 611	637	2 519	3 156
1995	9 645	5 705	3 230	710	4 270	4 218	1 947	1 762	67	383	695	1 012	33	192	348	506	25 865	12 889	38 754	1 296	4 906	6 203	648	2 847	3 495
1996	10 630	6 510	3 410	710	4 104	5 320	2 041	2 191	41	409	540	1 246	21	205	270	623	29 290	14 887	44 177	1 317	5 283	6 600	658	3 061	3 719
1997	11 330	7 210	3 410	710	3 691	6 398	2 044	2 642		450	321	1 465		225	161	733	31 990	16 700	48 690	1 350	5 458	6 808	675	3 163	3 838
1998	11 330	7 210	3 410	710	2 551	7 538	1 368	3 318		450	251	1 534		225	126	767	33 016	17 376	50 392	1 350	5 511	6 861	675	3 191	3 866
1999	11 330	7 210	3 410	710	1 061	8 488	978	3 708		450	78	1 707		225	39	854	33 871	17 766	51 637	1 350	5 650	7 000	675	3 269	3 944
2000	11 330	7 210	3 410	710	665	9 424	455	4 232		450		1 785		225		893	34 713	18 293	53 006	1 350	5 712	7 062	675	3 304	3 979
2001-2030	11 330	7 210	3 410	710	-	10 089	-	4 687		450	-	1 785		225	-	893	35 312	18 748	54 060	1 350	5 712	7 062	675	3 304	3 979

Key parameters

Cropping intensity (mean) - 95 % in wet season
- 65 % in dry season

Yields are maintained at level 1 for 4 years after being brought under smallholder cultivation

Diversified crops consist of two thirds sorghum to one third maize

	Rice (paddy) Wet season	Rice (paddy) Dry season	Sorghum Wet season	Sorghum Dry season	Maize Wet season	Maize Dry season
Yields at level 1,t/ha	2,6	3,0	2,2	2,4	2,2	2,8
Yields at level 2,t/ha	3,5	4,0	3,0	3,2	3,0	3,7

Table 5 - 6 VOLUME OF AGRICULTURAL PRODUCTION

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001 à 2030
MECHANIZED FARM (1)																						
Rice	t		3 541	3 541	3 541	3 541	10 230	12 333	12 333	12 333	14 066	18 924	22 625	22 625	26 565	29 466	32 211	32 211	33 432	33 927	34 422	34 422
Yellow maize	t						602	742	742	742	1 000	1 333	1 578	1 578	1 837	2 059	2 269	2 269	2 380	2 425	2 470	2 470
INTERIM LANDS (2)																						
Rice	t			989	2 684		1 017	5 848	10 361	15 453	14 193	10 574	8 370	9 294	5 113	4 548	3 955					
Yellow maize	t								1 098		1 620	1 260	1 116									
SMALLHOLDERS (3)																						
Rice	t				774	2 876	3 281	4 189	5 532	8 656	13 047	17 682	22 205	27 191	33 638	38 754	44 177	48 690	50 392	51 637	53 006	54 060
Sorghum	t			257	257	257	684	932	1 668	2 270	2 983	3 565	4 441	5 251	5 611	6 203	6 600	6 808	6 861	7 000	7 062	7 062
White maize	t			137	137	137	377	509	916	1 266	1 665	1 995	2 489	2 952	3 156	3 495	3 719	3 838	3 866	3 944	3 979	3 979
TOTAL PRODUCTION																						
Rice	t		3 541	4 530	6 999	6 417	14 528	22 370	28 226	36 442	41 306	47 180	53 200	59 110	65 316	72 768	80 343	80 901	83 824	85 564	87 428	88 482
Sorghum	t			257	257	257	684	932	1 668	2 270	2 983	3 565	4 441	5 251	5 611	6 203	6 600	6 808	6 861	7 000	7 062	7 062
White maize	t			137	137	137	377	509	916	1 266	1 665	1 995	2 489	2 952	3 156	3 495	3 719	3 838	3 866	3 944	3 979	3 979
Yellow maize	t						602	742	1 840	742	2 620	2 593	2 694	1 578	1 837	2 059	2 269	2 269	2 380	2 425	2 470	2 470
TOTAL CEREALS	t		3 541	4 924	7 393	6 811	16 191	24 553	32 650	40 720	48 574	55 333	62 824	68 891	75 920	84 525	92 931	93 816	96 931	98 933	100 939	101 993

(1) see table 5-1 for yields, table 3-7 for areas and table 3-1 for cropping intensities
(2) see table 5-1 for yields, table 3-7 for areas ; intensities as for mech. farm
(3) see table 5-5

The volume of production from production division lands, given in table 5-6, reaches a peak of 16 000 tons in 1990.

5.4 Farm net income

5.4.1 Smallholders

Future farm incomes to participating farmers must compare favourably with incomes under their present system of farming. They should also compare well with incomes from alternative activities to which a farmer may aspire. Thus they should be sufficient after payment of water charges and of all other farm production costs to retain and attract farmers to the irrigation scheme.

Farm budgets for typical 2,5 hectare farms under each of the three cropping patterns are given in table 5-7 and compared with the farm budget for a typical traditional farm in the Anambe basin.

The net cash income before water charges is available for purchase of food, household goods and services and repayment of project costs. Water charges given in table 5-7 are calculated in chapter 10. Their level permits the annual costs of project services to farmers including water distribution to be covered. After payment of water charges, farmers income is approximately double that in the present situation.

5.4.2 Mechanized farm

Capital and operating costs for the hypothetical 1 200 ha mechanized farm are given in table 5-8. Supporting details may be found in report 6.

The farm earns a net income of 55 million FCFA per year after allowing for replacement of farm machinery and farm buildings and equipment, interest charges at 10 percent on capital investment and on working capital, and payment of water charges. The net income rises to 66 million FCFA if interest charges are evaluated at 7,5 percent (as assumed for smallholders). These net incomes represent 13 percent and 15 percent respectively of capital

Table 5 - 7 FARM BUDGETS

	Traditional	2,5 ha rice-rice		2,5 ha rice-divers.		2,5 ha divers.-divers.	
		Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
1. General data							
Area of farm (ha)	16	2,5	2,5	2,5	2,5	2,5	2,5
People	18	5	5	5	5	5	5
Actives (weighted)	10,2	2	2	2	2	2	2
2. Area cropped in mean year (ha)	11	4,0	4,0	4,0	4,0	4,0	4,0
3. Gross value of production (FCFA)	543 600	458 600	614 700	416 400	557 800	363 900	490 700
4. Annual production costs (FCFA)							
Equipment, tools, oxen, etc		57 100	57 100	58 600	59 100	60 300	61 200
Seeds		18 000	21 600	12 200	14 600	3 800	4 400
Fertilizers		18 800	31 200	17 700	31 500	17 300	27 300
Pesticides and chemicals		32 000	34 500	21 000	23 100	13 900	15 600
Total	42 600	125 900	144 400	109 500	128 300	95 300	108 500
5. Net value of production (FCFA)	501 600	332 700	470 300	306 900	429 500	268 600	382 200
6. Family home consumption (FCFA)	151 700	58 600	58 600	53 000	53 000	47 400	47 400
7. Debt service (FCFA)	-	16 800	17 300	16 500	17 000	15 900	16 100
8. Net cash income before water charges (FCFA)	349 300	257 300	394 400	237 400	359 500	205 300	318 700
9. Water charges (FCFA)	-	77 500	155 000	67 500	135 000	57 500	115 000
10. Net income after water charges (FCFA)	349 300	179 800	239 400	169 900	224 500	147 800	203 700
11. Mandays required per year	1 148	236	246	242	249	253	257
12. Net cash income after water charges plus family consumption (FCFA)							
- per man day	436	1 010	1 211	921	1 114	772	977
- per hectare of farm	31 000	95 000	119 000	89 000	111 000	78 000	100 000
- per person	27 800	47 680	59 600	44 580	55 500	39 040	50 220

Note : Item 3 Gross value of production includes only value of agricultural production. Value of livestock production is estimated at 20 % of total farm income in the traditional case, (para. 2.6.6) or around 8000 FCFA per person per year. This is assumed to remain the same after development.

Item 6 Home consumption assumed as follows (cereals make up 80 percent of calorie requirements).

	Rice-rice	Rice-diversified	Diversified-diversified
Rice (kg)	1 412	706	-
Sorghum (kg)	-	420	840
Maïze (kg)		187	374

Home consumption in present situation based on consumption under diversified cropping pattern

Item 7 Value of farm equipment = 187 744 FCFA per 2,5 ha farm (cf report 6, annex 6, table 5)

Interest at 7,5 % = 14 080 FCFA/year

Production credit for wet season crop is based on 60 percent of annual production cost and 7,5 % interest over 6 months

Item 9 Water charges from table 10-6

Table 5 - 8 MECHANIZED FARM
CAPITAL AND OPERATING ACCOUNT (1)

Item	Cost (10^6 FCFA) Financial		Economic
1. Capital costs			
Farm machinery	169,12		
Buildings	56,53		
Equipment, vehicles, generating plant	34,95		
Central workshop (25 % of cost)	26,94		
Minor items and contingencies 10 %	28,75		
Total		316,29	
2. Working capital		116,20	
3. Annual fixed costs			
Depreciation on capital investment	38,66		
Interest on capital investment 10 %	31,63		
Interest on working capital 10 %	11,62		
Permanent staff	23,40		19,56
Central workshop	4,00		3,90
Other	11,31		10,27
Sub total fixed costs		120,62	33,73
4. Annual variable costs			
Seasonal labour	9,30		3,10
Production inputs	49,55		78,72
Maintenance of farm machinery	22,06		22,06
Fuel and lubricants	10,06		7,70
Aerial spraying	21,38		19,25
Other	7,39		8,31
Sub total variable costs		119,74	139,14
5. Total annual costs 3 + 4		240,36	172,87
6. Income from production		369,56	
7. Net income before water charges 6-5		129,19	
8. Water charges at 62 000 FCFA/ha		74,40	
9. Net income after water charges		54,79	

(1) for 1200 ha farm

investment including working capital. However no account has been taken of the capital cost of irrigation works and facilities.

5.5 Processing facilities

5.5.1 Rice mills

Industrial and multi-unit mills will together process all the rice grown by the mechanized farms and the project authority and an estimated 80 percent of smallholder rice production. The total amounts of rice milled each year are given in table 5-9, and amount to 88 percent of the 88 000 tons of paddy produced at full development.

While industrial mills will be established primarily to serve the mechanized farm units, any spare capacity would be available for processing of smallholder and project authority rice production. Some spare capacity will exist for all industrial rice mills in the first years after their construction.

Multi-unit rice mills will be progressively established from 1986 on. Initially the greater part of their throughput will originate from lands farmed by the project authority. The project authority therefore will play an important role in the establishment and initial operation of the multi-unit mills. Twelve mills will ultimately be required.

Industrial mills will have two processing lines each with capacity of 1 ton of paddy per hour ; bulk paddy storage ; finished products storage ; weighing, unloading and handling facilities ; and a power plant fuelled primarily by rice hulls. Drying equipment is not expected to be required. The mill will produce two grades of rice, whole grain and broken, in the proportion of about 70 whole grain to 30 broken for paddy obtained from the mechanized farm. Characteristics and production costs for a typical industrial rice mill are given in table 5-10. As shown in the table, industrial rice mills can operate very profitably at the assumed market price of rice, and would be profitable also at the price of broken rice of 80 000 FCFA/ton.

Table 5 - 9 RICE MILL PRODUCTION

		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001 a 2030
Mill throughput :																					
Mechanized farm and project authority (1)	t	3486	4460	6110	3425	11038	17851	22270	27221	28872	28813	30230	31084	30785	33039	35112	31183	32425	32909	33390	33381
Smallholders (2)	t			619	2298	2625	3350	4426	6922	10437	14144	17764	21751	26906	31002	35341	38954	40315	41311	42403	43246
Total	t	3486	4460	6729	5723	13663	21201	26696	34143	39309	42957	47994	52835	57691	64041	70453	70137	72740	74220	75793	76627
Industrial mills - addition (3)	No	1		1E		1E,2	2E				3	3E		4	4E						
Industrial mills - production capacity	t	5600	5600	6700	6700	15400	17500	17500	17500	17500	23100	28300	28300	33900	38100	→	→	→	→	→	38100
Production capacity required in multi-																					
unit mills - total	t						3701	9196	16643	21809	19857	19694	24535	23791	25941	32353	32037	34640	36120	37693	38527
- right bank	t						3701	9196	16643	17000	17000	17000	17700	→	→	→	→	→	→	→	17700
- left bank	t									4809	2857	2694	6835	6091	8241	14653	14337	16940	18420	19903	20827
Multi-unit mills - right bank	No						2	3	5	6	→	→	→	→	→	→	→	→	→	→	6
- left bank	No									2	2	2	3	3	4	5	5	6	→	→	6
Industrial mill throughput																					
Mechanized farm and project authority	t	3486	4460	6110	3425	11038	15275	15275	15275	15275	18875	22875	24875	27875	31741	33833	30374	31619	32101	32580	32580
Smallholder production	t			619	2298	2625	2225	2225	2225	2225	2225	2225	2225	2225	2359	2267	5726	4981	4999	5020	5520
Total paddy milled	t	3486	4460	6729	5723	13663	17500	17500	17500	17500	21100	25100	27100	30100	34100	36100	36100	36600	37100	37600	38100
Multi-unit mill throughput																					
Project authority production	t						2656	6995	11946	13597	9938	7355	6209	2910	1298	1279					
Smallholder production	t						1125	2201	4697	8212	11919	15539	19526	24681	23643	33074	34037	36140	37120	38193	38527
Total paddy milled	t						3781	9196	16643	21809	21857	22894	25735	27591	23941	34353	34037	36140	37120	38193	38527

(1) Total production less rice for treated seed

(2) Represents 80 % of smallholder rice production ; based on 160 % cropping intensity

(3) E = addition of storage capacity

Table 5 - 10 RICE MILL CHARACTERISTICS AND PROCESSING COSTS[1]

		Industrial mills 2 lines	Multi-unit mills 4 units
Mill capacity (tons of paddy /hour)		2 x 1 = 2	4 x 0,5 = 2
Paddy storage type		Silos	Bags and silos
Paddy storage capacity (tons)		4 000	1 100
Number of shifts		3	1
Volume of paddy milled (tons/yr)		9 800	3 200
Production (tons/year)	white rice 65 %	6 370	2 080
	Bran 13 %	1 274	416
Capital cost (10^6 FCFA) :	Building	30,4	14,3
	Equipment	22,1	11,6
	Storage	108,0	30,4
	Total	160,5	56,3
Working capital		8,5	
Operating costs (10^6 FCFA/year)	Personnel	33,8 (24,26)	8,97 (5,33)
	Insurance	3,43	2,05
	Fuel and oil	2,57	2,79 (2,13)
	Bagging materials	8,91	3,80
	Maintenance	4,49	1,83
	Storage costs	-	3,58 (1,49)
	Minor items 5 %	2,60	1,07 (0,76)
	Total operating costs	54,89 (46,07)	24,09 (15,90)
Depreciation of capital investment	10^6 FCFA/year	8,03	3,40
Interest on capital investment [3]	10^6 FCFA/year	16,90	5,96
Total production costs	10^6 FCFA/year	79,82	33,45
Production costs per tonne white rice	(FCFA/t)	12 531	16 082
Cost of paddy per tonne white rice ($41\ 500 \times \frac{1}{0,65}$)	(FCFA/t)	63 846	63 846
Credit for bran at 5 CFA/kg	(FCFA/t)	- 1 000	- 1 000
Production cost of white rice ex mill	(FCFA/t)	75 377	78 928
Proportion whole grain : broken rice	(%)	70 : 30	50 : 50
Weighted market price (see para 9.2.1)	(FCFA/t)	100 000	95 000
Producer margin	(FCFA/t)	24 623	16 072

Note
1) At producer or financial prices ; economic operating costs in parentheses where these differ
2) Values shown are for the first mill (pilot farm mill) but are typical of all mills
3) Includes interest on working capital

Twelve multi-unit rice mills with capacity of 2 tons of paddy per hour will be established throughout the project area to serve small farmers. Each multi-unit mill will include up to four milling units (0,5 ton per hour capacity) ; storage for white and paddy rice ; weighing and handling equipment ; a small office area and a spare parts storage room. Each mill will be capable of expansion from two mill units to four as production increases in the project area nearest the mill. With four milling units, each multi-unit mill could handle the production from about 600 hectares in a single work shift.

Characteristics and production costs for a 4 unit mill are given in table 5-10.

Multi-unit mills would be owned and operated by farmer cooperatives. The project authority would be instrumental in establishing the mills, training the operators and placing the operation on a sound footing, continuing to take an interest thereafter in a monitoring role.

Following harvest, farmers would transport their crops to the mill where the cooperative would arrange their purchase and at the same time settle the farmers'account with the cooperative, taking payment in kind for previous delivery to the farmer of agricultural inputs. After milling the rice would be marketed through either the cooperatives or through the project authority, or simply sold to the project authority or other responsible agency. Which of these arrangements applies will depend on the level of organisation of the cooperatives and on national policy with regard to rice marketing and distribution. It will be assumed that the cooperatives arrange for sale of their crops through the project authority. Industrial rice mills must be located on all-weather roads as near as possible to the mechanized farm. Multi-unit mills will generally be located in or close to existing villages and close to main roads. Tentative sites for rice mills are shown in figure 5-1. Further details including cash flows for the two milling programmes are given in report 7.

5.5.2 Rice seed treatment

The mechanized farm is assumed to renew half its rice seed with selected and treated seed, whereas small farmers would renew their rice seed once every three years. On this basis the project will require 1 041 tons of seed rice at full development. The addition of a seed treatment plant with a capacity of 0,5 ton/hour at the Pilot Farm rice mill will enable this demand to be satisfied, the plant being operated on a partial two shift basis. Seed rice will be grown on the mechanized farm in fields especially assigned to this purpose.

Characteristics and seed treatment costs are given in table 5-11. The present controlled price for seed implies a subsidy of 15-20 FCFA per kg.

5.5.3 Animal feed centre

Livestock and poultry production is complementary to the mechanized farm and will utilize its products or by-products as major inputs. The output of the animal feed centre will be meat and eggs for sale to personnel working or living on the project and fattened cattle for sale outside the project area.

In addition to providing food for project personnel and cattle for sale, the livestock and poultry enterprises will serve as a demonstration activity whereby farmers in the area can observe the results of using mixed animal feeds containing large amounts of by-products of rice, peanuts, cotton and sorghum to fatten cattle for beef.

At harvest time, the yellow maize will be transported in bulk trailers from the fields and sold to the livestock feeding centre. There it will be weighed and stored in round metal tanks until needed for feeding to animals and fowl. The maize will then be removed from storage and processed through the feed mixing centre. After being ground in a hammer mill it will be mixed with by-products of crops such as the hulls of rice, cotton or peanuts and either peanut or cotton cake as available to make a prepared mixed feed suitable for fattening cattle. The fowl rations will include ground corn, peanut cake, rice bran and fish meal if available. Production of ensilage would provide valuable cattle feed and this should be tried initially on a small scale.

Table 5 - 11 RICE SEED TREATMENT PLANT, CHARACTERISTICS AND PRODUCTION COSTS

Plant characteristics and operating costs [1]			
Seed required at full development		(t/yr)	1 041
Seed required for wet season planting		(t)	568
Plant capacity		(t/h)	0,5
Capacity per shift		(t/yr)	915
Paddy processed at full development at 75 % clean seed		(t/yr)	1 388
Plant utilization		(shift-wks)	79
Paddy storage capacity		(t)	725
Rice seed storage capacity		(t)	75
Capital cost	Building	10^6 FCFA	27,0
	Equipment	10^6 FCFA	7,0
	Total	10^6 FCFA	34,0
Operating cost (10^6 FCFA/yr)	Personnel		3,95 (2,12)
	Fuel and oil		0,70
	Bagging materials		1,70
	Maintenance		1,11
	Storage costs		1,77 (-)
	Chemicals		5,20
	Insurance		0,94
	Minor items 5 %		0,75 (0,59)
	Total operating costs		16,12 (12,36)

Production costs per ton of treated seed			
Cost of paddy at farmgate		FCFA/t	41 500
Additional costs for production of seed rice on mechanized farm		FCFA/t	2 500
Purchase price per ton untreated seed		FCFA/t	44 000
Purchase price of paddy per ton treated seed 44 000 x 1/0,75		FCFA/t	58 667
Processing costs :	Depreciation	10^6FCFA	2,05
	Interest	10^6FCFA	3,40
	Operating costs	10^6FCFA	16,12
	Total	10^6FCFA	21,57
Processing costs per ton treated seed		FCFA/t	20 720
Total costs per ton		FCFA/t	79 387
Less credit for sales to mill of untreated seed		FCFA/t	- 13 833
Net costs		FCFA/t	65 554
Additional costs for unsold seed [2]		FCFA/t	1 926
Distribution costs		FCFA/t	520
Total costs per ton treated seed		FCFA/t	68 000
Producer price of rice seed		FCFA/t	52 000

Notes 1) Economic operating costs in parentheses where they differ from financial costs

2) Sufficient seed is treated to supply the maximum cropped area, costs shown allow for the reduction in demand in years of insufficient runoff

Cattle for feeding (mostly males) will be bought from local farmers on a monthly basis at live weights of 70 to 120 kg, fattened for 12 months, and slaughtered when they reach a liveweight of 280 kg.

The egg laying flock will be established by purchasing sexed baby chicks on a semi-annual basis and growing the males into fryers at about 3 months of age. Female chicks would be grown into layers at about 6 months of age. The layers would be transfered from growing to laying facilities to produce eggs for a period of 12 months, at which time they would be sold as boiling fowl. The male chicks, separated from the female birds, would be grown for meat in adjacent facilities on a 13 week fattening cycle.

The facilities of the livestock center will include grain storage, feed mill, cattle handling facilities, cattle feeding pens, poultry housing, and an abbatoir. A site covering 10 to 20 hectares on a small rise 4 km west of Anambe has tentatively been chosen for the livestock center (figure 5-1).

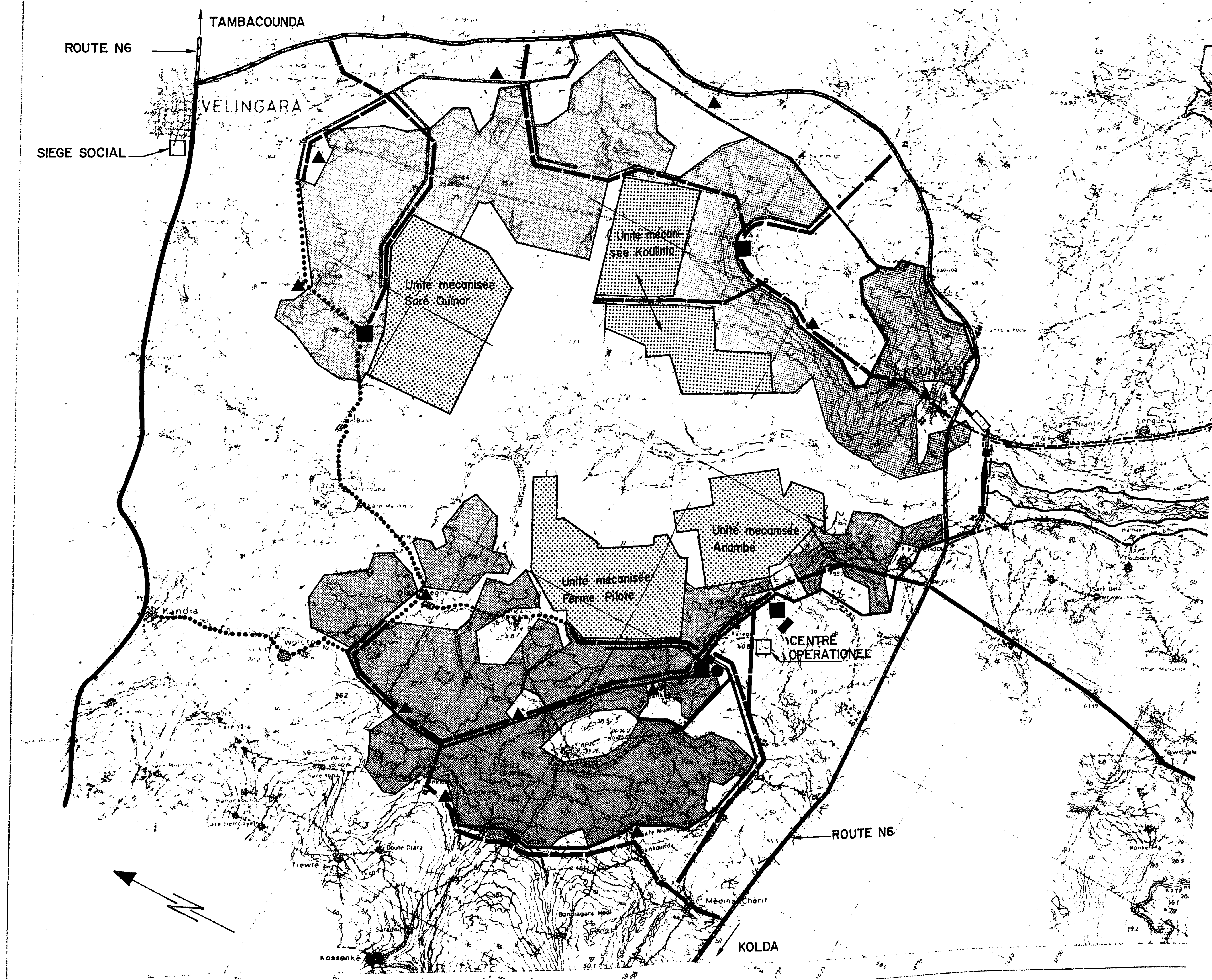
Characteristics and production costs are given in table 5-12 for the animal feed centre at full development. Cash flows are given in report 7. The enterprise as a whole gives a high return on capital invested as well as fulfilling an important demonstration role.

Table 5 - 12 LIVESTOCK FEED CENTRE

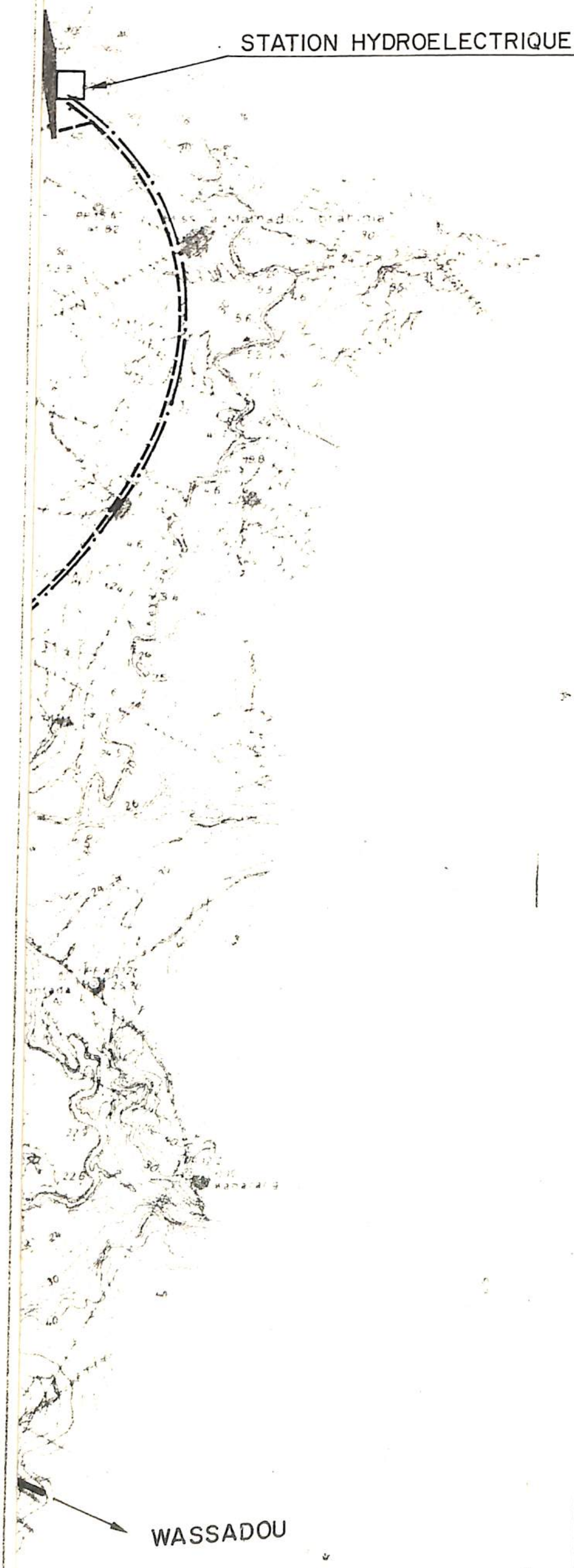
CHARACTERISTICS AND PRODUCTION COSTS AT FULL DEVELOPMENT

		Total	Cattle	Poultry	
				Meat	Eggs
Mill capacity	(t/hr)	2			
Grain storage capacity	(t)	1 500			
Purchases of cattle and chicks per year	(No)		4 682	17 776	2 547
Mortality rate	(%)		5	10	15
Sales	(No)		4 459	16 160	2160 hens 368000 eggs
Maïze consumption per head per year	(kg)		540	3,5	28
Maïze as percentage of ration	(%)		50	70	70
Other major ration ingredients			Rice hulls, cotton seed	Peanut cake, rice bran, fish meal	
Capital cost : Grind and mix mill and mixed feed storage	(10^6 FCFA)	30,0	28,0	0,8	1,2
Grain storage		20,0	19,0	0,4	0,6
Confinement facilities, handling equipment		23,5	18,5	2,0	3,0
Water system, abattoir		4,5	4,0	0,2	0,3
Total		78,0	69,5	3,4	5,1
Working capital : Livestock and poultry inventory	(10^6 FCFA)	94,6	93,6	0,2	0,8
Feed inventory		113,7	105,9	1,5	6,3
Other		49,4	45,7	0,6	3,1
Total		257,7	245,2	2,3	10,2
Depreciation on capital investment	(10^6FCFA)	6,58	5,80	0,31	0,47
Interest on capital investment,10%	(10^6FCFA)	7,80	6,95	0,34	0,51
Interest on working capital , 10 %	(10^6FCFA)	25,77	24,52	0,23	1,02
Total fixed costs	(10^6FCFA)	40,15	37,27	0,88	2,00
Fixed costs per animal/bird	(FCFA)		8 358	55	924
Variable costs per animal/bird 1)	(FCFA)				
Feed			23 760	300	3 084
Other variable			10 240 (8000)	150	1 416
Total			34 000 (32000)	450	4 500
Total production costs per animal/bird	(FCFA)		42 358	505	5 424
Purchase price young animal/bird	(FCFA)		20 000	100	200
Animal product (gross)			280kg	1,4kg	170 eggs + 1 hen
Value per unit	(FCFA)		250	500	50 per egg 600 per hen
Gross revenue	(FCFA)		70 000	700	9 100
Margin over purchases and production costs	(FCFA)		7 642	95	4 400

1) Economic costs in parentheses



TAMBACOUNDA
ROUTE N6
VELINGARA
SIEGE SOCIAL
Unité mécanisée Sare Quinor
Unité mécanisée Koulinto
KOUNKANE
Unité mécanisée Anambe
Unité mécanisée Ferme Pilote
Kandia
CENTRE OPERATIONEL
ROUTE N6
Médina Chérif
KOLDA
Kossanké
N



AMENAGEMENTS

- RIZERIE VILLAGEOISE
- RIZERIE INDUSTRIELLE
- CENTRE D'ALIMENTATION DU BETAIL
- TRAITEMENT DES SEMENCES
- PERIMETRE IRRIGUE (1 – 2) 1_PAYSANNAT 2_MECANISE
- BARRAGE AVEC RETENUE
- STATION DE POMPAGE
- BASSIN DE COMPENSATION
- CONDUITES DE REFOULEMENT
- CANAL PRINCIPAL BETONNE
- ROUTE D'ACCES
- LIGNE DE TRANSMISSION
- PISTE PRINCIPALE
- PISTE PRINCIPALE (EXTENSION)

INFRASTRUCTURE EXISTANTE

- ROUTE NATIONALE
- PISTE PRINCIPALE

REPUBLIQUE DU SENEGAL
MINISTERE DU DEVELOPPEMENT RURAL
SODAGRI

AMENAGEMENT DU BASSIN DE L'ANAMBE

INFRASTRUCTURE GENERALE

ELECTROWATT
INGENIEURS-CONSEILS S.A.
ZURICH - DAKAR

DESS	CONT	VISA
NIANG.		

ECHELLE	DATE	NUMERO DU PLAN	ANNEXE
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6. COMPLEMENTARY DEVELOPMENT

6. COMPLEMENTARY DEVELOPMENT

6.1 Introduction

The present chapter considers the environmental impact of the project and, where this may be detrimental, proposes mitigating measures.

The Anambe Basin development project described in this report is not, and does not attempt to be, an integrated development plan for the Basin as a whole. Such a plan would require a range and programme of data collection and evaluation beyond the scope of this study. However it is instructive to sketch the broad outlines of such a plan as indicated by present information and to view the project within such a framework. This is done in the last section of the present chapter.

6.2 Kayanga valley downstream of Niandouba

The proposed operation of the Niandouba storage scheme will result in a major reduction in wet season flow in the Kayanga and a small increase in dry season flow. But, more importantly, the variation in dry season flow between years and between the early and later part of the season will be virtually eliminated. Compensation releases are given priority above irrigation releases in the operation studies in order that the population in the Kayanga valley may also benefit from the project and so as to ensure preservation of the ecology of the river. Increased flood protection will be a further benefit to downstream villages.

A reconnaissance soil survey was carried out over some 39 000 ha of the Kayanga valley between the dam site and the frontier with Guinea-Bissau. It was concluded that areas of land suitable for rice cultivation are relatively small and scattered. The cost of developing land for irrigation is unlikely to be justified for a single crop per year. But lands suitable for double-cropping of rice and close to present populations merit further study. Such lands occur on the floor of the Kayanga valley and comprise some 500 ha. Spills from the reservoir at the end of the wet season would cause crop damage in these areas in wetter years. Larger areas of land are suitable for irrigated diversified crops although pumping costs will be greater as these lands lie at higher elevation.

It may be concluded that there is potential in the Kayanga valley for some small irrigation schemes based on dry season pumping from the river, similar to schemes in operation on the Senegal River. The water demands from such developments are most unlikely to exceed the available water supply in the foreseeable future.

6.3 Niandouba reservoir

The impact of the project on population and cultivated land in the reservoir area and the compensation for unsettlement are described in section 7.6.

The ecological impact of the reservoir will be reduced by clearing the area of standing timber. The costs of this operation have been accounted for with the cost of the dam.

There is only one important crossing of the Kayanga, that at Velingara Pakane (Koutyidi), linking Paroumba and Linkering (figure 2-2). This road is due to be upgraded soon under a rural works programme. The budget for improvement of this road should be transferred to development of a new link between left and right banks of the Kayanga, either over Niandouba dam or at some point such as Missira Mamadou Ibrahima just downstream.

6.4 Livestock

The Anambe Basin has about 70 000 ha of wooded savanna and grassland, much of it potentially good grazing land, of particular importance in the dry season when watering points and pasture become increasingly scarce in the region.

Based on studies of the value of the natural pasture (IEMVT, 1970) SOMIVAC estimate that in the Kounkane arrondissement the stocking capacity is 70 percent of the maximum during the wet season but over 200 percent of the maximum during the dry season. They estimate the dry season carrying capacity of the Anambe Basin at 8 300 UBT or about 10 000 head of cattle. This compares with an estimated cattle population of many times this figure (table 2-16).

In addition to overstocking, dry season cattle herding is characterized by long travel distances to watering points. Daily marches of 15 km are quite usual. The energy expended requires additional feed,equivalent to about one fodder unit per head,whereas the daily maintenance requirement is 3 fodder units for a cow in milk or a young animal and about 4 fodder units for a productive animal. Substantial weight loss occurs during the dry season, particularly during the last three months from mid March to mid June when water requirements of cattle double and natural water sources dry up.

The Anambe Basin project will influence food and water supplies for livestock :

- by removing 16 400 ha of wooded savanna from use as dry season pasture
- by providing watering points for cattle on the periphery of the irrigation perimeter
- by modifying the soil moisture regime outside the irrigation perimeters over about 10 000 ha comprising wooded savanna, cultivated land and the central floodplain
- by producing large amounts of crop by-products which can be fed to cattle

The 16 400 ha to be cleared support a livestock population of 2 340 UBT at an average stocking capacity of 7 ha per UBT (IEMVT estimate). Crop by-products from the future irrigation perimeters will amount to an estimated 25 million forage units per year and if 50 percent were exploited and combined with other feed to provide a proper ration, they could support over 12 000 UBT. The increased moisture supply which will be available to natural vegetation in the dry season is difficult to estimate. Nonetheless the 2 500 ha of central floodplain alone would support about 2 500 UBT over the most critical period (at 1 ha/UBT for floodplain grassland, IEMVT value). On balance dry season food supplies will be increased.

Watering points along the main canal network will provide water for livestock during the irrigation season, from January to the end of April. Thereafter cattle will seek water initially along drainage paths and subsequently in the centre of the Basin where moisture will be available throughout the year.

The present grazing pattern will therefore be slightly modified. Following the wet season cattle will remain to graze and water nearer their village base, receiving greater rations of hay and other crop by-products, and benefitting from reduced travel distances in search of feed. During the second half of the dry season cattle will descend to the Anambe River and Waĩma Lake in search of water and pasture, as well as feeding on crop residues provided from the dry season harvest.

A number of other measures can be taken to improve the value of grazing land and the health and value of the herd :

- controle of indiscriminate forest fires, particularly late fires from mid-February onward
- control of grazing intensities on natural pasture
- provision of cattle inspection points, cattle dips, and mineral licks at watering points
- control and supervision of mating and calving to improve the breed
- elimination of old and unproductive animals
- improvement of natural pasture (eg by introduction of stylosanthes spp.)
- conservation of wet season forage as silage
- improvements in market prices and the marketing system.

The last measure require stimulation of the economy in general to generate more purchasing power. Prospects for this are uncertain in the foreseeable future.

6.5 Forestry development

6.5.1 Present use of forested land

The Anambé Basin lies close to the boundary between Sudan and Guinea savanna. Its vegetation would ve classed as Sudano-guineen under the commonly used

West African terminology. It owes its character not only to climate but also to the effects of bush fires, removal of branches for animal feed and to the grazing of cattle and trampling of hooves.

The volume of standing timber is estimated to average 35 m^3 per ha ranging from thick scrub to tall trees, the latter being retained for shade and for their economic value when the forest is cleared.

The forest is primarily used as a source of fuelwood for the local population and as grazing land. Previous studies (IEMVT, 1970) estimated the stocking intensity at 0,86 UBT per ha. Natural growth of the forest could exceed 1 stere per ha (1 stere = 1 m^3 of stacked timber) but under present conditions is likely to be closer to 0,5 stere per ha.

It is clear from a comparision between the description of the forest population in 1952 and a survey of the present population that the Anambe classified forest has suffered from these influences.

6.5.2 Impact of the project

The project envisages the clearance of 16 400 ha of forest spread over 15 years. This area carries a volume of standing timber estimated at about 665 000 m^3, corresponding to 950 000 steres of firewood or the equivalent amount of charcoal, and 66 000 m^3 of quality timber suitable for woodworking or utilisable in construction. In energy terms this resource represents 417 GWh or 28 GWh per year over 15 years. Used as firewood or converted to charcoal it could theoretically satisfy 80 percent of the energy requirements of the population of the Basin including the town of Velingara during the 15 year development period. The present population, estimated at 44 000 persons, is expected to grow at 3 percent per year and to require 1,5 stere (0,95 m^3) per person per year.

In the context of the overall resources of the Basin, it is essential that the cleared timber be utilised. This will enable at the same time :

- preservation of the remaining forest and thereby conservation of the environment

- reduction of land clearance costs by an estimated 38 000 FCFA per ha
- collection of revenues averaging about 12 000 FCFA per ha for the right to exploit the forest

The Anambe classified forest covers a part of lands considered most suitable for irrigation and therefore presents a hindrance to the proposed development of the left bank perimeter. It will therefore be necessary to declassify the part of the forest which is in competition with the irrigation development and to replace this with at least an equivalent area elsewhere in the Basin.

6.5.3 Forestry development

The following development of the forest resources of the Basin will be carried out in parallel with irrigation development :

- protection and improvement of the existing forested areas
- establishment of plantations for fuel wood to compensate for the areas lost
- provision of grazing for cattle in forested land
- provision of shelter belts and line plantations within the irrigation perimeters

The remaining forest population will be placed in one of three categories, depending on the projected use of the land :

a) the Anambe classified forest covering 6 870 ha, divided into 8 blocks evenly distributed around the development area

b) the protected forest comprising the remaining 55-60 000 ha of forested land in the Basin

c) the nature reserve covering an area of about 2 500 ha below elevation 21,50 IGN

In parallel with the protection of the natural forest, some reafforestation of land that is presently under cultivation or in fallow is required. Land abandonned by farmers who find farming on project lands more profitable would be the first to be replanted with trees. Species with high yields will be introduced. On the basis of trials is similar areas the following yields from managed plantations may be expected

Species	Yield (m^3/ha/year)	Cutting cycle (years)
Eucalyptus spp	15-20	6-8
Gmelina	0-12	10-12
Bamboo spp	15-20	4-5

Within the irrigation perimeters where rice is grown on submerged or saturated soil, conditions are unfavourable for establishing a full network of windbreaks. These would also interfere with cultural operations. On the other land shelter belts and line plantations are envisaged along main roads, along secondary roads in smallholder farmed areas, along main drains and cattle trails and around the periphery of the development area.

6.6 Fisheries

No data have been obtained on the value of the Kayanga as a fishery resource. Current fish production appears to be small, however.

Construction of Niandouba dam and provision of a guaranteed dry season flow downstream will help conserve fish population and may lead to greater dry season fishery activity.

The management of Niandouba reservoir precludes any very significant fishery benefits. The reservoir area of 85 km^2 at maximum storage level will decrease annually to an average of about 20 km^2, and will frequently fall to 10 km^2. However, establishment of a fishery program in the reservoir would provide a useful supplementary income in the dry season for bordering villages.

The fishery program in Niandouba reservoir would require elimination of undesirable fish species prior to impoundment and the clearing of undesirable aquatic plants from the reservoir area that would also influence later yields. Following impoundment, initial stocking of the reservoir with desirable adapted species would be a requisite to establishment of a viable fishery. After the establishment of fish, the harvest would increase for a few years, but may then decrease due to a decline in the early optimum habitat conditions. Annual stocking of desirable fish species and minimal management practices will insure that desirable species will be harvested annually. The average annual yield for the reservoir is estimated at 30 kg per hectare. The value of the fish harvested is estimated as follows :

Average reservoir surface area	5 000 ha
Yield of fish	30 kg/ha
Annual fish harvest	150 000 kg
Value of fish harvest at 150 FCFA/kg	22,5 x 10^6FCFA
Production costs at 50 FCFA/kg	7,5 x 10^6FCFA
Net value of fish harvest	15,0 x 10^6FCFA

The opportunities for inland fisheries created by the project merit more detailed attention. For the present study the potential benefits have not been included in the economic evaluation.

6.7 Health

Development of rural infrastructure and cooperation, greater farm incomes and a more stable food supply will create conditions having important beneficial influences on health. On the other hand the construction of reservoirs, canals and drains creates an environment favouring the increase of the vectors of certain tropical diseases which depend on water during some stage of their cycle. Schistosomiasis or bilharzia will be the greatest risk to health.

Measures to be taken to ensure the health of project farmers and employees, will include a survey of present conditions ; adoption of water management practices which discourage the development of favourable sites for waterborne disease ; a scheme for regular epidemiological surveillance of the population and suspected sites, combined with health education at village level ; and promotion of village dispensaries for drug distribution.

6.8 Integrated Basin development

The Anambe Basin and its resources serve the following ends :

- production of food to meet local requirements
- production of crops for cash to meet other household requirements
- production of pasture and crop by-products to maintain, albeit in adequately, the existing cattle population
- production of fuelwood for local needs

The present system is by no means in equilibrium. Forests are being improverished by the combined actions of man,cattle and fire. Agriculture and herding compete for forest land,resulting in over grazing and the consequent danger of erosion. Fallow land represents a decreasing proportion of cultivable area, with consequent risk of decline in soil fertility and loss in land productivity. The impact of increasing fuelwold requirements, to satisfy both local demand and before long also the demand from less well endowed areas of Senegal is likely to accelerate the decline and disappearance of the remaining natural vegetation.

The measures which must be taken to arrest and reverse the decline of the environment are :

- development of irrigated agriculture over a gross area of about 19 000 ha as presented in this report
- preservation of extensive areas of woodland on the shallow lateritic soils around much of the periphery of the Basin
- creation of classified forest blocks from the remaining forested land in the zone between 30 m and 45 m IGN
- creation of plantations for fuelwood production on land presently under cultivation or in fallow
- provision of improved pasture in managed forests and strict control of stocking capacity on all natural pasture

- production of wet season fodder crops on presently cultivated lands and their conservation as hay or silage
- soil and water conservation measures, including development for cultivation of the radial watercauses above the irrigation perimeter along the lines envisaged by GERCA in 1962.

If these measures are taken, further extension of cultivated area will be confined to the irrigation perimeters and the peripheral valleys and depressions. Some reduction in cultivated area on the plateaux in favour of managed fuelwood plantations is envisaged. Cattle would be fed on a mixed diet of crop by products and hay or silage, as well as being allowed controlled grazing of uplands and bottom lands.

The irrigation project therefore plays a vital and integral role in preserving the land and forest resources of the Basin. Viewed in the light of a tentative Basin development plan the project serves the long term needs of the Anambé Basin as a whole.

7. ORGANISATION AND MANAGEMENT

7. ORGANISATION AND MANAGEMENT

7.1 Project authority structure

The success of large scale irrigation projects rests upon a number of factors : availability of suitably qualified technical staff, timely provision of all inputs, complete control of water from headworks to the farm ditch, liaison between farmer, canal supervisor, extension worker and management, and the adequate maintenance of all project works. The establishment of an efficient organisation is thus required to plan and administer such a project.

Responsibility for agricultural development of the Anambé Basin has been vested in SODAGRI who will plan and direct the Anambé project as the project authority, or the Anambé Basin Development Authority as it may be designated. This authority will be directly responsible to the Minister of Rural Development and Water Resources.

The structure and functions of the Anambé Basin Development Authority are shown on figure 7-1.

The Director General has complete responsibility for all operations. He delegates authority to departmental chiefs according to the various technical and administrative functions under their control, and ensures coordination of their activities.

There are four departments under the Director General, each with a chief of department :

- Engineering,
- Mechanized Farm,
- Agriculture and Extension ; and
- Business and Administration

In addition, at least during the development period, a Planning and Evaluation Unit is provided which is directly responsible to the Director General and whose main function is to report on the achievement of project objectives and recommend new approaches.

7.2 Departments of the project authority

7.2.1 Engineering

The engineering department will be responsible both for administration of major construction and for the direct design and construction of small rural works as required outside the main construction programme. It will also be responsible for water management and maintenance of irrigation works and facilities.

7.2.2 Mechanized farm

The mechanized farm department comprises on the one hand the operations division, with production sections including the four mechanized farm units, the animal feed farm, and the rice mills serving the mechanized farm, and on the other hand the support services. The latter consist of those services required by some or all of the production sections which can be provided most efficiently from a centralized pool or those services which require coordination either with other departments within the authority or with outside agencies. Such services include procurement of agricultural inputs, marketing, training of personnel, and crop protection by aerial spraying.

Day to day management of the production sections is assured by farm or mill managers. However the project authority,through the chief of the department, is responsible for coordination, planning and financial control and logistic support as necessary.

7.2.3 Agriculture and extension

The agriculture and extension department is divided into four divisions :

- research and extension services ;
- small farmer relations ;
- support services ; and
- production

The last division is concerned with farming lands which have been newly developed and are to be transferred to small holders as soon as possible. The pace of land development will initially exceed the rate at which small farmers can be settled on new lands and as a result the lands temporarily farmed by the project authority will increase to a peak area of 2 735 ha in 1989/1990, declining thereafter to zero in 1997. As the area farmed by the production division is reduced, the personnel and equipment of the division will be gradually incorporated into the mechanized farm production units or into the support service divisions of the mechanized farm and agriculture departments.

A research substation will be set up in the Anambé Basin to complement the research station at Djibelor and the substation at Sefa in Lower and Middle Casamance respectively. It will emphasize trials in those fields which are of particular importance to project development and where the results of research elsewhere are of least application (see report 12, annex 3).

The structure of the extension services reflects a parallel organization of small farmers' cooperatives. Village extension agents maintain direct contact with farmers and small farmer groups. They are supervised by extension officers who in turn are responsible to two chief extension officers responsible for the left and right bank irrigation perimeters, respectively.

The division responsible for small farmer relations fulfils the following functions :

- compensation to farmers for buildings and agricultural lands affected by project development, in coordination with local authorities ;
- land allocation and settlement ;
- organization, support and supervision of cooperatives ;

- distribution of agricultural inputs ; and
- arrangement of credit for small farmers, and recovery of debts.

Figure 7-2 shows the organisation of the research and extension services and the parallel organization of cooperative supervisors who are part of the small farmer relations division.

Support services include crop planning, mechanization (initial land preparation, equipment trials, tractor hire), hydrometeorological data collection, storage, processing and crop protection.

7.2.4 Business and administration

The business and administration department comprises commercial administration and financial divisions. The first is concerned with coordinating with the mechanized farm and agriculture departments with regard to orders for agricultural inputs and the collection,processing and marketing of production. The administration division is responsible for personnel, health, housing, training, and community relations. The financial division handles accounts, financial control, water charges and credit.

7.3 Personnel requirements

Personnel requirements for project operation and management are given in table 7-1. At full development the full-time staff required may be categorized as follows :

Senior managers	39
Junior managers/technicians	77
Foremen, supervisors, storekeepers, millers, power plant operators	83
Artisans	36
Office staff-secretarial, clerical, technical	41

Table 7 - 1 STAFFING SCHEDULE

DEPARTMENT	DIVISION	SECTION	TITLE	NUMBER BY PHASE I	II	III	IV	V	FULL DEVT.	OFFICE	HOUSE	TRANSP.
DIRECTION			Director general	1	1	1	1	1	1	V	A	Car
			Deputy director		1	1	1	1	1	HQ	A	Car
			Secretary	1	1	1	1	1	1	V		
			Receptionist		2	2	2	2	2	V/HQ		
			Typist	1	2	2	2	2	2	V/HQ		
			Messenger	2	2	2	2	2	2	V/HQ		
			Chauffeur	1	2	2	2	2	2	V/HQ		
ENGINEERING			Chief of department		1	1	1	1	1	HQ	A	4 WD
	CONSTRUCTION	Construction Supervision	Civil engineer	1	1	1	1	1		HQ	A	4 WD
			Technical assistant		1	1	1	1		HQ	C	Pick up
	OPERATION AND MAINTE-NANCE	Small works	Civil engineer						1	HQ	A	4 WD
			Technical assistant						1	HQ	C	Pick up
			Topographer	1	1	1	1	1	1	HQ	C	4 WD
			Assistant topographer		1	1	1	1	1	HQ		
			Draughtsman	1	1	2	2	2	2	HQ		
		Water management	Water master	1	1	2	3	4	4	HQ	B	Pick up
			Canal supervisor	3	5	9	13	18	18	COOP	C	Moby-lette
			Station supervisor	1	2	3	4	4	4	HQ	B	Pick up
			Station assistant	1	2	3	4	4	4			Moby-lette
			Guard	2	4	5	6	6	6			
		Maintenance unit	Chief of maintenance		1	1	1	1	1	HQ	A	Pick up
			Maintenance engineer	1	1	1	1	1	1	HQ	A	Pick up
			Technicians		1	1	2	2	2	HQ	C	Moby-lette
			Foremen	1	2	2	3	3	3			
			Mechanics	1	2	2	3	3	3	HQ	C	Moby-lette
			Drivers	2	5	9	12	15	15			
			Artisans	2	4	5	6	8	8			
			Labourers	5	10	15	25	30	30			
MECHANISED FARM			Chief of department		1	1	1	1	1	HQ	A	Car
	OPERATIONS	Mechanized farms 1 - 4	Farm manager	1	2	2	3	4	4	(Farm)	(A)	(P-Up)
			Assistant manager	1	2	2	3	4	4	(Farm)	(B)	(P-Up)
			Clerical assistant	1	2	2	3	4	4	(Farm)	(B)	(Mobyl)
			Storekeeper	1	2	2	3	4	4	(Farm)	(C)	(Mobyl)
			Mechanic	1	2	2	3	4	4	(Farm)	(B)	(Mobyl)
			Assistant mechanic	1	2	2	3	4	4	(Farm)	(C)	(Mobyl)
			Driver	12	28	28	46	62	62			
			Guard	1	2	2	3	4	4			
			Labourer (1)	12	28	28	46	62	62			
		Rice mills 1 - 4	Mill manager	1	2	2	3	4	4	(Mill)	A	Pick up
			Senior clerk	1	2	2	3	4	4	(Mill)	C	
			Junior clerk	1	2	2	3	4	4	(Mill)	C	
			Typist	1	2	2	3	4	4	(Mill)		
			Shift supervisor	2	6	6	9	12	12	(Mill)	C	
			Mechanic	2	6	6	9	12	12	(Mill)	C	Mobyl.
			Power plant operator	2	6	6	9	12	12	(Mill)		
			Miller	4	12	12	18	24	24	(Mill)		
			Labourer (1)	20	60	60	90	120	120			

(1) Part time labour not included

Table 7 - 1 STAFFING SCHECULE (cont.)

DEPARTMENT	DIVISION	SECTION	TITLE	NUMBER BY PHASE I	II	III	IV	V	FULL DEVT.	OFFICE	HOUSE	TRANSP
MECHANIZED FARM	OPERATIONS	Animal feed centre	Farm manager		1	1	1	1	1	(Farm)	A	Pick up
			Clerk		1	1	1	1	1	(Farm)	C	
			Typist		1	1	1	1	1	(Farm)		
			Mechanic		1	1	1	1	1	(Farm)	C	Mobyl.
			Cattle buyer		1	1	2	2	2			
			Cattle hand		5	8	11	14	14			
			Poultry hand		2	3	4	5	5			
			Labourer		2	3	4	5	5			
			Guard		2	2	2	2	2			
	SUPPORT SERVICES	Central workshop	Workshop manager	1	1	1	1	1	1	HQ	B	Pick up
			Mechanic	1	2	2	3	4	4	HQ	C	Mobyl.
			Assistant mechanic	1	2	2	3	4	4	HQ		
			Clerk	1	1	1	1	1	1	HQ	C	
			Typist	1	1	1	1	1	1	HQ		
			Guard	1	1	1	1	1	1			
		Coordination	Coordinator		1	1	2	2	2	HQ	B	Mobyl.
			Typist		1	1	1	1	1			
AGRICULTURE AND EXTENSION	RESEARCH AND EXTENSION	Research	Chief of department		1	1	1	1	1	HQ	A	Car
			Chief of division		1	1	1	1	1	HQ	A	Pick up
			Agricultural engineer	1	1	1	1	1	1	HQ	A	Pick up
			Agronomist/soil scientist	1	1	1	1	1	1	HQ	A	Pick up
			Soils technician	1	1	1	1	1	1	HQ	C	Moby-lette
		Extension service	Chief extension officer		1	1	2	2	2	HQ	B	Pick up
			Extension officer	1	3	7	10	14	14	Coop	C	Moby-lette
			Village extension agent	10	25	40	50	60	60			Bicycle
	SMALL FARMER RELATIONS	Compensation and land settlement	Surveyor	1	4	4	4	4		HQ	C	Pick up
			Surveyor's assistant	1	4	4	4	4		HQ		
			Sociologist (part time)		1	1	1	1				
			Draughtsman	1	2	2	2	2		HQ		
		Cooperative service	Chief cooperative supervisor		1	1	2	2	2	HQ	B	Pick up
			Cooperative supervisor	1	3	7	10	14	14	Coop	C	Moby-lette
	PRODUCTION DIVISION		Chief of division	1	1	1	1	1		HQ	A	Pick up
			Section manager	1	2	3	3	2		HQ	A	Pick up
			Assistant manager		1	2	2	1		HQ	B	Pick up
			Clerical assistant	1	2	3	3	2		HQ	C	
			Storekeeper	1	2	2	2	2		HQ	C	
			Mechanic	1	1	2	2	1		HQ	C	Moby-lette
			Assistant mechanic		1	3	3	2		HQ		
			Driver	6	14	36	36	22				
			Labourer	6	14	36	36	22				

Table 7 - 1 STAFFING SCHEDULE (cont.)

DEPARTMENT	DIVISION	SECTION	TITLE	NUMBER BY PHASE I	II	III	IV	V	FULL DEVL.	OFFICE	HOUSE	TRANSP.
AGRICULTURE AND EXTENSION	SUPPORT SERVICES	Crop planning	Agronomist		1	1	1	1	1	HQ	A	Car
			Clerk		1	2	2	2	2	HQ	C	
		Mechanization	Section manager	1	1	1	1	1	1	HQ	A	Pick up
			Field assistant		2	2	2	2	2	HQ	C	
			Mechanic	1	1	1	1	1	1	HQ	C	Moby-lette
			Assistant mechanic		1	1	1	1	1	HQ		
			Clerk	1	1	1	1	1	1	HQ	C	
			Driver	4	8	11	10	9	8			
			Labourer	4	8	11	10	9	8			
		Hydrometer services	Technician		1	1	1	1	1	HQ	C	Mobyl.
		Other services	Coordinator		1	1	2	2	2	HQ	B	Mobyl.
			Clerk		1	1	2	2	2	HQ	C	
			Typist	1	2	3	4	4	4	HQ		
BUSINESS AND ADMINISTRATION			Chief of department	1	1	1	1	1	1	V	A	Car
			Accountancy/finance expert	1	1	1				V	A	Car
	COMMERCIAL	Bulk purchase storage, etc.	Coordinator		1	2	3	3	3	V	B	Moby-lette
			Storekeeper		1	1	1	1	2	V	C	
	ADMINISTRATION	Personnel, etc.	Personnel manager	1	1	1	1	1	1	V	A	Car
			Personnel assistant		1	2	2	2	2	V	B	Moby-lette
	FINANCIAL	Accounting, etc.	Accountant	1	1	2	2	2	2	V	B	Moby-lette
			Clerks	1	2	3	4	4	4	V	C	
			Typists	1	2	3	4	4	4	V		
PLANNING AND EVALUATION UNIT			Agricultural economist		1	1	1	1		HQ	A	Car
			Technical assistants		2	2	2	2		HQ	C	Moby-lette

Note :

V - Vélingara registered offices
HQ - Operational headquarters
COOP - Cooperative union headquarters
A - House 120 m^2
B - House 60 m^2
C - Apartment unit

Extension agents	60
Drivers, chauffeurs	87
Guards, messengers	15
Labourers	225
Total	663

A further 400 labourers will be employed seasonally, the peak requirement following harvest.

The full-time and seasonal work force is distributed as follows :

	Full-time	Seasonal
Mechanized farm	152	300
Agro-industry	224	100
Operation and maintenance	105	
Extension services	76	
Other project authority	106	

7.4 Training and technical assistance

Development of the project area from its present technical base into a highly productive region will demand expertise both in depth and breadth. Much of the required expertise will be developed through academic training and practical experience as the project develops. However it will be necessary to employ outside experts both as consultants during the construction of project works and thereafter to fill certain key technical and managerial positions. Their tasks would include training of Senegalese professional staff to take over their functions.

The cost of consultancy services provided during construction of the works is allowed for in the provision for costs for engineering, construction supervision and administration. Expatriate technical assistance required for operation and management of the project is given in table 7-2.

Table 7 - 2   TECHNICAL ASSISTANCE SCHEDULE

Title	PHASE I 1962 83 84 85	PHASE II/III 86 87 88 89	PHASE IV 90 91 92	PHASE V 93 94 95 96	Total (man-years)
Agricultural economist	- - - -	——			5
Civil engineer	——	——	——	——	15
Farm manager I	——	——	——	——	15
Farm manager II		——	——		7
Processing manager	- - - -	——	——	——	12
Maintenance engineer	——	——	——	——	15
Agricultural engineer	- - - -	——	——		8
Agronomist/soil scientist	- - - -	——	——	- - - -	9
Accountancy/Finance expert	——	——	——		11
Total (man-years)	20	18 + 18 = 36	24	17	97

- - - - - - - - Part time (25 % of full time)

—————— Full time

The Agricultural Economist will head the planning and evaluation unit.

The Civil Engineer will be required for Phase I to reinforce the project authority during design, tendering and construction of the work. Thereafter he will be responsible for project operation and maintenance as well as for contract administration.

The Farm Manager will be required from the commencement of operation of Phase I. He will be responsible for day-to-day management of the mechanized farm and for training future farm managers. A second Farm Manager will be required from Phase II through to Phase IV when the area under mechanized farming reaches its peak.

The Processing Manager will be initially responsible for operation of both the industrial and multi-unit village mills. He will operate a training programme for mill managers during the period between processing of crops. He will also be responsible for setting up the mix and grind mill for the animal feed farm.

The Maintenance Engineer will be responsible for setting up and running the workshops required for servicing and repair both of the agricultural machinery for the production units and the maintenance equipment of the engineering department. He will also help train Senegalese technicians.

The Agricultural Engineer will be responsible for testing and development of agricultural equipment, both machinery for the mechanized units and animal-drawn implements.

The Agronomist/Soil Scientist will be responsible for running the Anambé research sub-station. He will be employed by ISRA.

The Accountancy/Finance expert will be attached to the business and administration department and be responsible for developing accounting procedures for all decentralized divisions and sections so that financial control and analysis may be applied. He will also help the cooperative unions develop proper accounting methods.

In addition to the experts indicated above, short term technical assistance will be required in the fields of management, training, credit, livestock development, marketing and community development.

The acute shortage of professional staff in Senegal renders it imperative that the project make special provision for the training of Senegalese professional and technical staff so that the expatriate technical advisors required in the early years can be phased out. Once the decision to start construction of the phase II works has been taken, Senegalese counterpart personnel should be recruited and their training needs determined. In most cases one or two years of academic training abroad combined with a few months practical experience at the end of the course will be sufficient. This training period could be scheduled for completion in the early part of phase II. The remaining staff training will be on the job as the personnel assume progressively higher responsibilities. The need for expatriate assistance until the end of phase IV reflects both the growth of the irrigated area to be managed and also the time required to develop local skills in sufficient depth to manage the project.

Shorter term training courses would be provided for key project technical staff, including :

- water masters and canal supervisors ;
- rice mill managers ;
- extension service officers ;
- cooperative officers ; and
- mechanics

Appropriate courses are available at WARDA and IRRI, and other institutions in Senegal (SAED, ISRA, SOMIVAC), or will be provided in-house by technical assistants on long or short-term assignments.

Training will be provided by project personnel or visiting experts to cooperative managers, accountants and storekeepers.

7.5 Construction management

The Anambé project requires the construction of a number of major works at widely different locations in a relatively remote area. Moreover each of these works are elements in the system of water delivery and thus function interdependently. The successful implementation of the project will therefore call for both an experienced contractor and careful construction supervision.

The system of construction management proposed is that recognized by FIDIC (Fédération Internationale d'Ingénieurs-Conseils). Construction supervision is carried out by the Engineer acting on behalf of the Employer. The Engineer supervises the execution of the works to the specifications laid down and is responsible for or approves design changes which arise as the work proceeds. Execution of the works shall be carried out by the Contractor to the satisfaction of the Engineer. The Contractor takes instructions and directions only from the Engineer or his representative on site.

The Engineer acts through a single Contractor. Where specialists and suppliers of equipment have been nominated or selected or approved by the Employer or the Engineer these shall be considered as nominated Sub-Contractors employed by the Contractor. The Contractor would generally be a civil works contractor, the supply and erection of electromechanical equipment being awarded to a nominated Sub-Contractor.

The construction supervision section within the project authority will administer and supervise construction through the Engineer, ensure that the Authority's interests are being followed, approve design changes and coordinate with higher levels in the project authority and in Government.

Ancillary works and facilities not constructed under the main contract include access roads, buildings and stores, houses and processing facilities. Access roads and buildings would probably be tendered for locally. Production facilities will probably be established by the project authority and its consultants who would provide the necessary coordination between foreign equipment suppliers and local builders.

7.6 Compensation to displaced persons

The creation of Niandouba dam and reservoir will result in the flooding of a number of villages and a considerable area of cultivated land. The extent of the reservoir is shown in figure 4-1. Villages and cultivated land are also shown.

The population which will require resettlement after construction of Niandouba dam has been determined with reference to the 38 metre contour, the reservoir level reached by a 1 in 100 year flood. A population estimated at 3 000 people from 22 villages will require resettlement by mid 1985 before the reservoir is scheduled to fill. The area of cultivated land which will be lost is estimated at 2 000 hectares including fallow,or about 1 500 ha of cropped land, affecting a total of 35 villages.

The amount of compensation to be paid will be negotiated at village level. Enquiries have not revealed any general guidelines which are followed in

Senegal. On the river Senegal compensation payments to displaced families have recently been about 100 000 FCFA per family (verbal information from SAED).

Compensation is assumed to be paid on cultivated land, housing and fruit trees lost. Each of the 3 000 persons displaced is assumed to cultivate 1/2 ha of land subject to inundation, from which he receives a net income of 22 500 FCFA (45 000 FCFA per ha),and to occupy 2 m^2 of traditional housing with a value of 4 000 FCFA per m^2. Compensation for cropped land is assumed to be on the basis of two years income. Compensation for land and housing is increased by 10 percent for fruit trees and other items of personal economic value. The resulting compensation payment amounts to 58 000 per person or 175 million FCFA for 3 000 persons. This has been increased to 200 million FCFA to account for communal buildings such as stores and schools.

Compensation payments can be reduced in financial terms by operating a land for land scheme with the farmers to be displaced being offered, say, a 2,5 ha irrigated plot plus additional land assessed according to the area of his previous holding. If it is assumed arbitrarily that 50 percent of farmers accept this scheme the reduction in compensation payment would be 67, 5 million FCFA. A value of 137,5 million FCFA has therefore been adopted as the compensation payment for financial evaluation and 200 million FCFA for economic evaluation.

7.7 Land allocation and settlement

The main beneficiaries from land development in the Anambé Basin will be those who will own and farm the project lands. Clearance and development of lands in the lower lying parts of the Anambé Basin will raise important questions concerning traditional ownership rights. Under the National Land Tenure Law of 1964 (Loi sur le Domaine National) the state in theory has a final claim on all land allocation. Permanent usufruct rights are to be given to those who cultivate the lands and not necessarily to those who traditionally claim to own the land. The potential for conflict between those with a traditional claim to land and those groups or individuals outside the local community to whom land has been allocated must not be underestimated.

Successful settlement of project lands will depend on close coordination with and support from local authorities, notably the Communautés Rurales.

Guidelines for land allocation, including criteria for selecting farmers and for determining the amounts of land to be received by each farmer, have yet to be established. However some general criteria can be stated :

- priority allocation of lands on the irrigation scheme will be to local farmers ;
- the farmers displaced by the creation of reservoirs or by the construction of project works should be offered the opportunity of farming on the Anambé Project, provided that they meet certain other criteria ; and
- some effort should be made to attract farmers with experience of irrigated rice from similar schemes.

Villages will be established as near as possible to the allotted farms, preferably on high lands out of command of the irrigation system or on unirrigable lands within the irrigation perimeters. Sites for new villages will be selected taking into account considerations of health, local sentiment, distance from irrigated lands and local topography.

The project authority will clear the area and provide a reliable source of drinking water, generally a simple village well or wells. Credit would also be available for purchase of materials for house construction. Land clearance costs for new villages are already allowed for by having applied unit rates for clearance to the gross irrigable area. The costs of digging a village well of about 2,50 m diameter to a depth of 12-15 metres is estimated at around 1 million FCFA to serve a village of 250 people or 4 000 FCFA per person. This cost is not considered part of project costs as the value of a safe and sufficient water supply compared with the present unsatisfactory water supply from village wells more than offsets the costs.

7.8 Small farmer organisation

As part of the proposed development plan for the Anambé Basin, the project authority will initially take over ONCAD's role of promoting the establishment of cooperatives and supervising their management and administration. This is in line with recent government policy entrusting the development of the cooperative movement to regional development agencies.

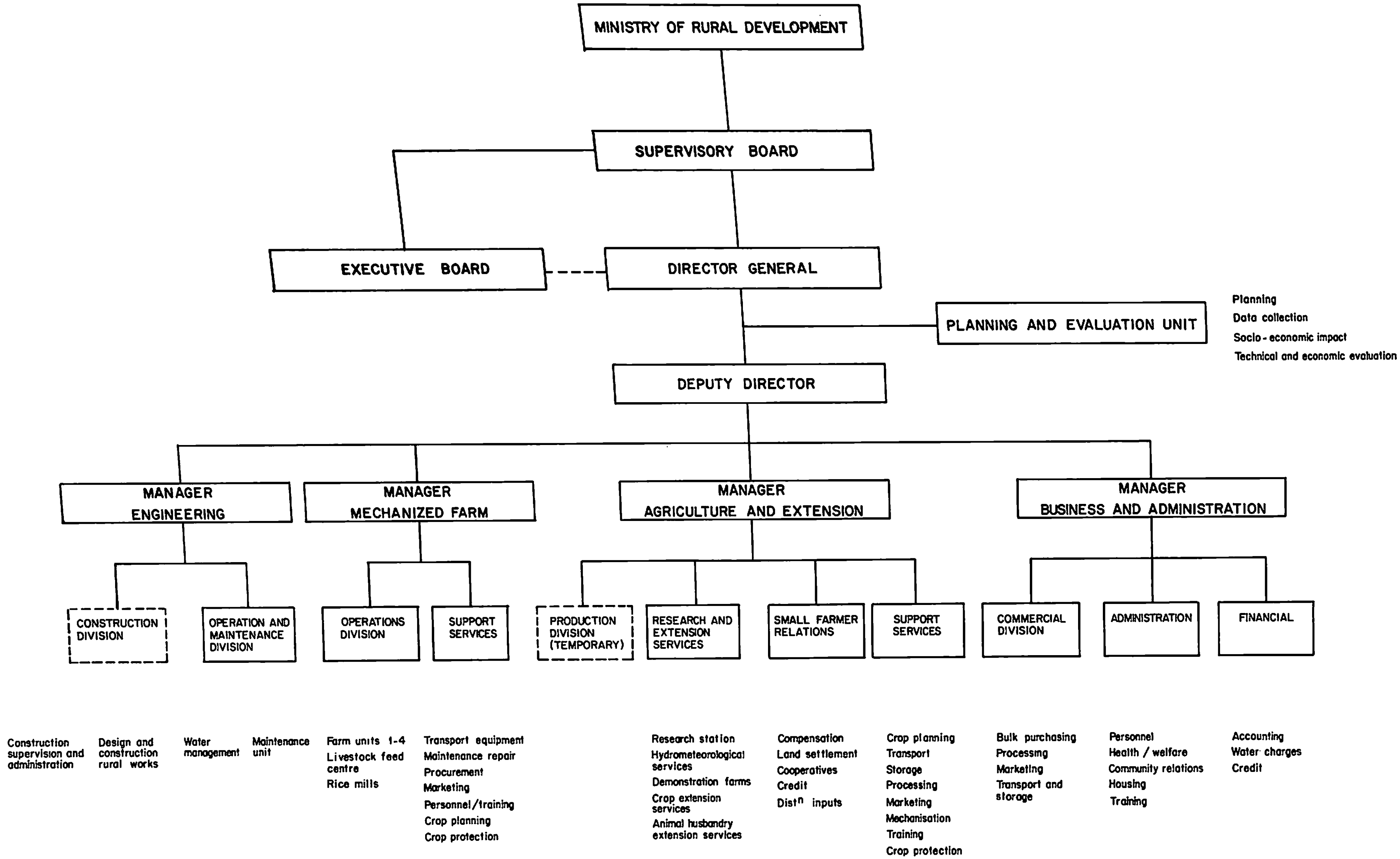
At a future stage of development, once the cooperatives have established their own trained and independent management teams and have acquired the experience of running the various agricultural support services provided to their members, the project authority will relinquish its controlling role and limit itself to the provision of irrigation water and extension advice.

The proposed organization of small farmers is shown on figure 7-3 and corresponds to the perceived needs of the small farmer on the irrigation project. The small farmer group will be composed of those farmers served by a common irrigation offtake and among whom the irrigation supply is rotated in turn. They will cooperate with regard to crop planning, extension advice, distribution of inputs, purchase and use of common equipment and maintenance of common facilities. They must therefore be carefully selected for their ability to cooperate with other farmers in the group.

Village cooperatives provide the base for the village extension agent. The village by virtue of its relative ethnic homogeneity, is a logical base for provision of a range of community services . It is too small a unit, however, to provide input procurement, processing and marketing services to small farmers. These services would be assured by the cooperative unions. Cooperative unions will have an elected body of representatives which will appoint a management team including a manager, an accountant, a storekeeper and a mill manager.

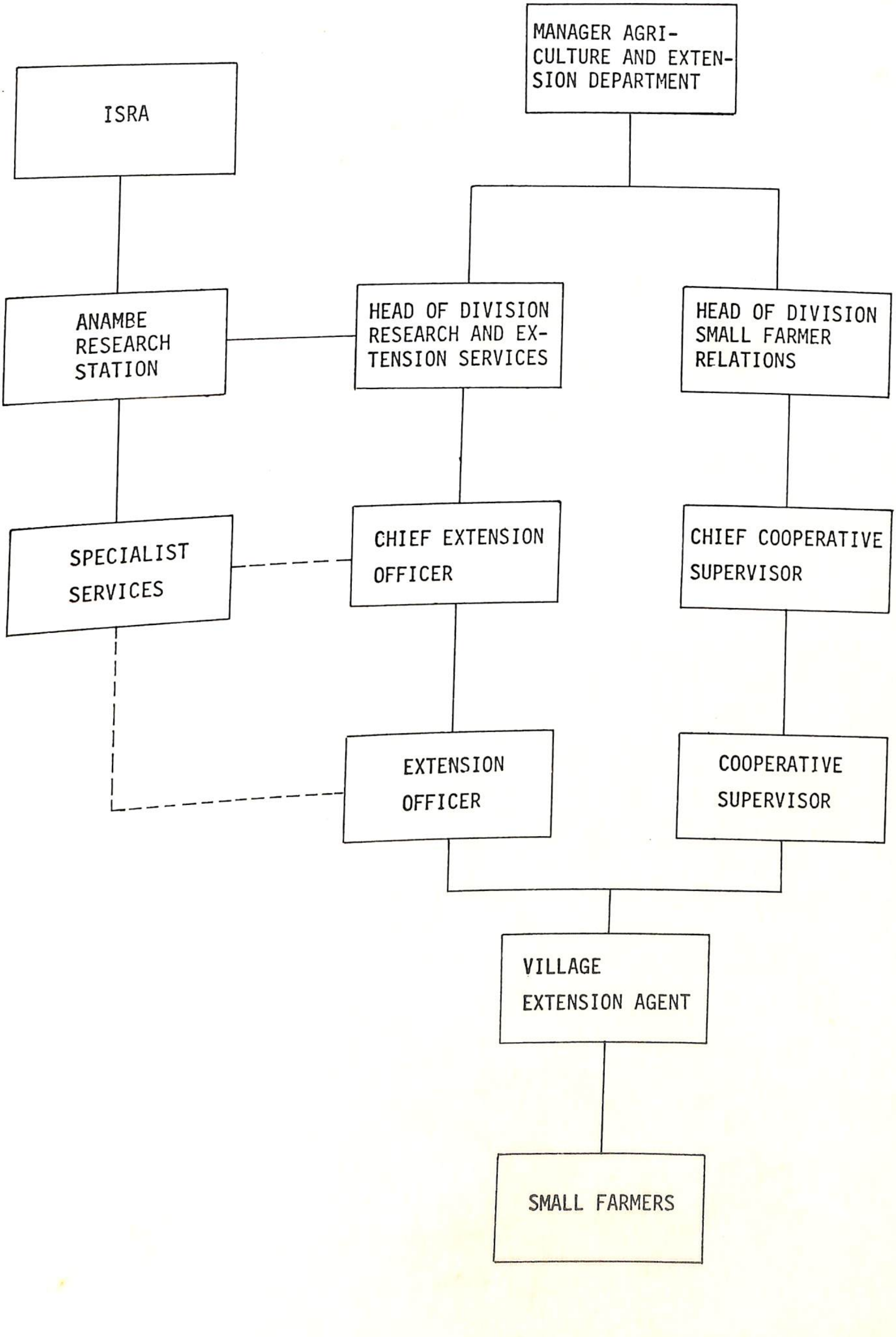
Initially this staff will be selected,trained and supervised by the project authority. Cooperative unions will be equipped with storage facilities, a rice mill, offices and shops. Fourteen cooperative unions are envisaged at full project development, based on the twelve village mills and on two of the industrial size mills.

The cooperative unions will combine to form an association to coordinate their activities.



ANAMBE BASIN DEVELOPMENT AUTHORITY (SODAGRI)
ORGANIZATION CHART

FIGURE 7 - 1



ORGANIZATION OF EXTENSION SERVICES FIGURE 7-2

Routine links with project authority		Cultivated area served (ha)	Cereals production handled (t/yr)
		(indicative values)	
Chief of department Agriculture and Extension	ASSOCIATION OF COOPERATIVE UNIONS	11 000	52 000
Cooperative supervisor Extension officer	COOPERATIVE UNION	800	3 700
Village extension agent	VILLAGE COOPERATIVE	150	700
Village extension agent	SMALL FARMER GROUP	17,5 - 35	80 - 165
	SMALL FARMER	2,5	15

SMALL FARMER ORGANIZATION

FIGURE 7-3

8. COSTS

8. COSTS

8.1 Introduction

In evaluating the costs of the project a distinction has been made between capital costs, the cost of the investment in project works and facilities, and the annual operating costs or recurrent costs. Capital costs include construction costs of works, general costs and the costs of buildings and equipment for the mechanized farms and agro-industry facilities. Recurrent costs include replacement costs, fixed operation and maintenance costs and variable operating costs (pumping costs).

Estimates of the costs of construction of irrigation works and facilities have been made on the basis of bills of quantities derived from plans and sketches. The unit rates applied have been established with a view to obtaining realistic cost estimates using only a limited number of measured items. They therefore include costs of mobilisation and demobilisation, cost of temporary works, costs of secondary items and general overhead costs.

No agricultural development scheme of the size of the Anambe project has been realised recently in Senegal. However,smaller projects have been carried out as well as other major construction works such as the trunk roads constructed over 1978 - 1980. Unit cost data have therefore been obtained for civil construction projects in Senegal. Other sources of cost data include local and international suppliers of materials and equipment and ongoing or completed projects in other parts of West Africa or further afield.

Cost estimates are based on prices prevailing on 1st July 1979. As far as possible all taxes, duties and subsidies have been excluded from the economic evaluation.

8.2 Capital costs

8.2.1 Irrigation works and facilities

The costs of irrigation works and facilities are summarized in table 8-1 by development phase. Detailed estimates of construction costs may be found in the following reports :

Table 8 - 1 CONSTRUCTION COSTS

(million FCFA)

		Phase I	Phase II	Phase III	Phase IV	Phase V	Total
1.	DAMS AND HEAD WORKS						
1.1	Niandouba dam and hydro-electric station :						
1.1.1	Access road		142				142
1.1.2	Dam		3 084				3 084
1.1.3	Hydroelectric station-civil works		480				480
1.1.4	Hydroelectric station - E&M		740				740
1.1.5	Transmission line		88				88
1.2	Confluence dam :						
1.2.1	Access road	68					68
1.2.2	Dam	397	21				418
1.3	Anambé flood protection dam :		469				469
1.4	Channel clearance and improvement						
1.4.1	Kayanga		173				173
1.4.2	Anambé		26				26
1.5	Sub total	465	5 223				5 688
2.	PUMPING STATION AND APPURTENANT WORKS						
2.1	Pilot perimeter pumping station:						
2.1.1	Access road	10					10
2.1.2	Civil works	48					48
2.1.3	Electromechanical equipment	121					121
2.1.4	Pipeline	67					67
2.1.5	Approach channel	37					37
2.1.6	Dismounting and reinstallation		55				55
2.2	Main right bank pumping station						
2.2.1	Civil works (ind. access road)		234				234
2.2.2	Electromechanical equipment		596	254			850
2.2.3	Pipelines		340				340
2.2.4	Approach channels		49				49
2.3	Auxiliary pumping station						
2.3.1	Civil works			106			106
2.3.2	Electromechanical equipment			255			255
2.3.3	Pipeline			28			28
2.4	Main left bank pumping station						
2.4.1	Access road		5				5
2.4.2	Civil works		141		38		179
2.4.3	Electromechanical equipment				400	330	730
2.4.4	Pipelines				270		270
2.4.5	Regulating reservoir				103		103
2.4.6	Approach channels		21				21
2.5	Sub total	283	1 441	643	811	330	3 508
3.	IRRIGATION AND DRAINAGE SYSTEM						
3.1	Main canals	526	1 756	922	1 870	2 335	7 409
3.2	Main drains		146	159	197	183	685
3.3	Main roads	95	144	175	255	312	981
3.4	Secondary canals and drains	160	380	395	506	537	1 978
3.5	Secondary roads	118	343	289	408	487	1 645
3.6	Sub total	899	2 769	1 940	3 236	3 854	12 698
4.	LAND DEVELOPMENT (including tertiary and farm level distribution system)	662	1 257	1 616	1 971	2 252	7 758
5.	BUILDINGS	292	475	178	190	125	1 260
6.	TOTAL COST OF WORKS	2 601	11 165	4 377	6 208	6 561	30 912
7.	Contingencies 10 %	260	1 116	438	621	656	3 091
9.	TOTAL CONSTRUCTION COSTS	2 861	12 281	4 815	6 829	7 217	34 003

- land clearance	: report 4,	Pedology
- dams, power station and transmission line	: report 9,	Dams
- pumping stations and appurtenant works	: report 10,	Pumping Stations
- irrigation and drainage network, road network, land development, channel improvement, regulating reservoir	: report 11,	Irrigation and Drainage
- buildings	: report 12,	Organisation and Management

A contingency allowance of 10 percent has been added to all construction costs.

General costs include :

- project administration and management
- detailed design
- construction supervision
- further studies and investigations
- compensation to displaced persons, rights of way

An amount equivalent to 8 percent of the construction cost including contingencies has been added to cover the cost of engineering, administration and construction supervision, the first four items of general costs given above. With regard to compensation the value of lands and buildings affected is estimated (section 7.6) at 200 million FCFA. A summary of the estimated capital cost is presented in table 8-2.

8.2.2 Processing facilities

The costs of investment in buildings and equipment for the mechanized farm and for processing facilities is shown in table 8-3. For the detailed developement of capital costs refer to reports 6, Agronomy and 7, Agro-industry.

Also shown in table are the investments in machinery and equipment required to farm lands held by the project authority for eventual transfer to small farmers. These costs are detailed in report 12, Annex 7.

TABLE 8 - 2

SUMMARY OF CAPITAL COST

(millions FCFA)

Feature or Works	Phase I (1420 ha)			Phase II (3020 ha)			Phase III (3050 ha)			Phase IV (3995 ha)			Phase V (4780 ha)			Total Project (16 265 ha)		
	local	foreign	total	local	foreign	total	local	foreign	total	local	foreign	total	local	foreign	total	local	foreign	total
1 CONSTRUCTION COST																		
1.1 Dams and Ancillary Works																		
Confluence Dam	233	232	465	10	11	21										243	243	486
Niandouba Dam				1700	1699	3399										1700	1699	3399
Niandouba Power Station				585	723	1308										585	723	1308
Anambé Dam				248	247	495										248	247	495
Subtotal	233	232	465	2543	2680	5223										2776	2912	5688
1.2 Pumping Stations																		
Pilot Perimeter	120	163	283	55		55										175	163	338
Main Right Bank				502	717	1219	64	190	254							546	907	1473
Auxiliary							157	232	389							157	232	389
Main Left Bank				125	42	167				297	514	811	82	248	330	504	804	1308
Subtotal	120	163	283	682	759	1441	221	422	643	297	514	811	82	248	330	1402	2106	3508
1.3 Irrigation System																		
Main Canals	316	210	526	1054	702	1756	553	369	922	1122	748	1870	1401	934	2335	4446	2963	7409
Main Drains				73	73	146	80	79	159	99	98	197	92	91	183	344	341	685
Main Roads	48	47	95	72	72	144	88	87	175	128	127	255	156	156	312	492	489	981
Secondary Network	80	80	160	190	190	380	198	197	395	253	253	506	269	268	537	990	988	1978
Secondary Roads	59	59	118	172	171	343	145	144	289	204	204	408	244	243	487	824	821	1645
Subtotal	503	396	899	1561	1208	2769	1064	876	1940	1806	1430	3236	2162	1692	3854	7096	5602	12698
1.4 Tertiary System and Farm Development works	331	331	662	629	628	1257	808	808	1616	986	985	1971	1126	1126	2252	3880	3878	7758
1.5 Buildings	175	117	292	285	190	475	107	71	178	114	76	190	75	50	125	756	504	1260
Subtotal-Construction Cost	1362	1239	2601	5700	5465	11165	2200	2177	4377	3203	3005	6208	3445	3116	6561	15910	15002	30912
1.6 Contingencies, 10%	136	124	260	570	546	1116	220	218	438	320	301	621	344	312	656	1591	1500	3091
TOTAL CONSTRUCTION COST	1498	1363	2861	6270	6011	12281	2420	2395	4815	3523	3306	6829	3789	3428	7217	17501	16502	34003
2 GENERAL COST																		
2.1 Administration & Engineering	120	109	229	502	481	983	193	192	385	282	264	546	303	274	577	1400	1320	2720
2.2 Resettlement				200		200										200		200
TOTAL GENERAL COST	120	109	229	702	481	1183	193	192	385	282	264	546	303	274	577	1600	1320	2920
TOTAL CAPITAL COST – IRRIGATION WORKS AND FACILITIES	1618	1472	3090	6972	6492	13464	2613	2587	5200	3805	3570	7375	4092	3702	7794	19101	17822	36923
3 PRODUCTION AND PROCESSING WORKS AND FACILITIES																		
3.1 Mechanized Farm (1)	94	219	313	108	251	359				98	229	327	98	229	327	398	928	1326
3.2 Production Division (1)	33	78	111	74	172	246	50	116	166							157	366	523
3.3 Agro - Industry Facilities																		
Industrial Rice Mills	74	60	134	105	86	191				105	86	191	97	79	176	381	311	692
Multi - Unit Rice Mills				101	68	169	65	43	108	158	106	264	121	81	202	445	298	743
Seed Processing Facilities				20	14	34										20	14	34
Livestock Enterprise				24	19	43				13	10	23	7	5	12	44	34	78
Subtotal	74	60	134	250	187	437	65	43	108	276	202	478	225	165	390	[illegible]	657	1547
TOTAL CAPITAL COST – PRODUCTION AND PROCESSING WORKS AND FACILITIES	201	357	558	432	610	1042	115	159	274	374	431	805	323	394	717	1445	1951	3396
TOTAL CAPITAL COST	1819	1829	3648	7404	7102	14506	2728	2746	5474	4179	4001	8180	4415	4096	8511	20546	19773	40319

Note (1) Includes initial purchase of farm machinery

Table 8 - 3 CAPITAL COST OF PRODUCTION AND PROCESSING FACILITIES
(million FCFA)

Year	Production		Processing[3]				Total
	Mechanised farm[1]	Production (2) division	Industrial rice mills	Multi unit rice mills	Seed treatment	Livestock	Total (1) To (6)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1980							
81	313,3		119,3				432,6
82		56,9					56,9
83		53,6	14,3				67,9
84							
1985	293,9		162,3		34,0	43,0	533,2
86	64,9	73,0	28,6	90,9			257,4
87		172,7		78,4			251,1
88		166,3		107,4			273,7
89				169,3			169,3
1990	221,9		119,4	49,5		23,0	413,8
91	105,3		71,5				176,8
92				45,4			45,4
93	221,9		119,3	16,5		12,0	369,7
94	64,9		57,2	45,4			167,5
1995	40,4			61,9			102,3
96				16,5			16,5
97				45,4			45,4
98				16,5			16,5
99							
Total	1 326	523	692	743	34	78	3 396

Note
(1) From report 6, table 6-11
(2) From report 12, table A7-1
(3) From report 7, tables 7-3, 7-5, 7-6, 7-7
Excludes working capital

8.3 Recurrent costs

8.3.1 Replacement costs

Replacement costs and the economic life of turbines, generators, pumps, motors and hydromechanical equipment for the three permanent pumping stations and the power house are derived in table 8-4. They are entered into the cash flow (table 10-1) as the equipment falls due for replacement. Replacement costs for the mechanized farm and agro-industry facilities are also entered into the cash-flow as they fall due until project year 22, when they are entered on an average annual basis.

8.3.2 Operation and maintenance costs

General operation and maintenance costs include those costs specifically associated with operating and maintaining the irrigation works. They also include the cost of the Agriculture and Extension department of the project authority which includes the extension services and agricultural support services. Operation and maintenance costs do not include services which would be run on a self-financing basis, such as a tractor hiring service, nor costs associated with distribution of agricultural inputs.

It is convenient to express operation and maintenance costs as a percentage of construction costs. The rates applied and the resulting annual costs are shown in table 8-5. On average, annual operation and maintenance costs represent 1,4 % of the capital costs of irrigation works and facilities.

8.3.3 Cost of pumping

Operation studies have been carried out by computer simulation to determine the annual amounts of useful hydro-energy generated at the power house and absorbed by the right bank pumping station. These computations were made for each year of a synthetically extended streamflow record of 61 years, covering two wet and two dry hydrological cycles. The results of this study, show that on average 86 percent of the energy absorbed by the right bank pumping station will be provided from hydro-energy produced by the project, the remaining 14 percent being supplied by the diesel groups. A graphic representation of the annual energy balance is given on figures 8-1

Table 8 - 4 REPLACEMENT COST AND LIFE OF ELECTROMECHANICAL EQUIPMENT

Item	Life of equipment (hours)	Annual utilisation (hr/y)	Life (years)	Year and phase of initial investment	Amount of investment (mill. FCFA)
Pilot perimeter pumping station (1)					
Pumps	30 000	1 200	28	1981/82 (I)	46,3
Motors (diesel)	15 000	1 200	14	1981/82 (I)	47,5
Main right bank pumping station					
Pumps	30 000	1 050	28	1984/85 (II)	106,9
				1987 (III)	71,3
Motors (electric)	40 000	1 050	38	1984/85 (II)	60,6
				1987 (III)	40,4
Hydromechanical equipment	-	-	25	1984/85 (II)	83,2
Auxiliary pumping station					
Pumps	30 000	1 050	28	1987 (III)	90,3
Motors (diesel)	15 000	1 050	14	1987 (III)	95,0
Hydromechanical equipment	-	-	25	1987 (III)	7,1
Main left bank pumping station					
Pumps	30 000	1 750	17	1989 (IV)	68,9
				1992 (V)	68,9
Motors (diesel)	15 000	1 750	8	1989 (IV)	154,4
				1992 (V)	154,4
Hydromechanical equipment	-	-	25	1989 (IV)	83,2
Power house					
Turbines	30 000	1 200	28	1984/85 (II)	475,2
Generators	40 000	1 200	33	1984/85 (II)	332,6

(1) The equipment is moved to the main right bank pumping station after 4 years.

Table 8 - 5 OPERATION AND MAINTENANCE COSTS

	Description	Rate for O & M %	Total Const. cost(1) (MioFCFA)	Operation and maintenance costs (Mio FCFA) Phase I	Phase II	Phase III	Phase IV	Phase V
1.	DAMS AND HEADWORKS							
1.1	Access roads(2)	3	249	1,2	3,8	3,8	3,8	3,8
1.2	Dams	0,5	4 718	2,4	23,6	23,6	23,6	23,6
1.3	H/E station-Civil	1,5	570		8,6	8,6	8,6	8,6
1.4	H/E station-E/M	3	879		26,4	26,4	26,4	26,4
1.5	Transmission	2	105		2,1	2,1	2,1	2,1
1.6	Channel clearance	5	236		11,9	11,9	11,9	11,9
1.7	Sub total		6 757	3,6	76,4	76,4	76,4	76,4
2.	PUMPING STATION AND APPURTENANT WORKS							
2.1	Access roads	3	18	0,4	0,6	0,6	0,6	0,6
2.2	Civil works	1,5	616	0,8	6,7	8,6	9,3	9,3
2.3	E/M equipment							
2.3.1	Electromechanical	3	1 872	2,9	24,1	39,4	49,1	56,2
2.3.2	Diesel motors	6	451	2,9	2,9	8,6	17,8	27,1
2.4	Pipelines	0,5	849	0,4	2,0	2,5	4,3	4,3
2.5	Approach channels	2	127	0,8	2,5	2,5	2,5	2,5
2.6	Regulating reservoir	2	122				2,4	2,4
2.7	Sub total		4 055	8,2	38,8	62,2	86,0	102,4
3.	IRRIGATION AND DRAINAGE SYSTEM							
3.1	Main canals	1,5	8 803	9,4	40,6	57,1	90,4	132,0
3.2	Secondary canals and drains	5	2 350	9,5	32,1	55,5	85,6	117,5
3.3	Main drains	2	815		3,5	7,3	11,9	16,3
3.4	Main roads(2)	3	1 166	1,7	4,3	7,4	12,0	17,5
3.5	Secondary roads	3	1 956	4,2	16,4	26,8	41,3	58,7
3.6	Sub total		15 090	24,8	96,9	154,1	241,2	342,0
4.	BUILDINGS(3)	1,5	1 497	2,6	6,8	8,5	10,2	11,3
5.	TOTAL			39,2	218,9	301,2	413,8	532,1

(1) Including 10 % contingencies and 8 % engineering, etc.

(2) 50 % of road maintenance costs to be covered by local Public Works department

(3) 50 % of building maintenance costs charged to project authority.

and 8-2. Pumping costs for each pumping station are presented in table 8-6, using an economic fuel price of 65 FCFA per litre (see para 9.2.5).

8.4 Local and foreign currency components

Project costs, including costs of farm inputs, have been separated into local and foreign currency costs (see table 8-2) by applying the foreign currency components given in table 8-7. The foreign currency component corresponds to the portion of the cost of each item made up from goods and services which are internationally traded.

8.5 Phasing of capital expenditure

Capital costs of irrigation works and facilities have been phased according to the construction programme shown in table 3-8, the capital cost estimates presented in table 8-2 and the investments in agro-industry and in the mechanized farm follow given in table 8-3. For all works and facilities an initial down payment to the contractor of about 20 percent has been assumed. The cash flows of capital costs are shown in table 8-8.

Table 8 - 6 ANNUAL ECONOMIC COST OF DIESEL FUEL FOR PUMPING(1) (2)

Year	Pilot perimeter pumping station (1 420 ha)			Main right bank pumping station (7 490 ha)			Auxiliary pumping station (2 255 ha)			Main left bank pumping station (8 775 ha)			Project total (16 265 ha)		
	Pumpage ($10^6 m^3$)	Fuel ($10^3 l$)	Cost (10^6FCFA)	Pumpage ($10^6 m^3$)	Fuel ($10^3 l$)	Cost (10^6FCFA)	Pumpage ($10^6 m^3$)	Fuel ($10^3 l$)	Cost (10^6FCFA)	Pumpage ($10^6 m^3$)	Fuel ($10^3 l$)	Cost (10^6FCFA)	Pumpage ($10^6 m^3$)	Fuel ($10^3 l$)	Cost (10^6FCFA)
1980															
81	0	0	0										0	0	0
82	8,7	122,6	8,0										8,7	122,6	8,0
83	11,8	166,3	10,8										11,8	166,3	10,8
84	17,7	249,4	16,2										17,7	249,4	16,2
1985	16,8	236,7	15,4										16,8	236,7	15,4
86				1,8	24,8	1,6							1,8	24,8	1,6
87				4,3	61,2	4,0							4,3	61,2	4,0
88				7,8	110,2	7,2	9,0	97,6	6,3				16,8	207,8	13,5
89				12,5	176,4	11,5	26,3	285,1	18,5				38,8	461,5	30,0
1990				12,3	173,4	11,3	25,9	280,7	18,2	13,0	267,7	17,4	51,2	721,8	46,9
91				12,1	171,0	11,1	25,5	276,4	18,0	28,2	580,8	37,8	65,8	1 028,2	66,9
92				12,0	169,7	11,0	24,9	269,9	17,5	45,2	930,9	60,5	82,1	1 370,5	89,0
93				11,9	168,1	10,9	24,4	264,5	17,2	59,0	1 215,1	79,0	95,3	1 647,7	107,1
94				11,8	166,5	10,8	23,8	258,0	16,8	72,9	1 501,4	97,6	108,5	1 925,9	125,2
1995				11,8	166,1	10,8	23,6	255,8	16,6	86,1	1 773,3	115,3	121,5	2 195,2	142,2
96										99,3	2 045,1	132,9	134,7	2 467,0	160,3
1997 2030				11,8	166,1	10,8	23,6	255,8	16,6	98,0	2 018,3	131,2	133,4	2 440,2	158,6

1) See back up information in report B, annex 2

2) At economic price of 65 FCFA/litre

Table 8 - 7 FOREIGN CURRENCY COMPONENTS

		Foreign component (%)
1.	CONSTRUCTION COSTS	
	Dams incl. appurtenant works	50
	Power station and pumping stations	
	Civil works	25
	Pipelines	55
	Electromechanical equipment	75
	Transmission line	55
	Drains, approach channels, land clearance, tertiary works, roads, regulating reservoir, secondary canals	50
	Main canals	40
	Buildings and equipment	40
2.	RESETTLEMENT COSTS	0
3.	AGRO-INDUSTRIAL FACILITIES	
	Industrial rice mills and livestock feed mill	45
	Multi-unit rice mills and seed treatment	40
4.	OPERATION AND MAINTENANCE COSTS	20
5.	PUMPING ENERGY COSTS	65
6.	MECHANIZED AGRICULTURAL EQUIPMENT	80

Table 8 - 8 CASH FLOW OF CAPITAL COSTS (million FCFA)
(where they differ from financial costs, economic costs are given in parentheses)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
PHASE I (incl. pilot farm)																	
Detailed design	—																
Tender	—																
Construction of confluence dam and pumping station	266	623 (582)															
Distribution network and on-farm works[1]	440	660	660	441 (210)													
Production and processing facilities[2]		313	57	54													
		119		14													
PHASE II/III Right bank																	
Detailed design			—	—													
Tender				—													
Construction :																	
Niandouba dam and H/E plant				1443	2896	1448 (1364)											
Anambé flood protection dam and modifications to confluence dam						25 / 235	353										
Main right bank pumping station and ancillary works				434	724	290											
Installation of pumpsets					—	—	91	211									
Foundations of left bank pumping station					59	139											
Move of Phase I pumping plant						65											
Auxiliary pumping station							139	323									
Main canals[1]				600	1795	600 (232) / 511	853	340 (130)									
Secondary and tertiary canals drainage network, on farm works				470	1412	470 / 545	850	793	545								
Production and processing facilities[2]						294	138	173	166								
						239	120	78	108								
PHASE IV / V Left bank																	
Main left bank pumping station and ancillary works					—			146	342								
Installation of pumpsets									190	285		118	274				
Main canals[1]								450	1935	599 (335) / 699	1937	875 (614)					
Secondary and tertiary canals drainage network and on-farm works								350	900	900	850	427 / 583	750	800	700	600	459
Production and processing facilities[2]											222	105		222	165	40	
										169	192	72	45	148	103	62	17
Total - Financial costs	706	1 715	717	3 461	6 886	4 861	2 544	2 864	4 186	2 652	3 201	2 180	1 069	1 170	868	702	476
Total - Economic costs	706	1 674	717	3 230	6 886	4 409	2 544	2 654	4 186	2 388	3 201	1 919	1 069	1 170	868	702	476

(1) Includes main canals, main drains, main roads and buildings
(2) Cash flow for production facilities above line, processing facilities below line

9. ECONOMIC BENEFITS

9. ECONOMIC BENEFITS

9.1 Markets for project production

Rice, maize and sorghum produced by the project will help reduce the present substantial cereals deficit, which requires Senegal to import large amounts of basic foods. At full production in 2001 the Anambé project will contribute about 57 500 tons of milled rice to domestic production. In 1990, following development of Phase III, production of milled rice will reach 25 500 tons. This compares with imports projected at 193 000 tons in 1990. Maize and sorghum production, at 3 000 tons and 1 700 tons in 1990 (and about twice these amounts at full development) is insignificant compared to projected demand.

Rice will supply three distinct markets. The local market in and around the project area will be supplied from smallholder production. Much of this rice will be milled by the consumers themselves in the traditional way. Local consumption is estimated to absorb 20 percent of smallholder production.

The second market is that for broken rice. This market, concentrated in the main towns of Senegal, and above all in Dakar, is presently supplied primarily from imports, presently running at around 175 000 to 200 000 tons per year. The project at full development will produce about 24 000 tons of broken grain rice which will substitute for imports in the urban market. The transport costs between the project area and Dakar, and the fact that Dakar as a seaport has ready access to imported supplies, both act to depress the competitiveness of broken rice from the project area on the Dakar market. Therefore as far as possible the rice produced by the project should be substituted for imported rice in towns closer to the project area, such as Ziguinchor and Kaolack.

The third market supplied by the project is that for whole grain rice. Consumer preference, price considerations and import restrictions have limited the sales of whole grain rice in Senegal. Import permits to licensed importers for premium quality rice are currently running at about 15 000 tons per year though actual imports appear to be below this figure. The income elasticity of demand for whole grain rice, considered to be a luxury item by the great majority of Senegalese, is likely to be higher than the income elasticity for rice consumption generally, the latter being estimated at 0,3. Project production of whole grain rice will reach about 10 000 tons in 1990 and 37 000 tons at full development. The project will therefore be in a position to supply a substantial part of the domestic market for whole grain rice. Export of the higher quality rice produced by the project is a possibility but one which has lower value to Senegal in terms of both economic and political objectives.

The proportion and volume of rice production serving each of the three markets discussed above is assumed to be as follows at full development in 1966 :

	Smallholder farms		Mechanized farm		Total Volume (tons)
	%	Volume (tons)	%	Volume (tons)	
Whole grain rice	40	14 056	70	23 367	37 423
Broken grain rice	40	14 056	30	10 014	24 070
Home consumed rice	20	7 028			7 028

Maize and sorghum are assumed to be consumed locally or, in the case of the yellow maize produced by the mechanized farm, used as animal feed.

9.2 Prices

9.2.1 Farmgate price of paddy and ex mill price of rice

Prices for cereal crops as given in table 5-3 are fixed by the Government which has authorized certain agencies to act as sole buyers for specific crops. Prices offered by these agencies are uniform throughout a region and uniform in respect to quality, except in the case of cotton and rice where discounts are applied for lack of quality.

These producer prices have been used for farm budget and financial analysis (chapter 5 and 10). For economic evaluation the farmgate price of paddy has

Table 9 - 1 RICE PRICE STRUCTURE, 1985

SUBSTITUTION OF PROJECT PRODUCTION FOR IMPORTED THAILAND RICE ON DAKAR MARKET AND IN OTHER MAIN TOWNS

	Broken grain rice FCFA/tonne	US $/tonne	Whole grain rice FCFA/tonne
Export price of Thai 5 % broken, FOB Bangkok (1978 terms)	100 450(2)	410(1)	100 450
Increase to mid 1979 Terms		10 %	
Export price mid 1979	99 000(3)	450	99 000
Export price of Thai 100 % broken rice	69 300(4)		
Ocean freight and insurance	11 000	50	11 000
Import price CIF Dakar	80 300		110 000
Plus port charges,customs and handling	3 700		3 700
Plus importers margin	1 000		1 000
Plus storage costs	2 500		2 500
Price ex-port Dakar	87 500		117 200
Less transport Dakar-Vélingara	10 000		10 000
Rice price, ex-mill, project area	77 500		107 200
Paddy equivalent price (65 % recovery)	50 375		69 680
Milling cost	8 500		9 500
Purchase and transport cost	1 000		1 000
Economic farmgate price of paddy for sale Dakar	40 875		59 180
Economic farmgate price of paddy for sale in main towns	43 960(5)		
Rounded to	44 000		59 000

Note (1) IBRD May 1977 forecast in 1977 constant dollars increased to January 1978 terms according to the Banks weighted Index of commodity prices

(2) Exchange rate 245 FCFA = 1 dollar (1978)
(3) Exchange rate 220 FCFA = 1 dollar (1979)
(4) For sale in other main towns :
- add transport Dakar - main town
- add/subtract difference in the costs of transport from Vélingara to the main town

Main town	Economic farmgate price for sale in town indicated FCFA/tonne
Dakar	40 875
Rufisque	41 632
Thiès	42 200
Diourbel	44 255
Kaolack	45 986
Ziguinchor	48 814
Average	43 960

been calculated with reference to world market prices, as projected for 1985 by IBRD, making due ajustement for 1979 money values and for intermediate costs of transport, storage and processing. The calculation is given in table 9-1. Paddy destined for sale as broken rice in urban centres has an economic farmgate reference value of 44 FCFA per kg. The corresponding value of paddy for sale as whole grain rice in Dakar is 59 FCFA per kg. Rice consumed locally in the project area, if referred to world market prices, would be valued at 98 FCFA per kg. This compares with prices obtaining in le local market of 100-110 FCFA per kg. Rice sold or consumed locally is therefore valued at 100 FCFA per kg, equivalent to a farmgate value for paddy of 65 FCFA per kg.

Based on these values and the percentages shown in the table above, weighted farmgate prices for paddy produced by smallholders and by the mechanized farm may be obtained as in table 9-2. Reference to the world market prices with due allowance for transport, handling, storage and dues, also enables for milled white rice given in table 9-2 in 1985 to be deduced.

A farmgate value of 54 FCFA per kg for paddy has been adopted, both for smallholder and mechanized farm production.

Table 9 - 2 ECONOMIC FARMGATE PRICE OF PADDY AND EX MILL PRICE OF RICE

	Farmgate price of paddy (FCFA/kg)	Ex mill price of rice (FCFA/kg)
Locally consumed rice	65	-
Broken rice sold in urban centres	44	82
Whole grain rice sold in Dakar	59	107
Weighted price :		
Smallholder farm paddy	54	
Mechanized farm paddy	55	
Multi-unit mill rice		95
Industrial mill rice		100

The values obtained for milled rice above compare well with prices pertaining locally in Casamance in markets outside government control. They are also comparable with prices which prevailed in Dakar in late 1979, taking account of the exceptionally low world market prices at which Senegal was obtaining its imports of broken rice at this time.

9.2.2 Farmgate price of maize and sorghum

The farmgate price of maize referred to world market prices and for sale in Dakar is equal to the government producer price (cf report 13, annex 1). Prices in the local market for both maize and sorghum were only very slightly above the producer price. Maize and sorghum are therefore valued at the present producer prices of 37 FCFA/kg and 40 FCFA/kg respectively.

9.2.3 Prices of factors of production

Fertilizer in Senegal is heavily subsidised. Economic reference prices have been calculated for urea and compound fertiliser as shown in table 9-3.

As there is no subsidy on the price of agricultural chemicals the economic price is assumed to equal the present retail price.

9.2.4 Unskilled labour

The selection of a shadow price or opportunity cost for unskilled labour does not have a major effect on the economic evaluation as firstly unskilled labour costs represent only a small part of construction costs and secondly as little hired labour is used on smallholder farms. The opportunity cost adopted for the economic evaluation is 400 FCFA per day (see report 13, para 3.2.5), close to the present return per man-day in traditional farming (see table 5-7).

9.2.5 Fuel

Imported crude oil is refined in Senegal by the Société Africaine de Raffinage. It is distributed by several of the multinational oil companies.

Fuel prices have been changing rapidly during the period of this study. The price of diesel fuel delivered to the project area is obtained as follows (tax free) :

Table 9 - 3 FERTILIZER PRICE STRUCTURE, 1985

	FCFA/tonne	Dollar US/tonne
Urea		
Reference price, 1979 (1)	50 600	230 (2)
Ocean transport and insurance	7 700	35
Port, customs, handling charges	3 700	
Importers margin, storage costs	3 500	
Price ex-port, Dakar	65 500	
Transport Dakar - Vēlingara 565 km at 20,8 FCFA/t.km	11 750	
Total	77 250	
Economic price delivered to project area	77 FCFA/kg	
Compound fertilizer, NPK (14.7.7)		
Compound fertilizer, NPK (14.7.7)		
Reference price, 1979 (3)	30 800	
Other charges as above	26 650	
Total	57 450	
Economic price delivered to project area	57 FCFA/kg	

Notes : (1) FOB Europe, in sacks

(2) Index of 130,9 applied to 1977 IBRD estimates in constant 1975 dollars

(3) Based on the price for urea and the ratios of active nutrients (28 : 46)

	Mid 1979	Early 1980
	(FCFA per ton)	
Diesel fuel ex refinery	55 000	74 000
Transport to project area	13 000	16 000
Total	68 000	90 000
Equivalent price per litre (FCFA)	57,8	76,5

An economic price for diesel fuel of 65 FCFA per litre has been adopted in the present report. This value reflects mid 1979 prices (as do all costs in this report) with an adjustment to take account of the upward pressure on fuel prices at that time. It compares with an actual price of 85 FCFA per litre at the pump in mid 1979.

9.3 Benefits from crop production

9.3.1 Introduction

The net benefits to the project from production of rice and other cereals is obtained as the difference in value of net agricultural benefits with the proposed project as against the "without project" alternative. Net benefits in either case are obtained by deduction of annual production costs from the gross farmgate value of agricultural production. All values are expressed in terms of economic prices.

9.3.2 Net benefits "with project"

Net benefits from agricultural production are given in table 9-4. Supporting data for costs of smallholder production are given in table 9-5.

9.3.3 Net benefits "without project"

The areas of cultivated land falling within the boundaries of the proposed irrigation perimeters are given in table 9-6. The largest areas of land under cultivation within the prospective irrigation perimeters lie in the

Table 9 - 4 NET AGRICULTURAL BENEFITS

(million FCFA)

Year	Gross value of farm production (1)				Farm production costs						Net value of farm production					
						Project authority					Net value of production with project					
	Commercial mechanized farm	Production division lands	Smallholder farm	Total gross value	Commercial mechanized farm (2)	Production division lands (3)	Land preparation (4)	Sub-total	Smallholder farms (5)	Total production costs	Mechanized farm	Production division	Smallholder farms	Total	Net value of production without project (6)	Net agricultural benefits
1980																
1981					13					13	- 13			- 13	5	-18
1982	191			191	109		5	5		114	82	-5		77	5	72
1983	191	53	15	259	96	23	13	36	5	137	95	17	10	122	5	117
1984	191	145	57	393	96	63	10	73	16	185	95	72	41	208	14	194
1985	191		170	361	117		6	6	48	171	74	-6	122	190	24	166
1986	575	55	218	848	276	24	25	49	63	388	299	6	155	460	24	436
1987	693	316	282	1 291	312	137	43	180	82	574	381	136	200	717	32	685
1988	693	600	400	1 693	304	262	43	305	114	723	389	295	286	970	41	929
1989	693	834	605	2 132	304	361	41	405	171	880	389	429	434	1 252	51	1 201
1990	797	826	886	2 509	320	361	14	375	252	947	477	451	634	1 562	61	1 501
1991	1 071	618	1 172	2 861	447	270	14	284	330	1 061	624	334	842	1 800	71	1 729
1992	1 280	493	1 469	3 242	532	216	28	244	412	1 188	748	249	1 057	2 054	71	1 983
1993	1 280	502	1 787	3 569	518	217	28	245	499	1 262	762	257	1 288	2 307	77	2 230
1994	1 502	215	2 157	3 874	639	119	20	139	595	1 373	863	76	1 562	2 501	77	2 424
1995	1 667	246	2 470	4 383	688	106	26	132	678	1 498	979	114	1 792	2 885	77	2 808
1996	1 823	214	2 788	4 825	723	92	14	106	759	1 588	1 100	108	2 029	3 237	77	3 160
1997	1 823		3 043	4 866	717				823	1 540	1 106		2 220	3 326	77	3 249
1998	1 893		3 138	5 031	711				842	1 553	1 182		2 296	3 478	77	3 401
1999	1 922		3 214	5 136	711				856	1 567	1 211		2 358	3 569	77	3 492
2000	1 950		3 291	5 241	711				871	1 582	1 239		2 420	3 659	77	3 582
2001 - 2030	1 950		3 348	5 298	711				883	1 594	1 239		2 465	3 704	77	3 627

(1) Volume of production from table 5-6
Economic prices rice 54 FCFA/kg
maize 37 FCFA/kg
sorghum 40 FCFA/kg

(2) At 144 000 FCFA/ha ; from table 5-8

(3) At 132 000 FCFA/ha ; derived from production costs for mechanized farm less 12 000 FCFA/ha for costs included under general O&M costs

(4) Costs shown apply for lands assigned to smallholder farms including those temporarily farmed by the production division. Land preparation costs for the mechanized farm are included in the production costs of the mechanized farm

(5) From table 9- 5

(6) Production supplanted by project

Table 9 - 5 ANNUAL COSTS OF SMALLHOLDER PRODUCTION

1. PRODUCTION COSTS PER HECTARE (FCFA)

	Rice				Sorghum				Maize			
	Wet season		Dry season		Wet season		Dry season		Wet season		Dry season	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Seed	5 900	7 080	5 900	7 080	475	713	475	713	2 000	2 000	2 000	2 000
Compound fertilizer	5 700	11 400	5 700	11 400	5 700	8 550	5 700	11 400	5 700	8 550	5 700	11 400
Urea	6 160	9 240	7 700	9 240	5 390	7 700	5 390	7 700	6 160	7 700	6 160	9 240
Herbicide	-	-	6 000	6 000	-	-	-	-	-	-	-	-
Insecticide	4 500	4 500	2 250	2 250	2 250	2 250	2 250	2 250	2 250	2 250	2 250	2 250
Seed and storage treatment	1 900	2 050	2 100	2 750	1 150	1 175	1 250	1 675	1 200	1 600	1 500	1 500
Farm equipment	14 953	14 953	14 953	14 953	14 953	14 953	14 953	14 953	17 153	17 953	17 753	18 653
Total	39 113	49 223	44 603	53 673	29 918	35 341	30 018	38 691	34 463	40 053	35 363	45 043

2. TOTAL PRODUCTION COSTS (million FCFA)

Year	Rice				Sorghum				Maize				Total			
	Wet season		Dry season		Wet season		Dry season		Wet season		Dry season		Wet season		Dry season	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Cost per hectare FCFA	39 113	49 223	44 603	53 673	29 918	35 341	30 018	38 691	34 463	40 053	35 363	45 043				
1981																
1982																
1983					2		1		1		1			3	2	5
1984	6		5		2		1		1		1		11	[illegible]	[illegible]	16
1985	24		19		2		1		1		1		43	[illegible]	[illegible]	[illegible]
1986	30		19		4		5		2		3		49	9	5	[illegible]
1987	39		24		3	2	5	[illegible]	2	1	3	1	63	[illegible]	7	[illegible]
1988	45	8	22	6	7	2	10	2	4	1	6	1	81	21	[illegible]	[illegible]
1989	57	30	15	23	7	2	18	2	4	1	11	1	125	29	17	[illegible]
1990	92	38	38	23	7	5	20	6	4	3	12	4	191	[illegible]	[illegible]	[illegible]
1991	126	49	55	29	7	6	24	8	4	3	14	5	259	45	[illegible]	[illegible]
1992	156	65	71	33	4	10	26	[illegible]	2	6	15	9	375	54	[illegible]	[illegible]
1993	169	103	84	40	5	10	25	25	3	6	14	15	396	65	[illegible]	[illegible]
1994	173	154	91	68	3	13	21	32	2	7	13	18	486	69	[illegible]	[illegible]
1995	167	208	87	95	2	14	21	39	1	8	13	23	[illegible]	76	[illegible]	[illegible]
1996	161	262	91	118	1	14	16	48	1	9	10	28	[illegible]	[illegible]	[illegible]	[illegible]
1997	144	315	91	142		16	10	57		9	6	33	[illegible]	[illegible]	[illegible]	[illegible]
1998	100	371	61	178		16	8	59		9	5	38	[illegible]	[illegible]	[illegible]	[illegible]
1999	63	418	44	199		16	2	66		9	1	40	[illegible]	[illegible]	[illegible]	[illegible]
2000	26	464	20	227		16		69		9			[illegible]	[illegible]	[illegible]	[illegible]
2001-2030	-	497	-	252		16		69		9		4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Sources : Economic prices of inputs : table 5-3
Economic cost of farm equipment : Report 6, annex 6
Input requirements : table 5-2
Areas : table 3-7

south of the study area close to the villages of Kabendou and Kounkané on either side of the Anambé river.

Table 9-6 BENEFITS FROM CROP PRODUCTION WITHOUT PROJECT

		Rice	Upland crops	Total
Gross cultivated land (including fallow)	(ha)	600	1 800	2 400
Percentage of land under fallow	(%)	50	30	
Reduction for rights of way and errors due to aggregation	(%)	10	10	
Net cultivated land	(ha)	240	1 080	1 320
Annual value of production per net cultivated hectare (FCFA) (see report 13, table 13-23)		50 000	60 000	
Net benefits (million FCFA)		12	65	77

With present farming methods the scope for further increases in cultivated area within the proposed irrigation perimeters is slight. Land must periodically be allowed to revert to scrub if it is to recover a level of natural fertility unless increased reliance is placed on fertilizers, a development which is difficult to predict. It is therefore assumed that the present yields and areas of cultivation within the proposed irrigation perimeters will also represent future conditions.

Whereas the areas shown are utilized for growing crops, the major part of the future perimeters are forested. These lands are used for grazing cattle. The greater part, those lands forming the upper and lower terraces and the central floodplain, lying below about 29,0 IGN, are grazed in the dry season. Studies (IEMVT, 1970) indicate that the central floodplain has a carrying capacity of 4-5 ha per UBT (Unité de Bétail Tropicale, representing 250 kg live weight of animal) and the terraces 6-10 ha per UBT. The highest lands within the irrigation perimeters are grazed in both seasons.

The economic value of project lands lies therefore primarily in their use as dry season rangeland. A value of 7 ha per UBT has been taken as representing the carrying capacity of the 16 400 ha to be cleared. The annual value of this grazing land is obtained as follows :

Number of UBT supported	:	16 400/7 = 2 343
Offtake rate	:	10 %
Weight per unit	:	250 Kg/UBT
Value of meat	:	200 FCFA/kg
Value of pasture per year	:	10 % X 2343 X 250 X 200 = 11,7 mill. FCFA
Value of pasture per hectare	:	710 FCFA/yr

Following project development, dry season vegetation in those areas near the irrigation perimeters or in the bottom lands which are unirrigated will have a considerably enhanced value. Moreover cattle would benefit from a readier access to water, provided from the irrigation canals. Crop residues which are used as animal feed will be available in greater amount and in both seasons. The combined effect of these influences is estimated to more than compensate for the loss of dry season grazing area, and the latter is therefore ignored in the economic evaluation.

9.3.4 Induced effects of project on surrounding lands

Small farmers who settle in the project area will be attracted partly from neighbouring villages and partly from further afield. The majority may be expected to make the transfer from rainfed seasonal to irrigated intensive agriculture rather cautiously, safeguarding the possibility of a return to their traditional holdings should their experience on the project prove disappointing.

Initially the labour transferred to the project by those presently farming outside the area may cause a certain decline in production outside the project. However the combined effects of population growth and the spin-off effect of the modern techniques employed on the project are expected rapidly to reverse this decline. The overall induced effect will undoubtedly be positive, but as there is no basis for quantifying this benefit it has been left out of consideration in the economic evaluation.

9.4 Benefits from agro-industry

Net benefits deriving from agro-industry are obtained as the difference between the gross value added in production and the costs of production.

The gross value added for each type of agro-industry enterprise is derived in table 9-8 . Milled white rice produced in industrial and multi-unit rice mills has been valued at FCFA 100 and 95 per kg respectively. A value for bran of 5 FCFA per kg has been assumed.

Production costs are summarised in table 9-7 . They are based on the financial cash flows presented in report 7, Agro-industry, modified to exclude interest and depreciation and with labour and fuel valued at their economic cost.

Net benefits from agro-industry are summarised in table 9-7.

9.5 Other direct benefits

9.5.1 Water supply

Water supplies in the Anambé Basin are generally unsatisfactory in terms of quality, reliability and accessibility. The irrigation network will greatly improve the situation for those living within and close to the development areas. Although the canals will not be a suitable source of drinking water for human consumption they will provide an important source of water for cattle. They will also provide an important social amenity in terms of bathing and washing facilities. The quantities of water removed from canals for domestic use and watering cattle will be quite insignificant compared to the quantity used for agriculture.

9.5.2 Flood control

Flood peaks will be greatly reduced in magnitude downstream of Niandouba dam except in very wet years. However, the damage caused by floods in terms

Table 9 - 7 NET BENEFITS FROM AGRO-INDUSTRY

(all values in million FCFA)

Year	Gross value added by agro-industry(1)					Processing costs(2)					Net value of agro-industry				
	Industrial rice mills	Village rice mills	Seed treatment	Livestock enterprise	Total gross value added	Industrial rice mills	Village rice mills	Seed treatment plant	Livestock enterprise	Total	Industrial rice mills	Village rice mills	Seed treatment plant	Livestock farm	Total
1980															
1981															
1982	39		1		40	28		1		29	13		0		13
1983	50		1		51	31		1		32	21		0		21
1984	73		2		75	37		1		38	41		1		42
1985	66		2		68	34		1		35	33		1		34
1986	156		3	61	220	72		3	40	115	87		0	21	108
1987	204	31	4	74	313	83	19	4	48	154	121	23	0	26	170
1988	204	86	6	78	374	83	46	5	51	185	121	57	1	27	206
1989	204	161	8	79	452	83	83	7	51	224	121	103	1	28	253
1990	204	208	9	107	528	83	109	7	69	268	121	135	2	38	296
1991	247	225	10	137	619	112	109	8	88	317	135	135	2	49	319
1992	293	238	11	159	701	124	114	9	103	350	169	144	2	56	371
1993	317	268	13	170	768	130	129	10	107	376	187	158	3	63	411
1994	352	281	14	190	837	156	138	11	122	427	196	170	3	68	437
1995	398	320	15	210	943	168	150	12	135	465	230	184	3	75	492
1996	422	369	16	229	1 036	173	172	13	148	506	249	210	3	81	543
1997	422	371	15	229	1 037	173	170	12	148	503	249	210	3	81	543
1998	427	394	15	259	1 075	175	181	12	154	522	252	222	3	85	562
1999	433	405	16	243	1 097	176	186	12	157	531	257	228	4	86	575
2000	438	416	15	[illegible]	[illegible]	178	191	12	160	541	260	235	3	87	585
2001 - 2030	445	[illegible]	15	[illegible]	1 129	179	193	12	160	544	266	236	3	87	592

(1) From table 9-8

(2) From tables 5-10, 5-11 and 5-12 and report 7

Table 9 - 8 GROSS VALUE ADDED BY AGRO-INDUSTRY

(all values in million FCFA)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001 à 2030
INDUSTRIAL RICE MILLS																				
Value of paddy purchased at 54 FCFA/kg	188	241	363	309	738	945	945	945	945	1 139	1 355	1 463	1 625	1 841	1 949	1 949	1 976	2 003	2 030	2 057
Value of white rice at 100 FCFA/kg	227	290	437	372	888	1 138	1 138	1 138	1 138	1 372	1 632	1 762	1 957	2 217	2 347	2 347	2 379	2 412	2 444	2 477
Value of bran at 5 FCFA/kg	2	3	4	4	9	11	11	11	11	14	16	18	20	22	24	24	24	24	24	25
Total value added	41	52	78	67	159	204	204	204	204	247	293	317	352	398	422	422	427	433	438	445
VILLAGE RICE MILLS																				
Value of paddy purchased at 51,25 FCFA/kg (1)						194	471	853	1 118	1 120	1 171	1 319	1 414	1 534	1 761	1 744	1 852	1 902	1 957	1 975
Value of white rice at 95 FCFA/kg						234	568	1 028	1 347	1 350	1 414	1 589	1 704	1 849	2 121	2 102	2 232	2 292	2 358	2 379
Value of bran at 5 FCFA/kg						2	6	11	15	14	15	17	18	19	21	22	23	24	25	25
Total value added						42	103	186	244	244	258	287	308	334	382	380	403	414	426	429
SEED TREATMENT																				
Value of paddy purchased at 54 FCFA/kg	4	5	8	8	15	24	30	41	44	49	55	60	64	70	76	74	72	73	74	75
Value of paddy sent for milling at 54 FCFA/kg	1	2	3	3	5	7	9	13	14	15	17	19	20	22	24	23	22	23	23	23
Value of clean seed at 70 FCFA/kg	4	4	7	7	13	21	27	36	39	44	49	54	58	63	68	66	65	66	66	67
Total value added	1	1	2	2	3	4	6	8	9	10	11	13	14	15	16	15	15	16	15	15
LIVESTOCK ENTERPRISE																				
Cattle : purchases at 20 000 FCFA/head					22,7	28,1	27,7	27,7	37,2	50,1	59,7	58,9	69,0	77,7	85,8	85,8	90,2	91,9	93,6	93,1
sales at 70 000 FCFA/head					75,6	93,7	92,3	92,3	123,9	167,1	198,9	196,5	230,1	258,9	286,1	286,1	300,5	306,3	312,1	312,1
Poultry meat : purchases of chicks					0,55	0,55	0,87	0,87	1,25	1,25	1,25	1,78	1,78	1,78	1,78	1,78	1,78	1,78	1,78	1,78
: sales of birds					3,47	3,47	5,54	5,54	7,95	7,95	7,95	11,31	11,31	11,31	11,31	11,31	11,31	11,31	11,31	11,31
Poultry eggs : purchases of chicks					0,16	0,16	0,25	0,25	0,36	0,36	0,36	0,51	0,51	0,51	0,51	0,51	0,51	0,51	0,51	0,51
: sales of eggs					5,65	5,65	9,00	9,00	12,90	12,90	12,90	18,40	18,40	18,40	18,40	18,40	18,40	18,40	18,40	18,40
: sales of hens						0,40	0,40	0,64	0,64	0,91	0,91	0,91	1,30	1,30	1,30	1,30	1,30	1,30	1,30	1,30
Total value added - livestock					61	74	78	79	107	137	159	170	190	210	229	229	239	243	247	247

(1) Weighted value of smallholder farm production excluding home consumption

of physical destruction and lost production under traditional agriculture is insignificant compared to the benefits which will derive from irrigated agriculture. Benefits from flood control will therefore be correspondingly small and have not been accounted for.

9.5.3 Transportation

The network of laterite surfaced roads serving the project area will play an important role in the agricultural development of the Anambé Basin. Improved farm access will result in reduced costs for transport of agricultural produce between farmgate and market. These benefits have been allowed for in deriving farmgate prices of agricultural commodities.

A large part of the main road system and the access roads to Niandouba dam and the confluence dam directly link villages with the national road network. Thus, for example, the access road to Niandouba dam will provide an all-weather link between Kounkané and six villages directly on the access road. Benefits deriving from use of main project roads and access roads, other than for specific project purposes, have been allowed for by including only half of the cost of these roads for the economic evaluation.

9.5.4 Land clearance

Of 18 800 gross hectares of land to be developed under the project, 16 400 hectares are presently uncleared. This area of wooded savanna represents a substantial resource which may be exploited for fuelwood, charcoal and quality timber as discussed in report 7. Land clearance will therefore be carefully planned and supervised so as to obtain the maximum benefit from the wood removed.

Approximately 90 percent of standing timber is suitable for charcoal production, the remaining 10 percent having an enhanced value as quality timber. Based on conservative estimates of the volume of standing timber, the tax paid on charcoal and quality timber extracted from the project area amounts to about 12 000 FCFA per ha. For the economic evaluation this tax is assumed to represent the net value of the wood after appropriate allowance for costs of production and extraction. The latter would paid by the contractor and would not be a cost to the project (the contractor retaining the wood extracted). As a result the costs of land clearance to the charge of the project will be reduced substantially. It is estimated (report 7) that the reduced time for land clearing operations after the area has been commercially exploited results in a cost reduction of 38 000 FCFA/ha.

The benefit from commercial exploitation of the uncleared land in the project area, for the purposes of the economic evaluation, is taken as the sum of the duties paid on wood or charcoal extracted and the reduction in land clearance costs, or 50 000 FCFA/ha.

9.6 Secondary benefits

9.6.1 Employment

The direct impact of the Anambé Basin development on agricultural employment has been allowed for in part by using a shadow price for labour (see paragraph 9.2.4)in deriving project costs. However this method fails to take into account the effects of the agricultural incomes generated by the project on other sectors of the economy - supporting services, small industry, crop processing, tec. The secondary employment generated will have a strong influence on maintaining and enhancing the vitality of the rural economy and in checking migration to the towns. The multiplier effects of the money spent by project farmers are likely to be greater than similar spending in urban areas as the import component in rural consumption and investment is lower. These effects are not generally quantified in project evaluation, but as they directly support government policy objectives they should be taken into consideration by the planning authorities.

9.6.2 Foreign exchange earnings

Senegal is a substantial importer of food grains and the amounts imported are expected to increase in the near future. The proposed projects will contribute to reducing this dependance on food imports and therefore release foreign exchange for other uses.

9.6.3 Intangible benefits

The project would result in substantial intangible benefits. These include :

- increase in per capita incomes
- greater security of food supplies both for local farmers and for the nation
- promotion of rural economy and hence checking of migration to towns
- increase in mobility due to improved infrastructure
- increase in cooperative endeavour among farmers
- increase in technical and managerial skills in the area.

Many of these benefits are specific national objectives under the National Development Plan and should therefore be taken into account by the planning authorities.

10. ECONOMIC AND FINANCIAL EVALUATION

10. ECONOMIC AND FINANCIAL EVALUATION

10.1 Economic evaluation

The flow of costs and benefits for the project as a whole is given in table 10-1. Economic cash flows for the separate elements - smallholder farms, mechanized farm and agro-industry - are found in report 13. Capital costs are allocated between smallholders and mechanized farm on the basis of cultivated area.

The project is assumed to have an economic life of 50 years, the expected life of the main civil works. All costs and benefits are given in constant mid 1979 prices. On the basis of the cash flows for the overall project and its various elements, economic rates of return are as follows :

Agriculture	5,0 %
- mechanized farm	4,9 %
- smallholders (including production division's farming of smallholder designated lands)	5,0 %
Agro-industry	28 %
Overall project (agriculture and agro-industry)	5,9 %

Project development as planned yields a rate of return of 5,9 percent. It is instructive to test the sensitivity of this result to a number of different changes in forecast costs and benefits. The rates of return given in table 10-2 are obtained under each of the stated assumptions.

The last case shown in table 10-2 is not considered feasible at the present time. Trials during Phase I will indicate the longer term feasibility of 24 hour operation.

As may be seen from the results of the sensitivity analysis, the project is not very sensitive to increases in cost nor to delays in implementation.

Table 10 - 1 ECONOMIC CASH FLOWS - OVERALL PROJECT

(million FCFA)

Year	PROJECT COSTS					PROJECT BENEFITS			NET ECONOMIC CASH FLOW (8)-(5)-(1)
	Capital costs	Recurring costs				Irrigation benefits	Agro-industry benefits	Total (6)+(7)	
		Operation maintenance	Replacement	Pumping	Total (2)+(3)+(4)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1980	706								- 706
81	1 674					- 18		- 18	-1 692
82	717	38	3	8	49	72	13	85	- 681
83	3 230	39	3	11	53	117	21	138	-3 145
84	6 886	39	3	16	58	194	42	236	-6 708
1985	4 409	51	45	15	111	166	34	200	-4 320
86	2 544	160	13	2	175	436	108	544	-2 175
87	2 654	219	7	4	230	685	170	855	-2 029
88	4 186	278	70	14	362	929	206	1 135	-3 413
89	2 388	301	7	30	338	1 201	253	1 454	-1 272
1990	3 201	390	123	47	560	1 501	296	1 797	-1 964
91	1 919	402	44	67	513	1 729	319	2 048	- 384
92	1 069	464	95	89	648	1 983	371	2 354	637
93	1 170	521	52	107	680	2 230	411	2 641	791
94	868	532	21	125	678	2 424	437	2 861	1 315
1995	702	532	261	142	935	2 808	492	3 300	1 663
96	476	532	140	160	832	3 160	543	3 703	2 395
97	45	532	251	159	942	3 249	543	3 792	2 805
98	16	532	150	159	841	3 401	562	3 963	3 106
99		532	162	159	853	3 492	575	4 067	3 214
2000		532	427	159	1 118	3 582	585	4 167	3 049
2001-2030		532	295	159	986	3 627	592	4 219	3 233

Table 10-2 ECONOMIC RATE OF RETURN, OVERALL PROJECT SENSITIVITY TESTS

Description	Rate of return %
Base case	5,9
Increase in capital costs of 20 percent	4,8
Escalation of fuel prices	
- 3 percent per year	5,6
- 5 percent per year	5,0
Delay in benefits of	
- 1 year	5,6
- 2 years	5,3
Change in price of cereals	
- increase of 20 percent	8,4
- decrease of 10 percent	4,6
Change in yields	
- increase of 20 percent	8,4
- decrease of 20 percent	2,9
Annual increase in net benefits of	
- 1 percent per year	7,7
- 2 percent per year	9,4
Irrigation during 24 hours each day	6,7

10.2 Financial evaluation

10.2.1 Sources of finance

The size and scope of the project both creates and solves financing problems. The amount of funds required, in relation to the total Senegalese budget, dictates that the project be funded from one or more loans, rather than out of current operating funds. On the other hand, the very magnitude of the project, and its considerable effect on the rice deficit as well as on the economy of the Upper Casamance, guarantees that a significant opportunity is made available to the lender or lenders to participate in a project that will have an important impact nationally.

In view of planned implementation of the Anambé by a Senegalese institution of which majority ownership and control belong to the government, a Government guarantee of repayment of borrowed funds is likely to be available. In view of the nature of the collateral (security) which the project could offer for the borrowed funds, a Government guarantee is almost certain to be required.

The private capital market in Senegal is almost certainly not capable of supplying the necessary funds. However, it is not unreasonable to expect that local banks might participate in the project, particularly for the financing of some of the local costs.

The most probable sources of foreign funds in the amounts required would seem to be international lending agencies specialezing in loans at concessional rates, and foreign governments that have concessional lending programs. Examples of the former are the International Development Association and the African Development Bank. Examples of the latter are the Saudi Fund for Development, the Development Loan Fund of the European Economic Community, and the "soft" loan programs of the United States Agency for International Development and the Canadian International Development Agency.

The sources and amounts of financing for the Anambé project are still uncertain at the time of preparation fo this report. Agreement has been reached in principle with the Saudi Fund for Development for loans to SODAGRI for up to $ 25 million, equivalent to about 6 000 million FCFA. Of this sum an amount equivalent to 900 million FCFA has been committed for development of the pilot farm. The terms of the loan allow for a grace period of 5 years a repayment period of 15 years and an interest rate of 3 percent.

For the project to be financially viable a major part of the capital expenditure must be funded from loans at similar concessionary rates or from grants. As the project meets many of the Government's most important objectives and in view of the fact that the main project beneficiaries are small farmers, credit from IDA and similar agencies will be sought. The Saudi Fund loan could be assumed to meet the foreign exchange costs of the mechanized farm of 5 000 hectares, comprising a 30 percent share of the foreign exchange costs of common facilities and the full foreign exchange costs for farm buildings and equipment and the industrial rice mills. Concessionary loans from other development agencies would cover the remaining 70 percent foreign exchange cost of common facilities, that part allocated to smallholder farm development, the cost of village rice mills, and a certain part of local costs. The assumption herein is that local funds from Government sources account for one third of total capital expenditure on irrigation works and production and processing facilities. Working capital requirements (table 10-3) are also met from local sources.

These assumptions made regarding financing are tentative and intended only to permit a preliminary financial evaluation to be made.

Capital expenditures for project works and facilities, separated into local cost and foreign exchange streams, are given in table 10-4 in constant money terms. The total funds required both from local and outside sources are also given in the table.

10.2.2 Debt services

Funds from outside sources are assumed to be available at the following terms :

	Phase I	Phase II to V
Grace period (years)	5	10
Interest during grace period (%)	3,75	3,75
Repayment period (years)	15	20
Interest during repayment period (%)	3	3

Interest during the grace period is added to the amount of the outstanding loan. Table 10-5 gives the loan service and repayment schedules for Phase I and later phases. The total debt service is given in table 10-4. All flows of funds are given in constant money terms.

Table 10 - 3 WORKING CAPITAL REQUIREMENT

(million FCFA)

Year	Mechanized farm(1)	Industrial rice mills(2)	Village rice mills(2)	Livestock feed farm(2)	Project operation and maintenance(3)	Total
1980						
81	64					64
82		6			24	30
83					3	3
84					3	3
1985	102				6	108
86	38	9		63	45	155
87			3	14	31	48
88			6	2	36	44
89			7		22	29
1990	77		6	27	56	166
91	67	7		34	19	127
92			6	25	46	77
93	72			4	41	117
94	29	11	9	24	17	90
1995	29			23	11	63
96				22	12	34
97			5			5
98				11		11
99			3	5		8
2000				4		4
2031	- 478	- 33	- 45	- 258	- 372	- 1 186

(1) See report 6, table 6 - 11

(2) See report 7, tables 7-3, 7-5 and 7-8

(3) To finance six months operation and maintenance plus pumping cost.

Table 10 - 4 SOURCES AND APPLICATION OF FUNDS

(all values in million FCFA)

Year	CAPITAL ACCOUNT BALANCE									CURRENT ACCOUNT BALANCE										
	Capital requirements						Sources of funds			Expenditures						Income			Balance	
	Project works and facilities									Recurrent costs										
	Local	Foreign	Total	Interest during grace period	Working capital	Total	Outside sources	Public funds	Total	O & M	Replacement	Pumping	Total	Loan service and repayment	Total	Agriculture and agro industry	Water charges to small holders	Total	Without rice quality premium	With rice quality premium
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
1980	365	341	706			706	471	235	706											
81	813	902	1 715	18	64	1 797	1 161	636	1 797							-13		-13	- 13	- 13
82	376	341	717	61	30	808	539	269	808	38	3	10	51		51	54		54	3	35
83	1 759	1 702	3 461	81	3	3 545	2 388	1 157	3 545	39	3	14	56		56	93	3	96	40	81
84	3 563	3 323	6 886	171	3	7 060	4 762	2 298	7 060	39	3	21	63		63	145	8	153	90	151
1985	2 527	2 334	4 861	249	108	5 218	3 490	1 728	5 218	51	45	20	116	225	341	61	22	83	- 258	-206
86	1 287	1 257	2 544	380	155	3 079	2 076	1 003	3 079	160	13	2	175	225	400	298	30	328	- 72	52
87	1 380	1 484	2 864	457	48	3 369	2 366	1 003	3 369	219	7	5	231	225	456	508	41	549	93	277
88	2 174	2 012	4 186	546	44	4 776	3 337	1 439	4 776	278	70	18	366	225	591	655	62	717	126	345
89	1 379	1 273	2 652	671	29	3 352	2 439	913	3 352	301	7	39	347	225	572	771	100	871	299	566
1990	1 732	1 469	3 201	763	166	4 130	2 897	1 233	4 130	390	123	61	574	225	799	873	143	1 016	217	518
91	1 117	1 063	2 180	871	127	3 178	2 324	854	3 178	402	44	87	533	225	758	906	186	1 092	334	668
92	469	600	1 069	959	77	2 105	1 672	433	2 105	464	95	116	675	225	900	987	218	1 205	305	682
93	549	621	1 170		117	1 287	780	507	1 285	521	52	140	713	1 831	2 544	1 026	296	1 322	-1 222	-808
94	431	437	868		90	958	579	379	958	532	21	164	717	1 885	2 602	1 021	366	1 387	-1 215	-762
1995	349	353	702		63	765	468	297	765	532	261	186	979	1 927	2 906	1 137	431	1 568	-1 338	-833
96	239	237	476		34	510	317	193	510	532	140	210	882	1 963	2 845	1 256	495	1 751	-1 094	-542
97	27	18	45		5	50	30	20	50	532	251	207	990	1 988	2 978	1 181	550	1 731	-1 247	-697
98	10	6	16		11	27	11	16	27	532	150	207	889	1 990	2 879	1 258	586	1 844	-1 035	-467
99					8	8		8	8	532	162	207	901	1 991	2 892	1 289	615	1 904	- 988	-409
2000					4	4		4	4	532	427	207	1 166	1 991	3 157	1 323	644	1 967	-1 190	-600
2001-2013										532	295	207	1 034	1 991	3 025	1 327	664	1 991	-1 034	-436
2014-2030										532	295	207	1 034		1 034	1 327	664	1 991	957	1 555
2031					-1 186	-1 186		-1 186	-1 186											

10.2.3 Recurrent costs

Recurrent costs are given in table 10-4 and include replacement costs for agro-industry facilities and the mechanized farm.

10.2.4 Water charges

The charge for irrigation water has been assessed on the basis of the following criteria :

- the capital cost of the schemes will be provided in the form of a subsidy to the project by the government through the project authority
- water charges will aim to cover all recurrent costs for the irrigation works and facilities, including operation and maintenance costs, provision for replacement costs, and pumping costs
- water charges will reflect relative water consumption, according to the different cropping patterns to be established on the project
- lower water charges should apply during the first four years after land development, reflecting a lower ability to pay.

Water charges are computed, as shown in table 10-6, by dividing the present value of recurrent costs by the present value of the area subject to water charges, making due allowance for charges during the first four years one half those at full farm production. For the project as a whole, water charges amount to 60 000 FCFA per hectare, being slightly higher for ricelands and lower for areas of diversified cropping.

Water charges to the mechanized farm have not been separated out in the financial evaluation as the reduction in net income to the project authority (which is assumed to operate the farm) is exactly balanced by the increased revenue from water charges.

Table 10 - 5 DEBT SERVICE EXPENDITURES (million FCFA)

Phase I

Year	Capital expenditure: Local	Capital expenditure: Foreign	Capital expenditure: Total	Sources of funds: Local sources (1)	Sources of funds: Outside sources	Interest during grace period on borrowed funds at 3,75 %	Total amount of loan (2)	Loan repayment at 3% interest over 15 years (3)
1980	365	341	706	235	471		471	
81	813	902	1 715	572	1 143	18	1 161	
82	376	341	717	239	478	61	539	
83	264	245	509	170	339	81	420	
84						97	97	
1985-1999								225

(1) Public funds amount to one third of total expenditure
(2) Interest during grace period is capitalized
(3) Allowing 5 years grace

Phases II to V

Year	Capital expenditure: Local	Capital expenditure: Foreign	Capital expenditure: Total	Sources of funds: Local sources (1)	Sources of funds: Outside sources	Interest during grace period at 3.75%	Total amount of loan outstanding (2): Annual	Total amount of loan outstanding (2): Cumulative	Loan repayment at 3% interest over 20 years (3): Interest	Loan repayment at 3% interest over 20 years (3): Principal	Loan repayment at 3% interest over 20 years (3): Total
1980											
81											
82	1 495	1 457	2 952	984	1 968		1 968	1 968			
83	3 563	3 323	6 886	2 295	4 591	74	4 665	6 633			
84	3 527	2 334	4 861	1 620	3 241	249	3 490	10 123			
1985	1 287	1 257	2 544	848	1 696	380	2 076	12 199			
86	1 380	1 484	2 864	955	1 909	457	2 366	14 565			
87	2 174	2 012	4 186	1 395	2 791	546	3 337	17 902			
88	1 379	1 273	2 652	884	1 768	671	2 439	20 341			
89	1 732	1 469	3 201	1 067	2 134	763	2 897	23 238			
1990	1 117	1 063	2 180	727	1 453	871	2 324	25 562			
91	469	600	1 069	356	713	959	1 672	27 234			
92	549	621	1 170	390	780		780	27 000	817	1 014	1 831
93	431	437	868	289	579		579	26 504	810	1 075	1 885
94	349	353	702	234	468		468	25 840	795	1 132	1 927
1995	239	237	476	159	317		317	24 969	775	1 188	1 963
96	27	18	45	15	30		30	23 760	749	1 239	1 988
97	10	6	16	5	11		11	22 494	713	1 277	1 990
98								21 178	675	1 316	1 991
99											
2000-2013									675	1 316	1 991

(1) Public funds amount to one third of total expenditure
(2) Net of repayment of principal. Interest during grace period is capitalized
(3) Allowing 10 years grace

Table 10 - 6 EVALUATION OF WATER CHARGES

Year	Recurrent costs for irrigation works (million FCFA)				Net irrigable area (ha)	Area of smallholder farms (ha)		Water charges to small holders (1) (million FCFA)
	O & M	Replacement	Pumping	Total		Level 1	Level 2	
1980								
81								
82	38		10	48	665			
83	39		14	53	945	105		3
84	39		21	60	1 420	280		8
1985	51		20	71	1 420	755		22
86	160		2	162	2 920	1 025		30
87	219		5	224	4 440	1 190	105	41
88	278		18	296	5 940	1 565	280	62
89	301		39	340	7 490	1 890	755	100
1990	390		61	451	8 690	2 820	1 025	143
91	402		87	489	9 990	3 750	1 295	186
92	464		116	580	11 485	4 400	1 845	218
93	521		140	661	12 685	4 800	2 645	296
94	532		164	696	13 885	4 800	3 845	366
1995	532		186	718	15 085	4 600	5 045	431
96	532	48	210	790	16 265	4 385	6 245	495
97	532	154	207	893	16 265	3 885	7 445	550
98	532		207	739	16 265	2 685	8 645	586
99	532		207	739	16 265	1 685	9 645	615
2000	532	154	207	893	16 265	700	10 630	644
2001-2030	532	27	207	766	16 265	-	11 330	664

(1) At average rate for smallholders given under 6 below. For farms at level 1 water charges are halved.

	Interest rate 8 %	Interest rate 10 %
1. P.V of recurrent costs (10^6 FCFA)	4 596	3 217
2. P.V of irrigable area (10^3 ha)	93,97	65,45
3. Cost per hectare (FCFA)	48 909	49 152
4. P.V of irrigable area, delayed 2 years	80,56	54,09
5. Cost per hectare	57 051	59 475

6. Water charges adopted for financial evaluation

Rice-rice cropping pattern	62 000 FCFA/ha
Rice-diversified cropping pattern	54 000 FCFA/ha
Diversified-diversified cropping pattern	46 000 FCFA/ha
Weighted average-project	59 600 FCFA/ha
Weighted average-smallholders	58 640 FCFA/ha

For the three cropping patterns, water charges represent the following proportions of net unallocated farm income (income after deduction of home consumption and debt repayment) for smallholder farms :

Cropping pattern	Net unallocated farm income 2,5 ha farm (FCFA)	Water charges (FCFA)	(2) : (1) %
	(1)	(2)	(3)
rice - rice	394 400	155 000	39
rice - divers.	359 500	135 000	38
divers. - divers.	318 700	115 000	36

Water charges of the indicated magnitude would leave farmers with an attractive net income in comparison with present farm incomes and in comparison with alternative employment. The return to the farm family's labour at full production averages about 2,5 times that in the present situation, comparing only the income from crop production (see table 5-7).

10.2.5 Income to project authority

Income accrues to the project authority from its management and operation of the mechanized farm, industrial rice mills and livestock farm. Payment of water charges by smallholders covers their part of project recurrent costs common to all irrigated areas.

Multi-unit rice mills have been treated as if they were owned and operated by the project authority, though they are established with the aim of transferring control of milling of smallholder production to the cooperatives.

The details of this arrangement, including provision for repayment of capital costs, are unclear at the present time and it is therefore simpler for the financial evaluation to include their operation with other agro-industry.

Project authority income is given in table 10-7. Milled rice produced by the project consists of whole grain and broken rice as described in chapter 9. The income given in table 10-7 is based on a rice price of 80 FCFA per kilo. Adopting a price of 100 FCFA per kilo for the whole grain rice and maintaining the price of 80 FCFA/kg for broken rice results in the additional income shown.

10.2.6 Financial cash flow appraisal

Table 10-4 shows that the income accruing to the project authority amply covers recurrent costs. Water charges (including those imputed to the mechanized farm but not shown in table 10-4) cover, on a long term basis, all recurrent costs except replacement of production and processing facilities. The latter are more than covered by the net revenue from operations.

Assuming that public funds for capital expenditure are made available in the form of a subsidy the difference between income and expenditure including debt services on foreign loans is given in table 10-4, columns (20) and (21). Even including the income deriving from a premium on higher quality rice, the overall financial cash flow to the project is not very satisfactory, substantial surpluses being followed by substantial deficits from 1993 to 2013 before the account is once more in substantial surplus. This suggests that a more appropriate loan repayment schedule should be found, more closely tailored to annual income net of expenditure.

10.2.7 Price contingencies

The capital costs presented in chapter 8 are based on the price level prevailing in mid 1979. It is not possible to forecast accurately what prices for labour, materials and equipment will be current by the time contracts are let and during the course of construction. Past experience may be an unreliable guide, especially to the costs applying to later phases of the development programme.

For project purposes the most immediate costs for which budget estimates are required are those pertaining to Phase I. However expenditure for Phase II

Table 10 - 7 PROJECT AUTHORITY INCOME FROM AGRICULTURE AND AGRO-INDUSTRY

(million FCFA)

Year	Income from agriculture		Income from agro-industry				Total income (2)to(7)	Rice quality premium	Total income with premium (8)+(9)
	Mechanized farm (1)	Production division (1)	Industrial rice mills	Village rice mills	Seed treatment	Livestock farm			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1980									
81	- 13						-13		
82	46		8				54	32	86
83	59	20	15		- 1		93	41	134
84	59	55	32		- 1		145	61	206
1985	38		24		- 1		61	52	113
86	192	21	68		- 2	19	298	124	422
87	253	120	96	17	- 2	24	508	184	692
88	261	234	96	42	- 3	25	655	219	874
89	261	316	96	76	- 4	26	771	267	1 038
1990	326	323	96	99	- 4	33	873	301	1 174
91	422	242	104	99	- 5	44	906	334	1 240
92	509	194	134	104	- 5	51	987	377	1 364
93	523	190	148	117	- 6	54	1 026	414	1 440
94	583	104	153	126	- 6	61	1 021	453	1 474
1995	666	93	182	136	- 7	67	1 137	505	1 642
96	757	81	197	156	- 8	73	1 256	552	1 808
97	763		197	155	- 7	73	1 181	550	1 731
98	824		200	165	- 7	76	1 258	568	1 826
99	846		204	169	- 7	77	1 289	579	1 868
2000	869		208	174	- 7	79	1 323	590	1 913
2001-2030	869		211	175	- 7	79	1 327	598	1 925

Note (1) Income from mechanized farm and production division has not been reduced to account for imputed water charges, and therefore includes water charges imputable to these farming units.

is also scheduled to fall partly within the next Plan period, mid 1981 to mid 1985, and therefore escalated cost estimates for the full right bank development have been made. Recent local price escalation, international cost trends and IBRD price projections have been considered in estimating future escalation rates. The following values have been adopted :

	Cost escalation Foreign (%)	Cost escalation Local (%)
1980	12	15
1981	10	12
1982	8	10
1983	8	8
1984	8	6

These rates have been applied to the capital costs given in table 8-8 at a compound rate from 1st January 1980. The expenditures shown are assumed to be incurred at the end of the year in which they fall.

The additional costs due to escalation are as follows :

	Phase I	Phase II / III
Start of construction	1980	1983
Construction period	3 years	6 years
Capital cost (10^6 FCFA)	3 647	19 980
Price contingencies (10^6 FCFA)	1 056	13 072
Capital cost including price contingencies (10^6 FCFA)	4 703	33 052

11. OUTSTANDING ISSUES

11. OUTSTANDING ISSUES

There are no outstanding issues, the resolution of which may preclude or seriously interfere with the orderly implementation of the project. The development potential for irrigated agriculture has been demonstrated ; availability of suitable land and water resources to satisfy the design requirements of the project has been established and moreover, there are no competitive uses for these resources ; and there is an assured market in Senegal and neighbouring countries for any level of production of cereal crops which can be achieved in the Anambé Basin.

It is possible that the rate at which small farmers take up irrigated plots on the project may exceed or fall short of that forecast. This has to some extent been anticipated with the provision of the Production Division of the project authority which, as formulated, can be expanded or contracted as required to assure efficient cultivation of all lands which are developed for irrigation without interfering with the orderly growth of peasant enterprise, and without impinging unduly on the local agricultural labour force.

The only major feature of the project which is susceptible of an alternative solution is the power supply facility for the pumping stations in the Anambé Basin which are required to lift water to levels commanding the irrigation service areas. The recommended project includes a hydroelectric power plant at Niandouba Dam to produce energy to power one of these pumping stations. As noted in chapter 3, the principal alternative sources of energy to drive the pumps include mechanical drive using diesel motors, and electric motors linked to a wood-fired thermal power station. The alternatives may also be combined in a number of ways. Preliminary economic analysis reveals no significant difference in the viabilities of the alternative power sources. The selection of the hydroelectric source was based largely upon the assumption that the recent trends of disproportionately rising costs of petroleum products will continue to a level which will make the cost and security of hydroelectric power clearly attractive. This has, to some extent, already occurred with the most recent price increases in petroleum products, which are not fully reflected in present cost estimates. It follows that the choice of a source of energy for pumping must be reviewed as part of the final design studies for Phase II of the project.

As the changes which may be made in the power mode for the project will not have adverse effects either on the development schedule or on project costs, the matter can be considered as a potential refinement of the configuration of works, not an outstanding issue with implications on project feasibility.

Certain other issues, none affecting project feasibility may,be reconsidered following development and operation of the first phase. One such issue is land clearance where practical experience will help to determine the most appropriate solution, taking into account the use of a scarce resource, soil conservation and development costs. The degree and precision of land levelling to be carried out by the contractor as opposed to that which can subsequently be undertaken by small farmers can also be better defined.

A further task to be undertaken before Phase II is started is a survey of the reservoir area to determine the magnitude of the unsettlement involved. As no guidelines appear to have been laid down yet by Government, it is important that a preliminary study be undertaken at an early stage, in coordination with local authorities.

During project development experimentation and research carried out on the pilot farm will result in the introduction of new crop varieties and improved cultural and water management practices, and possibly additional upland crops for the lands which are not suitable for rice cultivation. Such refinements have been anticipated and they can be accomodated at any stage of development without further implications on the design of project works and facilities.