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ANALYSIS OF THE IDP IRRIGATION COMPONENT

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IRRIGATION ANALYSIS

LIST OF ACRONYMS USED IN THE TEXT

FAO: Food and Agriculture Organization of the UN.

GERSAR: Groupement d'Etudes et de Réalisations des Sociétés d'Aménagement Rural.

GOM: Government of Mali.

IBRD: International Bank for Reconstruction and Development (World Bank).

IDP: Integrated Development Project (USAID)

IGN: Institut Géographique National.

SAED: Société d'Aménagement et d'Exploitation des Terres du Delta et de la Vallée du Fleuve Sénégal et de la Falémé.

SATEC: Société d'Assistance Technique et de Crédit (Government Development Company, France).

SENELEC: Société Sénégalaise de Distribution Electrique (National Electric Company of Senegal).

PIV: Small Irrigated Perimeter.

UGA: Autonomous Irrigated Unit.

USAID: United States Agency for International Development.

SONADER: Société Nationale pour le Développement Rural (National Rural Development Agency).

C

3.2. IRRIGATION ANALYSIS

3.2.1. Introduction

The Senegal River Basin has a very large, and so far mostly untapped, irrigation potential. With the completion of the upstream reservoir at Manantali and the low barrage near the mouth of the river at Diama to prevent salt water intrusion, there will be an estimated 300,000 hectares of irrigable land in the Senegal River Valley. Both of these dams are now under construction and scheduled to be completed in 1987 (Diama) and 1988 (Manantali). Currently, three are about 28,000 hectares under irrigation in the valley. This is only about half of the irrigation target of 60,000 hectares set for 1982 by the OMVS and member states in 1974. The major thrust of irrigation development so far has been on large irrigation schemes, or "perimeters" as they are known locally. These large perimeters have been plagued by high costs, poor yields, and low farmer participation, and the national development agencies charged with developing them have suffered from growing pains, mismanagement, and financial difficulties that have hindered their effectiveness.

Out of this experience has come a growing knowledge of the requirements for successful irrigation development in the Senegal River Basin. Each of the countries has acknowledged the inadequacies of the earlier top-down strategies and is seeking ways of reducing the dominant role of the regional development agencies (RDA's) and increasing farmer participation and motivation. The positive experience of small perimeters with lower per hectare development costs and higher average yields have demonstrated the advantages of irrigated agriculture. The experience of the small perimeters also suggests that an agricultural strategy based on greater farmer participation in control and management of irrigation schemes is likely to produce much better results than the highly centralized top-down approaches of the past.

3.2.1.1. General Site Characteristics

The Senegal River is the second largest river in West Africa. It is over 1,800 kilometers long and drains a watershed of more than 300,000 kms^2. Forty-five percent of the river's length forms the border between the countries of Mauritania and Senegal. Fifty-five percent of its drainage area is in Mali. About fifty percent of the water in the Senegal River originates in Guinea, outside the boundaries of the OMVS member states (Gannett et al. 1979). Several tributaries empty into the Senegal River, including the Bakoye, Bafing, and Falémé Rivers.

The Senegal River Basin is typically subdivided into three regions: the Delta, the middle valley, and the upper valley. The Delta begins at a poorly defined point between Mbagam and Ntiagar and ends at Saint Louis, where the river enters the Atlantic Ocean. The only tributary stream of significance in this region is the Gorgol, which is dry much of the year. The middle valley begins at Bakel, Senegal, where the shape of the valley changes from a narrow, well-defined channel with steep banks to a flatter profile characterized by alluvial flood plains 10 to 25 km wide. The

middle valley ends where the extremely flat Delta begins, about 100 km from the ocean at Richard Toll. The upper valley includes all the basin upstream from Bakel and thus lies mainly in the country of Mali. Senegal and Mauritania share opposite sides of the middle valley and Delta regions.

Abundant alluvial plains existing throughout the valley are suitable for irrigation. Size, topography, soils, and drainage characteristics of the plains vary, pointing out the need for different sizes and types of irrigation systems for specific sites. The development strategy is to develop small and medium-sized systems to serve large groups of farmers with small land holdings. Construction, operation, and maintenance designs should be labor intensive and should rely on locally available materials to the greatest practical extent.

A. Small and Medium-Sized Perimeters

The terms "small and medium-sized" refer to the development strategy as well as the absolute area of the site. Small perimeters generally range ~~in size from 15 to 20 hectares and are served by a diesel driven pump,~~ a network of canals, surface drains, some small flood protection dikes, and partially leveled plots. While donor-financed projects and RDA's (SAED, SONADER, and OVSTM) have generally prepared the land, farmers do all the planting, harvesting, weeding, and threshing, and farmer groupements maintain and operate the pumps and perimeter infrastructure.

~~The medium and~~ large perimeters will generally range from 40 to 1000 ~~hectares~~. Although the individual land holdings and parcels in these perimeters will be the same as for the small perimeters, the system design will place more emphasis on economies of scale, such as larger ~~and more efficient~~ pumping units, larger channels ~~and water control structures,~~ and more complex operation and water scheduling procedures. The medium scale perimeter designs will allow the farmer less control and require increased support from farmers' associations or government institutions and eventually more mechanized equipment for construction, operation, and maintenance. Farmers' associations or groupements are expected to take over all maintenance and operations by the end of this project, however.

B. Topography

Ideal sites are characterized by high, steep, river banks with land gradually and evenly sloping away from the river across the plain, to a natural drain which flows by gravity back to the river. This situation is not at all uncommon, especially in the reaches above and below Bakel. Some less ideal sites have undulating topography, requiring some land leveling and increased systems (cuts and fills).

Some sites have a low area parallel to the river and between the river bank and area to be irrigated. In this case, the low area must be traversed with an elevated open channel or siphon. In some cases there are irrigable lands on both sides of the depression, and the depression can be used as a

drain. Another common problem is land sloping toward the river for a considerable distance above the bank crest, which must be traversed with extra pipe on the pump discharge or an elevated channel.

During low water periods, some sites dry up or recede far from the banks, requiring excessive pipe for pumping. This problem will be ameliorated or eliminated with stabilized minimum flow and stage with completion of Manantali and Diama dams.

C. Soils

The soils in all proposed sites are alluvial deposits in the floodplain. The deposits result from the main river overflowing its banks, or from erosion off smaller watersheds discharging onto the floodplain. Soil texture varies from light sand and silt, usually encountered near the river banks in higher areas, to heavy, swelling clays found in the lower and poorly drained areas. Because of the complexity of the hydrology of small adjacent watersheds and the meandering river channel, no strict rules can be applied regarding locations of soil types. Many areas have tight clay soils or loams on high river banks. Typically, sandy soils and expanding clay soils have the poorest available moisture capacity. The latter are more suitable for rice cultivation. Medium textured soils have the greatest available moisture capacity and are most suitable for upland crops.

D. Flooding and Drainage Characteristics

Many of the sites are partially or wholly subject to flooding and/or poor drainage. Flooding can result from high river stages or storm runoff from small watersheds discharging onto the flood plain. There are also naturally low and marshy areas without surface drainage. Flood control and drainage must be considered in every site and appropriate measures taken where needed in design and operation. Drainage and flood characteristic will be accounted for in site selection, with perimeters needing little or no work taking top priority. Completion of the Manantali Dam will ameliorate flood and drainage problems to a limited extent.

3.2.1.2. Characteristics of the Proposed Irrigation Systems

The majority of the systems will use water pumped directly from the river for irrigation. In sites where it is feasible, impounded water from adjacent small watersheds will be pumped or fed by gravity to the irrigated area, or a combination of these methods will be used. 1/

1/ Each perimeter or site design will be synthesized and analyzed as a complete system, rather than viewed as separate and unrelated components. All the pertinent components between the water source and drainage outlet and the interrelationships of these should be considered. Analysis of efficiencies and cost effectiveness of components, such as pumps, engine channels, and water management and distribution techniques, will be related to the system as a whole.

A. Pumping Units

Diesel driven centrifugal pumps will be used for lifting water from the river to small perimeters, unless a reliable source of electricity is available. Experience to date has shown that small, low-speed, air cooled manual start engines such as the two cylinders Lister HR-2 are the most suitable. This unit is long lasting, easy to maintain, efficient, and light enough to be moved by six or eight men when mounted with the pump on a steel skid. Pumps and engines should be standardized to the greatest degree possible, allowing for a certain flexibility to accomodate variations in lift.

One pump of this size has the capacity to irrigate about 20 hectares, and more units can be added for larger perimeters. It is more practical than the larger pumps because of the security provided by additional units and minimization of spare parts and maintenance problems.

Pumps will be chosen to match the engine speed, power, and head requirements, with attention to efficiency, durability, and maintainability. Because the river level fluctuates considerably, it is particularly important to select and match units with acceptable characteristics over the entire range.

Pump/engine units may be mounted on the river bank or adequate floating rafts; whichever is more desirable. Bank-mounted units are considerably cheaper, but must be moved up and down to accomodate the rise and fall of river stages. From an economic and operation standpoint, both systems have been used successfully, but could be improved.

Suction for the raft-mounted pumps occurs through a permanently mounted steel flange pipe with appropriate screen and foot valve. Suction pipes on the bank-mounted pumps must be partially flexible to accomodate movement and variations in bank slope. A disadvantage of the bank-mounted units is that they have a tendency to leak air in the flexible suction pipe joints. Care must be taken to assure that vertical lift and friction loss in the suction pipe and flood valve do not exceed required net positive suction head of the pump.

Discharge pipes between pump outlets and the distribution system are currently made up of heavy PVC pipe with flexible quick-couples. Bolted steel flange pipe with one or two flexible joints and elbows should be considered as an option for discharge and suction pipes. Pipes lines should be sized to assure that friction loss and velocities are not excessive.

Pumping units for the medium-sized perimeters will be considerably larger stationary units, either diesel or electric driven. Electrified units may draw power from a national grid --if one is available and reliable-- or from a generating plant especially built for one or more perimeters. The units will include necessary housing, sumps and inlets adequately protected from floods, erosion, and sedimentation. In determining the optimum size

of the units, the efficiency and economy of scale of the larger units should be weighed against the security and control of a larger number of smaller units. These issues will be addressed in the project design phase.

B. Irrigation Blocks

Both the small and medium perimeters will be divided into irrigation blocks of suitable size and shape for irrigation rotation and scheduling. Experience with existing perimeters indicates that square blocks of approximately three hectares are adequate for the type of farming and land tenure and cultivation being used. Flooding of the level basin is considered the most appropriate method of distribution within the blocks in light of the small land holding and labor-intensive practices.

For the small perimeters, land leveling and grading will normally be limited to manual preparation of individual basins. For the medium perimeters, some land leveling with power equipment may be feasible and will be necessary.

C. Water Distribution Systems

Each perimeter will include an appropriate conveyance and distribution system for delivering the required quantities of water to respective blocks at scheduled times. Possible considerations for conveyance are compacted and properly graded earth channels, surface channels with appropriate lining, low-pressure buried pipe with controlled riser outlets for each block, or any combination of the above. In choosing systems for small perimeters, the emphasis should be on using labor-intensive construction and maintenance techniques with locally available materials.

Any recommendation for conveyance systems other than compacted earth channels should be based on proven evidence of cost effectiveness in terms of saved water, maintenance, or durability.

D. Water Control and Measurement

In large perimeters, where more than one block is irrigated at a time, systems will contain adequate structures for controlling and measuring water to each block, water appropriate flumes, wiers, or in-line meters. In systems with branched flows, the branching structures will be hydraulically designed to give proportional flows, or the flow in each branch can be regulated and measured.

Each block will have an adequately controlled turnout from the irrigation channel, with properly designed stilling basins and aprons where needed. Check structures will be placed at necessary locations for maintaining required water surface elevations in distribution channels. Adequate energy dissipators and stilling will be basin installed on necessary drop structures and pump discharge outlets. For small perimeters where one pump

is used to irrigate the entire area, the pump should run continuously at optimum speed to ensure that it operates at top efficiency. In doing so, the discharge of the pump will be constant at a certain water level in the river and cannot be easily altered to match the water demand of a specific crop. Irrigation should be carefully scheduled so that one block is irrigated at a time to ensure that the maximum discharge of the pump is utilized in one block. This will eliminate the need to use more sophisticated water measuring devices and help keep construction costs low. The proposed scheduling for water application on a small perimeter is presented in Appendix A.

E. System Operation and Water Scheduling

Each system design will include a complete plan for operation and water scheduling, including required depths (or inflow times) and frequencies for the specific soils and crops particular to the site and respective blocks. The operation plan will account for seasonal and crop growth stage variations in water requirement as well as rainfall.

F. Flood Control and Drainage

A complete assessment of flood control and drainage requirements will be made for each site. Perimeter designs will include necessary dikes, channelization inside and outside the perimeter, gravity or pumped drainage structures, and subsurface drains if required. Many small perimeters will require little or no flood control and drainage, and site selection will screen out areas requiring extensive work. Some flood control and drainage works will be required on most of the medium perimeters if full economic benefits are to be gained and adequate security provided. However, areas requiring extensive works will be avoided.

3.2.1.3. Site Selection Criteria

All of the sites selected for development under this project were identified by the respective RDA's and have been inspected by the members of the project design team.

A. Small or Village Perimeters

General site identification by RDA's is based on requests made by the villagers familiar with other small irrigated perimeters and wishing to develop their own perimeters. Almost all of the sites proposed are either in need of improvement or extension or are contiguous to existing perimeters. Other sites are identified through the studies undertaken on behalf of the RDA's (in particular the SATEC in Mauritania) or by RDA personnel on site. Finally, prospective sites are selected or ruled out on the basis or previous experience, available data, and careful evaluation of farmer interest and motivation.

B. Larger Perimeters

The existing large perimeters have been hurt by poor design and construction as well as by the insensitivity of agents towards farmers. Major reforms are needed in the area of organization and management. The Podor perimeter has been proposed as the site for a pilot project aimed at resolving social and organization problems and creating a model that can be replicated in other areas of the middle valley and the Delta. Since potential sites for small irrigated perimeters are limited, the development program in the Basin will have to move in the direction of larger irrigation schemes.

The Podor perimeter is described in detail below. The site was identified several years ago, and follow-up research since then has led to a reformulation of the perimeter's design. The Podor perimeter is representative of development by the large perimeters in the middle valley. The project's strategy will be to shift gradually from a small to a medium-sized perimeter development approach, based on small perimeter models of management, organization, and farmer participation.

3.2.1.4. The Proposed Sites

The Project includes irrigated perimeter development in five sectors in Mauritania, Senegal, and Mali: Kaedi and Gouraye, in Mauritania; Bakel and Podor in Senegal; and Kayes, in Mali. Fig.9, Appendix C, Perimeter Location Map, shows the villages in each sector where perimeters will be developed. Irrigation is not a completely new farming system to many villages in the area that already have perimeters. It has already been tested and a strong demand has been voiced for its expansion. At the same time, there is a need to upgrade and improve operation of existing perimeters to improve their productivity and assure their economic viability.

The project will finance the upgrading of approximat 703 hectares of existing perimeters. The construction of 2,120 hectares of new small village perimeters, 1,907 hectares of medium-sized perimeters, and 933 hectares of gravity-fed irrigation. Existing perimeters and those to be upgraded and constructed in each sector are presented in Appendix B, Tables 1, 2, 3 and 4. Additional information on characteristics of each site was developed by the project design team, but is not presented in this report. This information is on file and will be used in the development of individual site plans, which USAID will have to approve before funds can be released for rehabilitation or construction.

a/ In Mauritania, the project includes the development of 2,250 hectares[1/] of additional irrigated perimeters in the Kaedi and Gouraye Sectors during the seven-year life of project. These perimeters will be developed through the combined efforts of AID and the World Bank through two separate but closely coordinated projects. In addition to these perimeters, another

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1/ See Tables 1 and 2, Appendix B.

300 hectares are now being financed in the Kaedi Sector under an FED project that will continue through 1984.

The construction of the 2,250 1/ hectares of new perimeters will involve two phases. The first phase covers three years (1984-86) and will involve only small perimeters. During this phase, the World Bank will finance technical assistance, equipment, construction, and operating costs required to develop 75 small perimeters with 1,570 hectares. AID will provide assistance during this period to upgrade SONADER extension services, strengthen farmer associations, and improve agricultural credit and input supply systems. AID will also finance the preparation of a development plan for the Gouraye Sector and feasibility studies for continuing perimeter development.

The second phase will cover four years (1987-90), and will involve consolidating the small perimeter program and introducing medium-sized perimeters. AID will finance the upgrading of existing perimeters in the Gouraye Sector and an 80-hectare extension of the village perimeter at Soulou. Introducing medium-sized perimeters will begin with the development of two perimeters of approximately 300 hectares each. The two sites proposed for these perimeters are Winding and Dirol in the Kaedi Sector. The medium-sized perimeter plan entails constructing small dams to establish seasonal reservoirs in low-lying basins, from which water for perimeter irrigation can be pumped. By this time, phase one project activities will have improved agricultural extension and introduced animal traction and other labor-saving and productivity-increasing technologies so that this larger-scale irrigation development will be possible. The medium perimeters will be organized along the same lines as small ones, with farmers associations directing all development and cultivation activities.

b/ For Senegal, the project will have two separate components. First, it will finance the upgrading of existing perimeters and the construction of new perimeters in the Bakel sector. This activity builds upon and continues the activities of the Bakel Small Irrigated Perimeters Project (AID Project 685-0208). In selecting the sites for Bakel, the project design team relied heavily on experience gained in the Bakel project and worked closely with the technical assistance team in Bakel. Second, the project will finance the first two stages of the development of the Podor medium-sized perimeter. The proposal for Podor is based in part on the feasibility studies conducted by GERSAR. 2/ Additional studies will be undertaken by the USAID/RBDO staff engineer who will also prepare the final blueprints for the perimeter. These plans will fully investigate technical options to increase efficiency in construction and operation of the perimeter and

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1/ See Tables 1 and 2, Appendix B.

2/ a/"Etudes de Réhabilitation, de Factibilité et d'Avant-Projets Détaillés de Périmètres d'Irrigation sur la Rive Gauche du Fleuve Sénégal", GERSAR 1981.

b/"Périmètre de Podor: Schéma d'aménagement, avant projet sommaire, évaluation économique." GERSAR - Août 1982.

to reduce costs. Work planned for the Bakel sector includes upgrading 13 perimeters with a total of 281 hectares, and constructing or expanding perimeters in 13 villages with a total of 714 hectares. The Podor perimeter site contains approximately 1,580 hectares. In total, the project will develop 1,063 hectares under a phased approach. The remaining area will be developed in later years, depending on the success of the earlier phases.

c/ For Mali, the project will initially focus on upgrading and improving the productivity of existing perimeters. Ten of the eleven existing perimeters covering 232 hectares will require some upgrading. For the later phase of the project, the Government of Mali has earmarked some 933 hectares for the construction of gravity-fed irrigation systems.1/ These sites are located in depressions parallel and back from the river and will involve the trapping and gradual release of rainwater runoff rather than pumped irrigation. The decision as to whether to go ahead with the construction of these perimeters will be made during the fourth year of the project, based on the development scenario chosen as a result of the Kayes Regional Development Plan as well as irrigation feasibility studies conducted under the project.

The location of each perimeter and existing number of hectares are shown in the plans attached as Appendix C. The plans are divided into eight sections starting upstream in the Kayes sector and moving downstream.

3.2.2. Program for Upgrading Existing Small Perimeters

The project design team examined existing small perimeters in the Bakel, Gouraye, and Kayes sectors in order to estimate the work and cost requirements for bringing the entire developed area of the perimeter into production. Perimeters in the Kaedi sector were not included as they are being rehabilitated in a separate project funded by the FED. The following items were examined:

- irrigable surfaces;
- condition of the main canals; slope, section, seepage losses, elevation differences, condition of banks;
- condition of the concrete works: basins, gates, intakes, turnouts, etc.;
- condition of the secondary and tertiary canals;
- need for paddy leveling;
- condition of the drainage system and the drain canals;
- protection against runoff and drainage of rain water;

1/ "Aménagement des Cuvettes," Cercle de Kayes, Project Paper, Direction Nationale du Génie Rural, Ministère du Développement Rural, February 1980.

- condition of the pumping system: engine, hourly consumption of fuel and oil floats, platform, discharge piping, intake valve, stilling basin;

- pumping rates and total volumes;

- supply and stocking of motor fuel.

Using these items, the team developed estimates of the work required to upgrade small perimeters in the three sectors. The analysis was undertaken at the feasibility level, and firm costs have been established for the overall rehabilitation to be carried out in each sector. Before any rehabilitation begins, a final design study for each individual perimeter should be prepared. This rehabilitation design site plan should be prepared under contract through the RDA and technical irrigation engineer in each sector.

The feasibility analysis for upgrading perimeters recommends the following improvements, in order of priority:

A. Pumping:

Motor pumps should eventually be overhauled to replace broken parts, repair or replace the float system, and check on its mooring to the banks. A conduit canal for low water may also have to be built. The tubes of the discharge piping system should be checked and parts replaced or added as necessary.

The stilling basins should be remortared or repaired and energy dissipators constructed.

After these conditions are met, the irrigated surface should be increased to correspond to the capacity of the motor pump. This additional area will of course depend on the type of cultivation foreseen and its water requirements. Creating secure, controllable fuel reserves is also important. Taking into account the agricultural aspects of the rehabilitation program, the pumping system used on the small perimeters must be examined to determine its usefulness in other situations.

The water requirements for individual perimeters should be calculated to determine optimum pumping requirements. For the purposes of cost calculations, pumping needs for a typical perimeter of 15 net hectares were defined as follows:

Crop		Rainy Season	Dry Season
Rice	Vol.	7,630 m^3/Ha	18,430 m^3/Ha
	Fuel	127 l/Ha	344 l/Ha
Corn or Mixed Crops	Vol.	1,850 m^3/Ha	9,100 m^3/Ha
	Fuel	22 l/Ha	186 l/Ha

B. Canals

The canal sections are dependent on several factors: the slope, the flow, and surface roughness. Canal rehabilitation could entail a total reconstruction of the banks to bring them above the level of the entire irrigated area, or it might require merely straightening out the canals.

Seepage loss will be measured along the canals through the use for example of sill gauges and small flow meters. If losses are judged excessive, which should be rare, the interior sections should be lined with flagstones or concrete lining. Plastic layers are too frail to stand up under animal hooves. Moreover, concrete or flagstone linings will prevent the canal banks from sagging due to infiltration.

C. Concrete Works

These small construction works control the water level in canals. Old works should be repaired and new works constructed. At the intersection of the main and sub canals, it will be necessary to install a small water control box with a small metal gate to control water flow and prevent erosion. If the canals have excessive slope, drop fixtures should be installed to control water speed. Some permanent check structure should also be installed along such a canal to facilitate siphoning.

D. Leveling

Levels should be controlled while the plots are evened out manually. Small dikes will be needed in the rice paddies to control water levels.

E. Drainage System

Drainage ditches should be excavated and manually calibrated, and a perimeter dike with an outlet channel should be built to protect the system against runoff. Certain perimeters will require greater use of heavy equipment to achieve a better drainage system thoughout the whole area. A preliminary study should be conducted to examine the topography, outputs, earthwork estimates, and other factors. If necessary and possible, the use of heavy equipment should be contracted and coordinated with the other works in the area.

F. Flood Protection

While ridges along the river banks are not reached by the river's annual flood stage in most cases, earthwork is sometimes necessary. Frequently, the back sections of an area are inundated. It might be useful, therefore, to build a dike equipped with a one-way backwater gate.

All rehabilitation construction will be guided by the specifications outlined in this document, for the construction of small perimeters. These guidelines are in conformity with the existing situation and potentialities.

The aim is to create a system that will limit degradation and damage, with operations and maintenance to be carried out as described further on. In addition, these technical improvements will be reinforced with others such as new cultivation methods, varietal changes, and agricultural inputs as recommended in the report on agriculture as well as the installation of windbreaks and protective fences against animals.

3.2.2.1. Sites for Small Perimeter Rehabilitation

A. Small Perimeters in the Bakel Zone

The initial program covers 13 perimeters representing a total surface of 281 hectares. The sites are presented in Table 3, Appendix B. Their rehabilitation consists primarily of the construction of canals, and small concrete works to be built during the first three years of the program.

B. Small Perimeters in the Kayes Area

This program covers a total of 232 hectares over ten perimeters.

All aspects of rehabilitation will be carried out by farmer groups, as in Bakel, during the second and third year of the program. Work requiring heavy equipment will be carried out in the third and fourth years of the project, when development of the small basins is scheduled to begin.

C. Small Perimeters of Gouraye and Kaédi

Rehabilitation works in the Kaédi region are bieng implemented under a different project financed by FED.

Although the perimeters in the Gouraye region are relatively new, certain inadequacies have already been discerned. For example, Diougountourou lacks a drop structure and adequate drainage and Woumpou needs to relocate and line a main canal. In this sector, the team estimates that work will be needed at ten sites covering a total of 190 hectares.

3.2.2.2. Financial Evaluation of Rehabilitation Works

Evaluation of these small projects is extremely difficult. Those engaged in the project itself will have to define precisely the work to be done. Some rough estimates have been made, however, including the following:

A. Equipment: Each perimeter will need approximately:

- 20 wheelbarrows,
- 20 pickaxes,
- 40 shovels,
- 40 hoes,

and various smaller tools. The total cost for this equipment will be $5,000.

B. Pumping: One float in four should be replaced at $4,300 per unit. Each set will require an average of $300 for repair and replacements. In addition each perimeter will require five pipe elements per pump, for a total of $1,500.

C. Concrete work: One out of two perimeters will have its main canal covered with flagstone or concrete, each requiring an average of six small works. A perimeter of 15 hectares will thus require five tons of cement.

D. Earth removal: Each perimeter will need about 10 hours of work for a bulldozer or back-hoe. These excavations should be carried out with other necessary construction on dikes and drains, at a rate of $185 per hour. Farmers' groups will assume labor costs and will not be reimbursed (See Economic Analysis, Volume III, Section 1.0. for more details).

3.2.2.3. Summary of Rehabilitation Costs (in US dollars)

Senegal: Thirteen perimeters and 18 pumps - 281 ha.

Mali: Ten perimeters and 15 pumps - 232 ha.

Mauritania: Ten perimeters and 13 pumps - 190 ha.

	Senegal	Mali	Mauritania
Tech. As. (design, topo, soil studies)	US$ 35,000	US$ 75,000	US$ 50,000
Equipment 1/	pm - credit	pm - credit	pm - credit
Pump Floats	pm - credit	pm - credit	pm - credit
Pump Parts	pm - credit	pm - credit	pm - credit
Piping	pm - credit	pm - credit	pm - credit
Construction	US$ 27,000	US$ 16,000	US$ 16,000
Heavy Equipment	" 19,600	" 37,000	" 37,000
Special Works, Administration, Transport.	" 7,200	" 10,000	" 5,000
Contingencies: 15%	" 14,200	" 21,000	" 16,000
Total:	US$ 103,000	US$159,000	US$ 124,000

1/ Replacement equipment will be purchased by the farmers and farmer associations under the credit program at a cost of $300/hectare. This figure omits $178,000 for this reason.

Yearly Expenditures in 1982 US Dollars:

	Senegal	Mali	Mauritania
First Year	US$ 29,000	US$ -	US$ -
Second Year	" 58,000	-	" 62,000
Third Year	" 16,000	75,000	" 62,000
Fourth Year	--	84,000	--

3.2.2.4. Methods of Financing

The project will finance the costs of fully assessing and conducting design, topographical or soils studies to guide the work. Each perimeter will be evaluated on an individual basis and a site improvement plan prepared. The project will fund the costs of correcting problems that have resulted from errors in judgment by the RDA's concerning site selection, perimeter design, or supervision of construction. However, farmers will bear the costs for general improvements and equipment replacement. Because financing for replacing equipment will be available through the credit program, its cost is not reflected in the cost estimates for rehabilitation.

3.2.3. Construction of Small Perimeters

As outlined earlier, the project will include the construction of 23 new perimeters in the Bakel sector, 41 in the Gouraye sector, and 38 in the Kaedi sector. Because of the large number or sites involved and the similarity of construction design in most sites, the design team has developed a model of a small perimeter to use for cost estimations. While there are variations to this model in all sectors, the design team feels that it is representative of the perimeter areas, topography, irrigation systems, and construction costs. The development of this model and the costs derived from it are also consistent with the presentation of the irrigation master plans prepared by GERSAR 1/ and the small perimeter project identification document prepared for the Kaedi and Gouraye sectors by the FAO. 2/

The general model for a small perimeter involves an irrigation scheme located on the banks of the river with a group of sixty farmers, providing each with approximately 0.25 hectares. The perimeter covers a 20-hectare area and has a farmed net area of 15 hectares. The perimeter is served by a motor pump, a network of canals, a system for drainage, and dikes for protection against river flooding, as necessary.

1/ "Schéma Directeur des Aménagements Hydro-Agricoles de la Vallée du Sénégal Rive Droite en Mauritanie," GERSAR, for SONADER, June 1980. "Etudes de Réhabilitation, de Factibilité et d'Avant-Projet Détaillés de Périmètres d'Irrigation sur la Rive Gauche du Fleuve Sénégal," GERSAR, for SAED, 1981.

2/ "Projet de Périmètres Irrigués Villageois, Rapport de Préparation," FAO/World Bank Cooperative Programme, Report No. 41/81 MAU. 5, December 3, 1981.

A. Pumping Costs

In order to derive cost estimations for application of this model, the design team reviewed agricultural data to determine cropping patterns, soils textures, rainfall, and evapotranspiration, in order to determine water requirements for the model perimeter. The review of agricultural data led to refinements of the model for each zone. Water requirements for the Bakel and Gouraye sectors in the upper valley are identical, although the allocation of land to different types of cultivation changes the water requirements. Thus, the following three models have been developed:

1. the Bakel model: 7.5 hectares of rice and 7.5 hectares of mixed crops.

2. the Gouraye model: 3 hectares of rice and 12 hectares of mixed crops.

3. the Kaedi model: 10.5 hectares of rice and 4.5 hectares of mixed crops.

The water requirements for each of these models are summarized in Tables 5 and 6 for the Bakel, Gouraye, and Kaedi sectors, respectively.

Based on the water requirements derived from these models, the analysis compared the three motor pump units currently being used in the area. The three units include: (1) Deloule pump Ø 240 with Lister motor HR2 at 1450 rpm., (2) Deloule Pump Ø 260 with Lister motor HR3 at 1450 rpm., and (3) Gorman Rupp Pump with Lister motor HR2 at 1500 rpm. The first unit, Deloule pump Ø 240 with Lister motor HR2 at 1450 rpm., was found to be best adapted for the various pumping conditions and was therefore used to calculate pumping costs.

The water requirements appearing in Tables 5 and 6 were increased by 15 percent to account for losses in the system, and the number of hours of pumping was obtained by taking the discharge of the pump as a function of the manometric head of pumping for the month considered. The consumption of Diesel fuel was then calculated per season and per crop as follows:

3.2.3.1. Specific fuel consumption of HR2 Motors = 4.65 l/hr

For a model of 15 ha (7.5 ha of mixed crop)
(7.5 ha of rice)
in Bakel.

Crop		Total Fuel Consumption	Volume of pumped water	Fuel consumption per hectare
Rice	Rainy season	953 l.	57.214 m³	127 l/Ha
	Dry season	2580 l.	138.216 m³	344 l/Ha
Mixed Crop	Rainy season	165 l.	13.846 m³	22 l/Ha
	Dry season	1395 l.	68.235 m³	186 l/Ha
Total	2 crops/year	5093 l.	277.511 m³	

Total pump moving time: 1110 Hr/year

Oil consumption:
Oil change every 150 hrs.

7 oil changes x 11 l = 77 l.
refilling to level = 36 l.
Total = 113 l.

The cost of 1 cubic meter of water:

$$\frac{5.093 \times 150 + 113 \times 450}{277.511} = \underline{/\ 2.94\ \text{FCFA}\ /}$$

The price per unit of water is the same for the Gouraye sector. This price does not include the amortization and upkeep of the motor pump. For the Kaedi sector, pumping conditions are different, with higher but limited peak pumping periods. Using the water requirements from Tables A2 & A3 the following figures have been calculated for diesel fuel costs:

Consumption of diesel fuel: 0.229 x 19.25 x 2271 = 10,011 liters

Consumption of oil: 176 + 76 = 249 liters

Cost per m³ pumped water: $\frac{10{,}011 \times 27 * 249 \times 112}{445.691}$

water

= /0.67 UM./

B. Infrastructure Development Costs

For the purposes of costs calculation, this section describes the characteristics of a standard small irrigated perimeter. This perimeter has a gross area of 20 hectares and net cultivated area of 15 hectares. Its scheme of crop allotments entails, for the sake of consistent identical configurations, a gravitational system whose components are illustrated in Figure 1, Appendix D.

It should be equipped with a safety outlet allowing the overflow of the maximum discharge in case of error, and a sluice gate at the entrance of the system before the regulator described further on in Figure 2, Appendix D2.

Water enters the system through a head gate composed of a weir to control the incoming flow and a shut-off valve to direct the flow alternatively to the two canals (see Figure 3).

For a flow of 60 liters/second, the weir should measure 60 cm; the depth of the corresponding overflow would be 15 cm. The heights corresponding to the different flows allow the measurement (in conjunction with the time) of the volumes passing through.

The stilling basin should have a minimum volume of 0.5 cubic meter, and should be constructed in concrete and rock masonry lined with watertight plastering. The outlet of the earthen canal should be lined.

The canals would be of two kinds. The first would have a trapezoidal interior section, and be constructed of a nonpermeable compact material. The embankment would be built by the farmers with wheelbarrows and compacted with hand compactors. The berms along the river banks are generally sandy and have high losses through percolation. This type of canal would thus be best suited for the rice paddy zone (Canal 2 in Figure 2).

Figure 3 shows a profile-model of canals, which should ensure a flow of 60 liters/second throughout. The longitudinal slope has been taken between 0.2 and .25% and the coefficient K =30. The maximum velocity is estimated at 0.05 m/second.

The second canal would have a rectangular section after cleaning the stripping of the topsoil concrete and cast in place. The base would be of lightly watertight plaster. Expansion joints of 10 - 15 m. will be necessary. This canal would also be built by the farmer group. This kind of canal is suitable for the sandy, permeable berms along the river bank (Canal 1 in Figure 4, Appendix D3).

Figure 5 shows the profile pattern of a rectangular canal with a flow of 60 liters/second, a longitudinal slope of .3 percent, and coefficient of K = 70. The maximum water velocity would . 33 m/second.

Irrigation of the plots would be done uniformly by locally-manufactured plastic siphons with a diameter of 53 mm, discharging an average of 3-36 liters/second, or a diameter of 63 mm, discharging 4.3 - 5.2 liters/second with a head of 20-30 cm (plastic siphons, made in Senegal).

To maintain this head, the canals would be divided by checks to control the water level. Four to six checks of this kind would be necessary for a small perimeter. Structures would be located at the extremities of the canal overflowing into the drainage system. Figure 6, Appendix D4, shows this principle of irrigation.

In a trapezoidal canal where the wetted perimeter is 2.70 m, a check 1.20 m wide would have an overflow of 10 cm, which is well within the 20 cm freeboard.

In a rectangular canal, the check would be reduced to the 50-cm width of the canal. The overflow depth of 17 cm would be confined by raising the sidewalls to ensure a freeboard of 8 cm. The height of the canal (.60 m) would correspond to three rows of standard concrete blocks which will facilitate construction.

Figures 7 and 8 show the control checks placed in the trapezoidal and rectangular canals.

From the siphons, water would flow into head ditches for distribution by furrows to the crops. Like the preceding works, these would be excavated by the farmer groups.

An alternative scheme for the rice paddies proposes replacing the checks and the siphons with gates that would direct water to successive units of three plots each that are traversed by the head ditches.

C. Land Preparation and Drainage Costs

1. Preparation of the Soil

The sites selected for the construction of the small perimeters are generally covered by sparse vegetation which can be cleared with hand tools supplied to the farmer groups. Large amounts of earthwork are not necessary, but leveling out the micro-relief over the whole rice paddy zone is recommended. The depth of cut and fill should be no greater than 10-15 cm, taking into account the thinness of the topsoil. Mechanizing this work will be necessary in some cases.

Rice should in principle be irrigated by flooding the paddies, which are demarcated by small dikes. The dikes will be constructed along the contour lines and along the line of the slope in order to separate the paddies. Differences in elevation between the extreme points in the paddies should not exceed 10 cm. With a ground slope of 0.5 percent, the distance between two dikes should be 20 m. The dikes would have an average height of 40 cm and be constructed with the fill from excavation of the bordering upstream head ditch. The head would transport water from the canal gates or siphons to each paddy. The paddies would be filled from downstream to upstream.

As stated earlier, irrigation of rice by submersion could be replaced by the simple wetting of the paddies.

The mixed crops would be irrigated by furrows with a length that would not exceed 30-40 m, thereby requiring 20-25 irrigation furrows for a head canal of 750 m (Figure 9, Appendix D5).

In each case, the most appropriate solution should be chosen according to the general slope of the terrain and the shape of the plots. The length of the principal canal would be reduced in the second alternative, as the same gates would alternatively serve three plots.

A collection ditch will border the upstream side of the principal canal in the rice zone to protect it from the surplus water running off from the mixed-crop zone. A plan is shown in Figure 10.

Farmer groups would undertake all these works, using tools provided by the project.

2. Drainage

Collection ditches will gather the excess water and direct it towards the principle drain situated in the low point of the cultivated zone. At present, it is not possible to calculate the surplus volume and dimensions of the paddies for the small perimeters. The main drain must be correctly laid out in order to ensure drainage without the retention and runoff of excess water.

Drainage of certain perimeters will require larger works such the excavation of a system to eliminate the ridges, construction of a protection dike with sluice gate, construction of a collection canal to protect the low areas from catchment basin runoff, etc. These special cases will be studied in detail. The use of heavy equipment will be necessary to assist the farmer groups if large amounts of earthwork are required. Such interventions would be coordinated with other machinery work undertaken in that area.

3. Related Developments

Fishponds may be installed next to certain perimeters as desired by the farmer groups. These are described in the Agricultural Analysis, Volume III, Section 3.2. These fishponds would be served by a handmade earthen canal from one side of the Canal in the mixed crop zone. Drainage would also be ensured by the main drain. If the construction requires the use of heavy equipment, it should be undertaken concurrent with other works in the same vicinity to avoid the high costs of special trips.

No roads will be built in these small perimeters. Nevertheless, the pipeline from the pump should be buried and properly back-filled to allow the passage of vehicles, tractors, or other agricultural equipment along the berm of the bank between the river and the canal. In the lower section, access into the perimeter would require temporarily filling irrigation and collection ditches or construction culverts.

Certain embankments would of necessity be rebuilt each year. Windbreaks and fences are discussed in the Agricultural Analysis, Volume III, Section 3.2.

D. Execution of Works

The FAO/SONADER report [1/] from which financial estimates are derived outlines two methods developing the small perimeters according to the work to be carried out:

1. Type "A" sites may be developed manually by farmer groups equipped with the necessary tools. SONADER estimates a maximum of 4,500 work-days for 20 hectares assessed at 225 work days per hectare. Of course, evaluation of the work required is somewhat subjective.

The report proposes furnishing cement and necessary tools. The motor pump would be purchased through a form of credit. The farmers would be compensated for their labor through the provision of food. The World Bank and SONADER would collaborate in developing small perimeters in Mauritania. This project will not finance any payment to farmers for labor on their small perimeters.

2. Type "B" sites require the use of heavy equipment and earthwork that cannot be carried out by hand or that exceeds the threshold of 4,500 work-days. The work would consist of:

- Land clearing;
- Building a protection dike if runoff is a danger;
- Constructing a head canal on fill if the terrain counter-slopes towards the river;
- Leveling if the micro-relief is uneven, and clearing the land, if necessary.

The division of responsibility would be the same as indicated for Type "A", with the stipulation that the use of heavy equipment would be financed by the project.

The RDA personnel and the techncial assistant would work with the villagers in final selection of the sites, definition of the precise zones to be irrigated, and determination of type of irrigation systems as well as any ancillary works to be included in the original layout (fishpond, windbreaks, village and livestock watering points, etc). The groups of villagers responsible for constructing and operating the perimeter will have formed by this time.

Subsequently, the site would be surveyed and a plan prepared on a scale of 1:2,000. The irrigation and drainage system would be laid out on this plan by the irrigation engineer. Elevations of levels drawn from IGN (Institut Géographique National) would permit an accurate assessment of flood risks

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1/ "Projet de Périmètres Irrigués Villageois, Rapport de Préparation," FAO/World Bank Cooperative Programme, Report No. 41/48 MAU.5. December 3, 1981.

based on historical record and would aid in the design of adequate flood protection, both from the river and from local runoff.

Departures from the "typical" perimeters described in the earlier parts of this chapter will be designed where other techniques and materials may seem appropriate. Notably at Gandé in Bakel, the roughness of the ground may preclude the usual gravity distribution system without excessive cost for leveling and the loss of good top soil. On the basis of topographical plans, the irrigation engineer will determine the costs of alternative systems, looking at the life-time costs of such systems as pipe distribution for gravity application, sprinkler application, raised canals, and other processes (excluding drip irrigation for the present, at least). Even if the economies are slightly unfavorable, trial installations should be considered to develop reliable installation and operating costs. Such techniques may pave the way for development of land not presently being considered, which is more costly than the typical smaller perimeter but still less expensive than large perimeters requiring diking and long canals.

This work could probably be carried out most expediently by competent private contractors in each country. Topographers would assist with elevations and leveling which would be verified by the irrigation engineer.

All manual construction would be undertaken by the farmers' group organized by an extension worker for each construction site. These extension workers would be supervised by the RDA construction supervisor, who would visit the sites regularly to check on the quality and accuracy of work in order to ensure proper operation of the completed perimeter. The construction supervisors would be assisted by the irrigation engineer, one of whose tasks would be to make any necessary adaptations to the plans.

It has been estimated that perimeter construction requires about six weeks of supervised effort. Therefore, with a nine-month construction season, a team consisting of one construction monitor and three extension workers would supervise the construction of 18 perimeters per year. This rhythm is unlikely to be maintained in practice, and a significantly slower rate is proposed below. Insofar as possible, the irrigation engineer will schedule operations to concentrate field personnel in one area for most effective control.

Operation of earthmoving equipment by the contractor will require particular organizational care to keep idle equipment time and costly movement of equipment to a minimum, which means maximum coordination with the community development and training teams.

E. Program of Work

The dynamics of the participatory approach make it impossible to set a precise schedule of development for the perimeters at this time. Such scheduling must wait until the Technical Assistance Teams are actually in the field and the sociological work has begun. The following table represents reasonable goals from all the aspects involved in this integrated development scheme.

- Small Perimeters -

IDP Year	1	2	3	4	5	6	TOTAL
BAKEL Perimeters	12	10	3	-	-	-	25
Ha developed in Year	214	206	50	-	-	-	470
Ha under cultivation (gross)	107	317	470	-	-	-	470
Mauritanian Perimeters							
GOURAYE-Type A Perimeter	8	2	2	2	-	-	14
Type B Perimeter	-	12	13	2	-	-	27
Ha in Year	192	286	312	80	-	-	870
Ha under cultivation	148	393	671	809	870	870	870
KAEDI-Type A Perimeter	4	-	-	9	-	-	13
Type E Perimeter	-	12	13	-	-	-	25
Ha in Year	82	246	267	185	-	-	780
Ha under cultivation	62	274	528	734	780	780	780
TOTAL Ha under cultivation* MAURITANIA	190	637	1164	1503	1570	1570	1570

* 75% of area under production in first year.

3.2.3.2. Financial Evaluation of the IDP Program

A. In Senegal - Bakel

Tax-free prices beginning 1982 in US dollars at the rate of $1 = 300 CFA.

Unit Prices

1. LISTER HR2 + DELOULE with floats, complete with accessories 100 m of specified flexible pipe, installed and mounted	$ 16,500
2. Stilling Basin (materials)	
Entrance Works	190
Rectangular Canal in Concrete Block (Materials)	570
3. Trapezoidal Earthen Canal	p.m.
4. Weir for Cement Canal	7
5. Weir for Earthen Canal	87
6. Plastic Siphons	40
7. Gates (Materials)	140

B. Estimations for a Model Small Perimeter

This estimate includes neither costs for labor of the farmer group nor the use of heavy equipment for leveling, excavating collection basins or low-river pumping channels, compacting, diking, etc. Costs for construction of an earthen canal are based solely on group labor. The sand and gravel for concrete blocks and fill material for the earthen canal are assumed to be available in the surrounding area.

C. Costs for Other Works

1. Engines

As discussed above, in some cases, heavy equipment use will be necessary to construct small perimeters. Lacking a survey plan, the types of equipment that would be required are difficult to identify or qualify. An overall added cost can be calculated and added to the construction program. (See Table 7, Appendix B). In order to avoid the movement of heavy equipment for only one job, this work will be executed through a contract arrangement with Collenga. The technical team can, at that time, determine the exact amount of work to be undertaken.

Nonetheless, the cost of a normal operation is as follows:

- Excavation of collection ditch for runoff of low-river-level pumping channel: Excavation shovel = $90/hr and removal;

- Pre-leveling of the perimeter: Bulldozer-graders = $100/hr;

- Construction of closing dike of a marsh with an open sluice gate:

- Motor Scraper	$ 150/hr
- Bulldozer	150/hr
- Bulldozer/Grader	100/hr
- Compactor	75/hr
- Cistern	75/hr
- Dump Truck	25/hr

Taking an estimate of 100 hrs for all heavy equipment to accomplish the work for each new perimeter, the cost will be $9,680 per perimeter or $484 per hectare. Half of this amount is budgeted as a contingency since only about 50 percent of the new perimeters will require heavy equipment.

2. Labor

The amount of labor necessary from the farmers' group to construct the small perimeter may be estimated at 240 workdays per hectare.

3. Construction Material Unavailable on Site

If sand, gravel, or fill for the canal are not available nearby, contracting a dump truck would cost $25 per hour. In this case, removal and handling should be provided by the farmers' group.

D. Operating and Maintenance Costs of Motor Pump

Annual Operating Costs

Diesel Fuel	$ 2,547
Oil	170
Pump Operator's Salary	667
Miscellaneous and Contingencies (approx. 10 percent)	358
Subtotal	$ 3,742

Annual Maintenance

Maintenance at 2 percent	$ 663
Motor Repairs After 4 years approx; 50 percent	3,700
Yearly Average	
Miscellaneous and Contingencies (approx. 10 percent)	437
TOTAL	$ 4,800

E. Mauritania - Gouraye and Kaedi

Chapter V of the FAO/SONADER report has established the development costs and labor estimates for work based on two Type A perimeters. This small perimeter also serves as a basis for the non-mechanized work on a Type B perimeter.

The unit prices shown in this report must be figured into the present evaluation to give more precise information for type of construction planned in the project.

1. Work Executed by Machines for Type B Perimeters

According to the estimates made in the feeder road Analysis/Volume III, Section 3.4., approximately 70 percent higher than those of Senegal. Taking the base costs in Bakel and applying these to the volume of work in Mauritania, the total cost can be estimated as follows:

Bulldozer	30 hrs x 150 x 50 U.M. x 1.70	=	382,500 UM
Bulldozer-Grader	36 hrs x 100 "		306,000
Loading Shovel	10 hrs x 90 "		76,500
Tractor	24 hrs x 15 "		30,600
Vibro-Compactor	8 hrs x 20 "		13,600
Dump Truck	30 hrs x 23 "		63,750
			872,950 UM
			(1982)

or US$ 917,500 (1982)

per Type B perimeter.

2. Work Executed by the Farmers' Groups on Type A and Type B Perimeters

In terms of the amount of work executed by the farmers' groups on Type A and Type B perimeters, the SONADER estimates should be adjusted with additional elements. The cost per hectare presented by SONADER is 900-200 UM 1982, with individual components as follows:

- Motor Pump 270 m^3/hr	550,000 UM 1982
- Penstock & Accessories	220,000
- Pipe PVC Ø100 & 200	100,000
- Transportation of Equipment	198,000
- Cistern 4,000 liters	88,000
- Construction of a Storehouse	132,000
- Remunerations to the Farmers	450,000
- Tools for Construction	66,000
	1,804,000 UM 1982

for 20 geographical hectares.

3. Unit Prices

Tax-free prices at the beginning of 1982 in US dollars with $1 = 50 UM are as follows:

- Motor pump LISTER HR2 + DELOULE with float, complete work accessories, and 100 m of flexible specified piping, installed and mounted	$ 17,000
- Stilling Basin (material)	620
- Rectangular concrete canal (material-m.)	22
- Trapezoidal Earthen Canal	p.m.
- Weir-Cement Canal	8
- Weir-Earthen Canal	95
- Plastic Siphons (4 m)	44

Estimates for model perimeters and an illustrative budget are outlined in Tables 8 and 9, Appendix B.

3.2.4. Construction of Medium Perimeters

3.2.4.1. Basic Concept of a Medium Perimeter

A. The Need to Construct Medium Perimeters

In the middle valley area, the progressive disappearence of sites suitable for developing small perimeters will naturally stimulate a search for sites that may not be as favorably situated. These new sites are likely to be larger and more exposed to flooding. Water sources for irrigation will be difficult to tap or far-removed from the perimeter sites, and developing these sites will require higher levels of technical competence, more substantial financial backing, and a more sophisticated level of social organization than are currently available to farmers' associations in the villages.

The topography of the middle valley does not have the kind of extensive zone characteristics of the Delta region; rather, it is marked by medium-sized sites that have so far remained undeveloped. The regulation of the river's flow rate after construction of the Manantali Dam, the unavailability of suitable sites, and various socioeconomic factors will stimulate the already growing interest in these new sites. Results obtained from the operation of large perimeters in the Delta area and in the middle valley have yielded the following observations:

1. Construction work on the large perimeters is completely mechanized. As a result, initial investment costs are very high. These perimeters were constructed to operate on the basis of round-the-clock irrigation. In practice, irrigation time per day has dropped to 16 hours or even 12 hours in some cases. The farmer, entirely dependent on the RDA, has no incentive to work efficiently. Worse still, calculations for the project were made so rigidly as to leave no operational margin for error. Consequently, yields have been irregular. Moreover, cases of serious damage have necessitated costly repairs, and even routine maintenance, conscientiously carried out, has been expensive.

The small perimeters, on the other hand, are almost entirely constructed by the farmers working together in autonomous associations. Farmers are more directly involved in the development process, though they sometimes lack effective management support. Yields are higher and less variable on small perimeters than on the large ones, and problems are easier to identify and correct.

In the light of these considerations, medium perimeter design should be based on the successful aspects of both small and large perimeter operation, with attention to the constraints of both extremes.

B. Developing a Medium Perimeter

The Autonomous Irrigated Unit will be designed on the basis of the small perimeter's strategy.

A group of 60 farmers to whom land has been allocated will be entitled to and responsible for a plot covering 20 hectares gross, or about 15 hectares net. Construction work and responsibilities will generally be the same as those for the small perimeters.

The medium perimeter will be made up of an association of several of these farmer units, each with its own administrative status. At the same time, it will be necessary to create cooperatives, which will eventually take over the operation and maintenance of the perimeter.

C. Description of Infrastructure

1. Water Collection

Whenever possible, there should be only one water intake point for perimeters measuring up to 200 or 300 hectares. This point could be a gravitational intake point along a waterway (though in the proposed zones, that would be extremely rare), a retaining dam (such as was described in connection with basins in Mauritania and Mali), or, more frequently, a pumping station. Design considerations for such a station would be based on its location, the volume of water required, and the variation of intake levels in relation to the outflow level.

As a rule, the station would consist of infrastructure and equipment, which may be fixed or mobile; one or more thermal or electric pumps; and a reception basin incorporating a system for regulating the discharge level and even for starting the pumps. The systems recommended within the context of the project will be dealt with in greater detail in the section describing the various selected perimeters.

2. The Irrigation System

The system for regulating water inflow into the canal or canals can be a sluice gate set to maintain a constant downstream level. In such a case, the system of main and secondary canals can be said to be "controlled from downstream." The range of depths in the canal caused by fluctuations between the maximum to the zero levels will be very small, as the canal is practically always full, though it never overflows.

Each Autonomous Irrigation Unit will be entitled to have an intake system equipped with a valve for controlling the volume of water drawn. The system would be made up of a series of NYERPIC-type modules. A simpler alternative would be a regulating sluice gate in conjunction with a gauging weir.

An additional advantage of installing a sluice gate is that it offers a certain degree of operational flexibility, since the flow volume is

controlled but not limited. Each unit will form a hydraulic area with the characteristics described in Section 3.2.1.2., and will be situated downstream from the intake points.

It should be noted that water loss in this system will naturally be greater than water loss levels on the small perimeters. The increase in the surface served by the pump will range from 15 to 40 percent.

The canals of the collective network will be mechanically constructed of tamped earth to the extent possible. They need not be lined, except in stretches of high permeability. Rectangular concrete canals will be used only in high permeability zones. Such instances should be rare in this project, since in general the land areas it covers are less permeable than in the small perimeter zones.

The incorporation of feeder roads and collective drainage channels into construction work on the medium perimeters will necessitate the construction of such crossover installations as inverted siphon passages, main intakes with inverted siphon passages, paved sections, and culverts.

As all of this construction work will be done under contract and designed under standard specifications, there is no need to elaborate further.

3. Drainage Operations

Drainage ditches will empty into the secondary and main drains that make up the collective drainage system. Whenever possible, excess water will be drained off by gravitational flow; otherwise, it will be pumped out.

In cases where a perimeter is threatened with flooding from catchment basins, a protecting dike and/or perimeter canal, of a size determined by the nature of the catchment basins in question, will be constructed to divert runoff.

Components and overall sizing for drainage systems will be determined separately for each perimeter according to the volume of water to be evaluated and the time required for this evacuation. The collective drains may be mechanically constructed.

4. Flood Control

While small perimeters are as a rule situated beyond the reach of average-frequency river flooding, medium perimeters do not share this advantage. They are vulnerable to flooding either directly from the river, by way of the river marshes, or even by floodwaters from the marshes themselves.

Though regulation of the river flow by the Manantali Dam will considerably reduce the level of average floods, the medium perimeters will remain susceptible to flooding.

It would be reasonable to protect the perimeters in order to safeguard the resources invested in improving them and to ensure that production can proceed under conditions of security. An economic study should make it possible to weigh the risks involved against dike construction costs, with a view to estimating the optimum protection level.

5. Related Developments

A network of feeder roads will link the perimeters to main roads. These roads will allow communication and maintenance of key infrastructural installations. Thus, a path will run along the dike and the main canals, which will be made of compacted earth.

As described in the Agricultural Report Section 3.2., windbreaks and fish ponds will be options that the farmers can choose for diversified production on their perimeters. Criteria for site studies will be undertaken by the IDP for the long-range development plan of the Autonomous Irrigated Units.

6. Operation and Maintenance

Large perimeters require much greater organization than do small ones. Care should be taken from the earliest stages of perimeter design to structure operation and maintenance so as to maximize the profitability of agriculture while limiting the role of the RDA's as rapidly as possible.

3.2.4.2. The Podor Perimeter

This site is on a plain in the Senegal River Valley between that river and Doué Creek, 267 kilometers from Saint Louis and nearby Podor. See Figure 9, Appendix C and Appendix D6.

This study was based on the following documents:

- The GERSAR "Master Plan for Improvement", dated March 1981;
- Manuscript addendum to the GERSAR Master Plan entitled "The Podor Pilot Scheme", March 1982, delivered by SAED at the beginning of May 1982;
- Data gathered on site by the IDP design team.

A. Site Description

Podor is one of the vast silting basins situated in the middle valley of the Senegal River. It is surrounded by a series of riparian strips. Its boundaries are the Senegal River, Doué Creek, Podor, and a forest reserve. Every year the site is partially flooded through an opening created by the Moussa Wagnari Creek. The extent of flooding depends on the Senegal River's own flood levels.

The annual cycles of flood and ebb have left substantial deposits of clayish soil in layers at the bottom of the basin.

Various programs have been proposed for development to be adopted for the Podor Perimeters. Most recently, SAED proposed to equip the entire 1,184 hectares in two successive years. This goal seems unrealistic. As an alternative, this project proposes a longer phasing to cause less strain -- whether at the level of the individual farmer or of the community. While this approach will undoubtedly 1) raise unit and overall costs as contractors must mobilize in successive years to undertake new construction campaigns and 2) cause economic return from investment to be delayed, it is felt that this return is more nearly assured.

The project proposes to gradually bring the targeted hectares into production over the first five project years. The small village perimeters will be constructed starting in year two, and sections C_1, M_1, and C_2 will follow each following year, respectively.

In this way, 810 net hectares or two-thirds of the irrigable land within the dike would be developed, at a rate corresponding to the ability of farmers to effectively prepare and exploit land. The remaining land would be put under irrigation in later years. This program may require adjustments based on the results of contacts with farmers and the formation of viable groupements. A particular strength of this plan is that it allows for 300 net hectares to be developed first by villages along the Doue who hold traditional land rights to the area involved in the project. This should help minimize tensions resulting from the transfer of part of this area for development by Podor villagers.

The walo land farmed in flood recession near Station E1 would not be touched at first, and could be farmed by controlled submersion during the flood if the need should be felt, during a transition phase. The walo land to the east and north of the planned dike would be left for flood recession farming. As the farming population grows in numbers and skills, the necessary investments for complete water control in this area can be planned to permit intensive farming by the time the "artificial flood" is stopped (after the year 2000).

According to information from SAED, the detailed pilot study currently being drawn up by GERSAR should be sufficiently well-developed to permit its use in constructing the perimeter. Under the IDP, these plans would be provided to an engineering firm to prepare final detailed drawings, specification, and bidding documents.

After the construction of the Diama Dam, water supply levels in the Senegal River and Doué Creek are expected to remain satisfactory: the low-water mark will not drop below zero, and the Diama Dam will keep the salinity levels from rising.

The Podor perimeter lies along the link road serving Podor, which is connected to the main Dagana-Ndioum-Matam highway.

B. Completed or Ongoing Studies

Within the context of the studies previously cited for the pilot scheme, the topographical map initially based on the 1:50,000 scale M.A.S. map has been replaced by a map on the scale of 1:5,000. Other documents recently made available include:

- a map of soil types and their suitability for crops, scale: 1:5000;
- a hydrological model of the Senegal River.

GERSAR has recently completed a detailed pilot study of the Podor Project. The IDP proposes a slight modification of the GERSAR plan to meet specific demands of farmers, to decrease the construction costs, and to minimize operating costs.

C. Hydrology - Flood Control

The GERSAR study projects flood peaks occurring once every decade (1/10) and once a century (1/100) and presents three hypotheses, based on the present situation, the situation after construction of the Diama Dam, and the situation after construction of both the Diama and Manantali Dams. Probable flood levels are projected as follows:

Natural Conditions (in meters)		DIAMA		DIAMA AND MANANTALI	
		Medium Term	Long Term	Medium Term	Long Term
1/100	7.00	7.82	7.87	7.35	7.41
1/10	6.10	6.76	6.82	5.90+	6.10+

The layout of the dike planned for the current project is presented in Figure 12, Appendix D. This dike protects an area of 1,580 hectares.

It has been proposed to level the dike to a height of 7.20 meters to ensure that the area is adequately protected against decennial flood peaks, with a freeboard height of 1.10 meters, after the construction of Diama and Manantali. Alternatively, it could be said to have adequate protection against hundred-year peak flood levels, but with no freeboard height provided. This is in fact the height of the Nianga Perimeter Dike, lying just south, and off the Podor road, which serves as a dike between the bridge over Doué Creek and the road leading to the Podor Dike. Any increase in the height of the dike will entail substantial increases in earthwork and necessitate raising the asphalt road.

+ These estimates take into account the moderation of peak levels by Manantali as well as by the construction of perimeters in the valley.

D. Land Development

The pilot plan proposes three categories of soils:

- Category 1: Soils in fondé areas. Only slightly susceptible to flooding, or not at all. Deep soils of medium texture: less than 25 percent clay, more than 70 percent sand. These soils are well drained and permeable. Though they are closest to the settlement zones, they are traditionally the least cultivated soils. Fondé: about 20 percent.

- Category 2: Finer-textured soils: 50 percent clay or 90 percent sand. These soils are in scattered locations, and are often more flooded than Category 1 soils. False Hollaldé soil: About 30 percent.

- Category 3: Soils in the silting zones: Over 60 percent clay, used for flood-recession farming; hard to drain. Hollaldé soils: about 50 percent.

E. Improvement Scheme

Improvement of the Podor site will be carried out in accordance with the guidelines outlined in this chapter.

While the GERSAR pilot plan proposes a dike protecting an area of 1,580 hectares in its initial stage, this project proposes to develop the area in two phases. In light of past experience, it is felt that a gradual approach with careful examination of all aspects of the development process is essential if Podor is to serve as a model medium perimeter in the middle valley. The project's approach should prove that medium-sized perimeters can work effectively as long as appropriate technical, economical, and social constraints are considered carefully in development plans.

A significant deviation from the GERSAR plan is the incorporation of 300 hectares of small perimeters within the dike protected area. Advantages to be gained from this strategy are as follows:

1. Farmers in seven villages will be able to participate immediately and at low cost;

2. Farmers associations and management skills can be developed gradually; and

3. Project achievements can be reassessed and evaluated as each phase is completed.

In keeping with this approach, the present plan calls for diking the Doué in project year five, leaving the option for continuing with the individual pumps for each 20 hectares or combining the farmers associations into larger groups and utilizing larger pumping stations. The infrastructure for the initial small perimeters will be the same as for other small perimeters, with all work performed by the farmers until year five.

Due to the large surface area and the morphology of the basin, the perimeter has been divided into several hydraulic sectors, each with an independent water inlet and irrigation system. The sectors will continue to share common drainage and road networks, however. Even though the irrigation systems will be independent of each other, they will follow the same developmental and operational norms. Crop selection per Hydraulic Sector should be as follows:

Hydraulic Sector	Net (ha)	Gross (ha)	Crops
C1. 1	110	147	Rice
C1. 2	110	147	Mixed Crops (*)
C2	130	173	Rice
M1	80	107	Rice
M1	80	107	Mixed Crops
M2 + M3 + Lower Half C2	300	382	Small perimeters
Total	810	1063	

(*) with crop rotation

GERSAR water supply requirements estimates are as follows:

Monthly Water Requirements per Hydraulic Sector in Cubic Meters per Hectare (Efficiency Level of the System: 0.7 m3/ha).

Crop Type	J	F	M	A	M	J	J	A	S	O	N	D	Total
Rice	4160	4590	5020	5720	6050	-	5550	3100	5040	4800	1680	-	48700
Mixed Crops	3430	2800	2660	850	-	1300	3900	3210	1530	540	2160	2700	25080

The basic hydraulic principles of the project include the following:

1. Pumping will be done from the Senegal River or Doué Creek, with a possibility of some gravitational flow, though this is unlikely.

2. The principal irrigation system will be regulated by downstream control.

3. Sub-systems for hydraulic sectors will be controlled from upstream. Water intake will be through a control installation such as a weir type.

4. The drainage network will feed partly into the pond serving as a buffer, as well as into the outlet where there is another buffer zone together with drainage pumping station (E 1).

5. There will be double-cropping on all of the irrigated perimeter, with recession-cropping in the buffer zone of station E 1. The Debi-Maoundou pond will be kept at a level of 2 m to be used mainly as a water reservoir for livestock.

6. It is suggested that a strip of land along with the paved dike-road be used as an overlapping zone. It could also be used for fishponds, since it is easily irrigated and drained.

F. The Irrigation System and Internal Network

This system will be based on the control basin at the pumping station, and will be regulated by one or more NEYRPIC-type constant flow gates set to maintain a constant downstream level. The canals will be trapezoidal in shape. Figure 13 shows their standard profile. The canals of the principal system will be constructed of tamped earth by a contractor.

Supply canals within the basic units, each of which measures 15 hectares (net), will be constructed by the farmers' group. Each unit will be a hydraulic sector served by an irrigation "module" supplying individual plots and following a rotation schedule. A unit of this type will bring together 60 plot owners, each having a plot measuring 0.25 hectare. Water will be supplied to individual plots through calibrated siphons designed to permit the constant flow volume at fixed heads.

The installation for water intake into the secondary canals from the principal canal is presented in Figure 14. It is based on 2 gear-controlled sluice gate and a graduated flume. (See Appendix D9.)

The GERSAR study does not recommend lining the canals, since seepage rates in the area are too low to make lining necessary. Nevertheless, care should be taken to check specific stretches for pockets of sandy soils on the surface.

G. Pumping Stations

According to GERSAR, a technical note bearing on design principles for pumping stations is due to be presented to SAED. Pending receipt of this note, therefore, the following is based on the few notes and interview reports available.

The supply of water to the Manantali Dam will scarcely affect supply conditions at the low-water mark. Water regulation at the rate of 120-140 cubic meters/second at Podor will maintain a water level at least equal to the regulatory level at the Diama Dam, i.e., 1.5 meter.

1. Pumping Energy

The GERSAR study calls for five pumping stations (plus one for drainage) driven by electric motors and supplied by on-site diesel-motor generators. Consideration has been given to several alternate pumping systems, including the following:

- Supplying individual pumping units for each Autonomous Irrigated Unit, offering each farmers' group self-sufficiency for its own pumping needs; this would require 50 or more pumps at considerably more investment cost (each with its own small canal up to 2.5 kilometers in length), while still requiring communal organization for dike maintenance and drainage.

- Reducing the number of pumping stations to two, one each in Doué Creek and on the river. Large main canals would be needed along the dikes with some sections in several meters of fill.

- Providing pumps driven directly by diesel motor. These have experienced problems in the past due to poor installation, management, operation and maintenance, but have been the most successful type used in perimeter development in the basin. This approach will be used in the Podor model perimeter.

For the IDP it is assumed that one centralized electric power plant will be built on the Senegal River to supply electricity for pumping stations C_1, M_1, and C_2, since the distance between these three stations will be about 1.5 km. The centralized power plant will have several advantages:

- It will cut down the cost of construction, since one power station will replace three in the GERSAR plan.

- It will provide more security, since there will be three generators and one standby to secure continuous operation of the plant with variation of output depending on the energy demands for pumping.

- It will minimize operating costs because of less supervision, security guards, etc.

- The cost of energy from Ndiayène would not be significantly less than on-site generation, though the financial cost to SAED/farmers would be less.

- Nianga and the town of Podor have diesel power plants. Operating and maintenance experience is available, and some operations can be combined, with subsequent savings.

- Should Ndiayène be built, any generators purchased will have a high salvage value.

It is recognized that the operation of these power stations will place a burden on SAED in an area where past performance has been spotty at best. Farmers associations are expected to become managers and operators of the system before the end of the life of project, however.

As indicated earlier, for the initial operations on the smaller plots, diesel engines would power the pumps.

2. Electric Pumping Stations

Since the total head variations are not significantly different, and the pump characteristic curves are flat at top efficiency, it is recommended that one standard pumping unit be chosen for all stations. This approach would make the stocking of spare parts and repair easier. A few spare pumping units should be purchased at the same time for all stations. The one exception is the drainage pumping unit E1, which will be different from the irrigation units and will have a total head of only 4 meters.

H. The Drainage System

1. Drainage Principles

Water is to be drained off along natural drainage axes. Water from the 380-hectare catchment basin is to drain into the Debi-Maoundou Pond (the nonusable area measures approximately 110 hectares).

At a height of 2.50 meters, this pond has a storage capacity of 498,000 m^3. Decennial peak-level rainfall would entail an accumulation of no more than 110,000 m^3 of water. In other words, the pond will easily contain that volume. However, even in the unlikely event of the water level reaching the +2.50 meter mark, a drainage channel installed at that point will evacuate excess water toward Station E1. The remainder of the perimeter drains into the E1 outlet, where drainage water can be evaluated by gravitational pressure or by the pumping station. In exceptional periods, the main drain from Sector C1 will cause temporary flooding at the station. To prevent crop damage, this flood water should be contained within a buffer zone measuring 11 hectares.

The type of pump recommended is a vertical axis submersible electric pump. Each station would be provided with one or several such units installed in a coffered earthen well measuring 4 meters across, and situated on the inside of the dike. Water would be tapped by a pipe linking the river with the well. Flow would be regularized by means of a stilling and distribution basin which could also accomodate an automatic gearing system. This type of installation is presented in Figure 14, Appendix D9.

2. Low River Level

Low water level figures to be factored into this project were based on the SOGREAH Study, in which provision is made for the Diama Dam and various hypothetical cases of land development. Since hypotheses to be factored into the program are so complex, the findings are correspondingly varied. The GERSAR study is based on a hypothesis that the operational control level of the Diama Dam would be 1.50 m and there would be 50,000 hectares of improved land.

	March	April	May	June	July	August
Level (in meters) on the Senegal River and on Doué Creek in an average hydrological year	1.50	1.50	1.39	1.09	0.93	2.20
Level (in meters) on the Senegal and the Doué in the worst drought year in 10 yrs	1.50	1.47	1.11	0.64	0.40	1.50

The main drain from Sectors M1 and C2 as well as parts of C1 will drain away water from an area of 1,310 hectares. Assuming there is no compensation basin upstream from this station, this means Station E1 should have a pumping capability of 2.61 cubic/meters per second. It would be a good idea to create a buffer zone to reduce the necessary capacity of the station. This item will be examined in the detailed pilot study.

The construction contractor will build the drainage system with heavy equipment. Model cross-sections are presented in Figure 15, Appendix D10.

3. Road Network

The GERSAR project suggests the construction of a network of feeder roads within the perimeter to facilitate all-weather access to and operation of the main works. This road network would have the following features:

- the main roads would be made of compacted earth embankments, measuring 7 meters overall across, with a 5 meter-wide central traffic strip surfaced with laterite.

- Secondary roads linked to the main roads will be constructed alongside the drainage mains, so that cut from the excavation can be used as fill. Both the main and the secondary canals should be accessible from either side.

I. Construction Costs

The documents delivered by SAED include no financial evaluation of the Podor perimeter. Thus, in the absence of a quantity survey estimate, contractors' invoices, and suppliers' invoices, the calculations are based on price indices given by GERSAR. The figures below are based on 1983 prices.

1. Unit Prices

- Dike Construction:
  GERSAR gives the following construction costs:

. Dike measuring 410,000 m3 at 900 FCFA/m3	369,000,000 CFA
. Closing the canal under the paved Podor highway	26,000,000 CFA
Total	395,000,000 CFA

- The Pumping Station:
  Suppliers' prices for a modular unit electric pump including on-site delivery and installation plus cost of flexible pipe, intake valve, and control console for the station are as follows:

. Pump	4,057,000	CFA tax-free
. Console	965,000	" " "
. Tube Ø 800, 7m long	1,100,000	" " "
. Intake valve	165,000	" " "
. Transport and Installation (15%)	943,000	" " "
Total	7,230,000	" " "

GERSAR's cost estimate for civil engineering work for the six stations is 222,000,000 CFA, tax-free.

Purchase of equipment and engineering work on the installation of nine NEYRPIC gates plus estimates cost of siphoning for the six stations: 185,000,000 CFA, tax-free.

Local electric power stations:

C1 + C2 + E1:	149,000,000	CFA tax-free
M1 + M2 + M3:	136,000,000	" " "

2. Network Infrastructure

Approximate prices listed in the Improvement Scheme, updated to 1982 price levels are as follows:

- Irrigation canals 1, 2 and 3	182,400	CFA/ha gross
- Mains 1, 2 and 3	72,800	" " "
- Civil engineering construction work on the networks	182,400	" " "
- Main roads at 342 CFA/m (32 km)	10,944	" " "
- Secondary roads at 285 CFA/m (16 km)	4,560	" " "
	453,104	" " "
- Improvement on a plot-to-plot basis with the participation of the farmers' association (tools, equipment, windbreaks, minor equipment, etc.)	360,000	" " "

3. Construction Supervision

Total cost of the operation including services, equipment, vehicles, and transportation, are estimated at 6 percent of the total value of equipment and construction of the perimeter.

4. Studies for Construction Plans

If these studies are entrusted to the contractor selected, costs amounting to about 7 percent of the cost of construction work covered by the implementation studies (engineering) should be factored in.

J. Cost Summary

For the completed perimeter, involving the development of 1063 hectares gross or 810 hectares net, construction costs will be stated in 1983 prices.

K. Operation and Maintenance

In the medium-term at least, there is no viable alternative to operation and maintenance of perimeters by a governmental body such as SAED. Unquestionably, there have been instances in the past when SAED has lacked the means and the organization to adequately perform its managerial role. In practical terms, however, no private enterprise is capable of undertaking that responsibility, although specific tasks could be contracted out; nor are farmers organizations likely to develop the capacity (and create the necessary financial reserves) for some years to come. To start with, therefore, SAED will be responsible for flood protection, water, drainage, and access to the Autonomous Irrigated Units. The farmers' groups will be fully responsible for operation and maintenance within these units. As these associations grow and obtain greater organizational and management capabilities, they will take on more responsibilities for operation and maintenance of the overall system.

USAID funding for construction of each phase of perimeter construction is contingent upon the organization of farmers associations and the execution of satisfactory protocols by these groups with SAED spelling out its responsibilities and those of farmers associations. The payment to be made to SAED by the farmers should cover both fixed costs for maintenance, administration, and the constitution of a sinking fund for equipment renewal, as well as variable costs dependent on water use, and especially on energy costs for pumping.

These protocols must be acceptable to the farmers, SAED, and USAID, and must be accompanied by plans to set up operation and maintenance teams. A large part of the work could be done cost effectively in conjunction with the large Nianga perimeter only a few kilometers away, south of Doué Creek.

A preliminary estimate of operation and maintenance costs is appended. These should be covered by farmers payments, as discussed above, and do not include administrative costs.

I D P Year	(In Millions of CFA Francs)				
	3	4	5	6	7
Dike at 3 percent	11.8	11.8	11.8	11.8	11.8
Pumping Station, Energy at 100 F/KWH+	6.2	14.5	16.4	26.0	29.4
Pumping Station, Civil Engineering at 4 percent		4.9	8.4	8.4	11.9
Irrigation Drains & Roads		21.5	29.0	29.0	44.2

+ Operating at 75 percent for first year

3.2.4.3. The Bakel Collenga Perimeter

The second site proposed in the study for the construction of a medium perimeter is located in Senegal, upstream from Bakel. SAED has not made available any documents on which study could be based. Only half of the planned topographical survey of this zone has been completed.

This study is based on the following:

- information not specifically related to Collenga, contained in the March 1981 GERSAR Master Plan for Improvements;

- an OMVS-Teledyne Geotronics map on a scale of 1:10,000, covering the zone; and

- verbal information provided by Mr. NI, Head of Improvements Sections at the SAED office in Bakel. Mr. NI is currently in charge of construction of a 92-hectare perimeter in this zone. Verbal information was also obtained from SAED officials in Saint Louis.

A. Site Description

The Collenga Plan lies immediately upstream from Bakel and covers an area of about 250 hectares. Its boundaries are the Senegal River; a group of hills including the catchment basin outlet, covering an estimated total of 600 km2; and a creek bordering the southern and eastern extremities. The normal bed of this creek is only enclosed in the downstream stretch leading to its confluence with the Senegal River. Provision has been made elsewhere, within the upper valley regional development plan, for the study of the catchment basin whose runoff floods the site every year.

The topography of this area is quite flat, and vegetation cover is sparse. The characteristics of the soils in the area are summarized in the Agricultural Analysis, Section 3.2. Volume III.

A total of 244 hectares can be developed at this site into a medium-sized perimeter. More detailed study of flood data and the watershed for Collenga will determine the height and length of the flood protection dike. For the purposes of budget estimations, a dike 4 km long is proposed. The whole scheme is divided into two sections. The existing section, covering 92 hectares, is fed by four secondary canals -- C1-1, C1-2, C1-3, and C1-4. Water is taken from the main canal C1 by calibrated divisors. The new section will consist of canal C2, which delivers water to secondary canals C2-1, C2-2, and C2-3, and canal C1-5, which is an extension of C1. See Fig. 10 Appendix C.

The perimeter is made up of 10 autonomous small perimeters of about 25 hectares each. (Four are existing and six more will be created). Because of the topography of the area, the development plan calls for only one main canal and pumping station. Water delivered to each of the small perimeter units will be measured and the farmer association charged accordingly. A farmers' association will be responsible for the development of the internal irrigation

network and for cultivation within each small perimeter, and a federation of these groups will be responsible for the pumping station. The main canals and flood protection dikes will be constructed by a contractor using heavy equipment. All other construction will be done by hand by the farmers.

B. The Current Situation

At the moment, a perimeter is under construction on a section of the plain measuring 92 hectares. Construction work is the responsibility of groups of farmers numbering 320 in all; each farmer will be allotted 0.25 hectares net. This USAID-financed project is administered by the SAED office in Bakel. The project has a few machines, but not enough to handle the quality of work necessary for the construction of collective infrastructure on a medium perimeter. Specifically, it has been observed that embankments built on the project use no hard-packed filler material at all. In most cases, they are simply made up of topsoil scraped up at the worksite itself. As this material is very dry, the project will need a water truck and earth-packing machines.

The perimeter under construction is based on four autonomous units of 25 hectares each, possessing a 65 liters-per-second module, divided by a small vertical sluice gate from the intakes on the secondary canal into two water channels, each handling 30 to 35 liters per second. These channels are simultaneously supplied by two tertiary installations. The planned irrigation schedule is nine hours daily.

The main canal, built of topsoil as described above, has to handle the water flow volume necessary for the simultaneous irrigation of four Autonomous Irrigated Units, a total of 260 liters per second. There is an arrangement for variable distributors to provide intakes from the secondary canals. At the top of the perimeter, water intake is accomplished by four pumping stations on floating platforms consisting of a LISTER HR 3-type motor with a DELOULE pump.

C. The Development Principle

The underlying principle of developmental work on the perimeter will be to create a hydraulic sector measuring 25 hectares for each group of farmers. The following data should be taken into account:

1. The entire plain is susceptible to flooding caused by runoff water from the catchment basins as well as by the Senegal River overflowing its banks.

2. No Autonomous Irrigated Unit Perimeter can be situated right alongside the river; therefore, all units would need rather long supply canals.

3. Considering the large number of Autonomous Irrigated Units, a correspondingly large number of pumps concentrated in a single place for pumping water could create operational problems.

4. The problems usually associated with managing a battery of autonomous pumps and maintaining a common infrastructure, as well as significant possibilities of achieving economies of scale in the areas of investment and operational capital, point to creation of a network of collective installations, including dikes, pumping station, collective irrigation system, drains and tracks, to be managed on an integrated basis.

It will be necessary to draw up an implementation plan to construct collective infrastructural installations (preferably by the contracting firm), and to construct internal installations by the farmers groups, in accordance with principles spelled out in paragraph 3.2.4.1., and equally applicable to Podor.

D. Hydrology - Flood Control

As stated above, the plain is susceptible to flooding by runoff water from the catchment basins. To determine the best means of flood protection, it will be necessary to conduct a study most probably culminating in the construction of a protective dike as well as the dredging and regauging of the creek.

Furthermore, the site is also susceptible to flooding when the river overflows its banks. The project study will determine whether it is advisable to construct a dike to protect the site against such floods. According to the GERSAR Improvement Plan, summarized below, the perimeter may count on the following water levels at different phases of work on the dams under construction, and depending on the frequency of floods:

Bakel Station	Lower Water mark (1year/2)	High-Water Marks at the Following Frequencies			
		1 year/2	1/10	1/100	1/1000
Present Situation	11.58	21.45	23.10	25.15	26.60
After Diama goes into operation	11.60	*	*	25.40	26.75
After both Diama and Manantali go into operation	15.25	*	*	23.90	25.50

* Not available

E. Agronomic Data

Constraints related to soil types and the selection of crop options have resulted in a different distribution of crops and a modified schedule of water requirements for Collenga Autonomous Irrigated Units as compared with the small perimeters. Of the project's five Autonomous Irrigated Units, four are located on rice fields, while the fifth will be completely devoted to mixed cropping.

This initial approximation will serve until the implementation plan is available. Net water requirements per hectare for plot irrigation are presented in Appendix B.

	J	F	M	A	M	J	J	A	S	O	N	D
Rice	4400	2948	4807	5940	2486	--	2805	--	902	3377	1408	--
Mixed Crops	1219	1284	1675	1043	--	19	777	38	342	736	1786	227

As indicated, two crops will be planted annually, insofar as water availability in the Senegal River can meet requirements before construction of the Manantali Dam (1989).

F. The Pumping Station

If the hypothesis for a single intake proves valid, with the perimeter under construction having four pumps and the extended perimeter requiring at least six more, and if every Autonomous Irrigated Unit possesses its own pumping station, the result will be a battery of individually operated pumps.

This project proposes an alternate approach of setting up an integrated pumping system made up of several optimal-design units. This station would have the extra advantage of possessing a standby pump, thus offering all users protection against initial breakdowns. The station would be run by a competent team selected by the farmer groups. This system would relieve farmers from having to concern themselves directly with such problems as fuel supplies, repairs, and maintenance work.

1. The Autonomous Irrigated Unit Module

The Autonomous Irrigated Unit devoted to rice farming will observe a different irrigation schedule from that of the small perimeters practicing mixed farming, because the rotation will involve six unit plots measuring 2.5 hectares each. Moreover, water loss occurring in the much longer individual and collective canal system will be greater. For the purposes of this study, we estimate this loss at 20 percent, which means it will be necessary to increase each plot's water requirements by a factor of 40 percent in order to obtain the discharge levels required of the respective pumps.

In this case, the water manager will work out the best practical modulation of water supplies to the farms, but an average figure will be useful for determining the dimensions of the pumping station.

2. Identification of the Optimal Pumping Station

Beginning with a hypothesis of a total of 13 Autonomous Irrigated Units -- 11 devoted to rice farming and 2 to mixed cropping -- we must then calculate the requisite maximum flow volume at the top of the network, with all the rice-planting units simultaneously having irrigation times of 10 to 13 hours per day depending on corresponding phases (See Table 12.B) while the two mixed-cropping units using a 50 liters/second module hold off their irrigation operations during major peak periods on the rice farms (for instance, when flow > 65 liters per second).

Maximum Q at the pump = 11 x 78 = 858 liters/second or about 3,100 cubic meters/hour. The manometric level increase at current low water periods may be estimated at 16 m, if we factor in possible head losses from a strainer.

Taking into account a reduction of four pumps with a capacity of 775 cubic meters per hour to handle the maximum flow volume (with one standby pump), the machine with the most suitable specifications would be a DELOULE 96-70/25029/290-250 model pump, supplying of 775 cubic meters per hour at 16 manometric height working at 86% efficiency, plus a 60 HP LISTER HR6 model motor, all mounted on a floating platform of metallic casings filled with polyurethane foam.

At any rate, it will be necessary to make sure that the pumps operate efficiently at lower manometric heights. This initial estimate is merely intended to facilitate the financial estimates in the absence of any documentation. A final solution will be presented in the implementation project.

G. The Irrigation System

A large head work will be needed to receive the discharge from several penstocks and act as a stilling and distribution basin. The main canal should be regulated from downstream with the help of a NEYRPIC-type gate at the exit of the basin, controlling the downstream water level in the canal. Depending on the gradient and the length of the main canal, other sluice gates may have to be installed.

If the canals are to be outfitted with drainage canals to serve a number of Autonomous Irrigated Units, there will be no need for any installations at these points. This solution is particularly suitable for canals with a low gradient. Water intake to supply the subperimeters will be accomplished by means of installation of the type presented in Figure 13. Such installations may or may not be coupled with a siphon-type crossover.

Within the unit, the distribution mode will be identical to that described in the case of the small perimeters (Chapter III). It will be possible for all farmers' groups to irrigate their farms simultaneously when they so desire.

The collective canals will be constructed of mechanically compacted earth. The project plan will state the type of material to be used and also point out that the canals might possibly have to be lined. Construction work here, too, will be done by the contractor.

H. Drainage System and Feeder Road Network

On the collective level, the drainage system should make it possible to evacuate excess drainage water and ten-year peak level floodwater within three days. The plan will determine volume and flow levels to be taken into account and the manner in which excess water will be evacuated from the perimeter - factors we are now unable to assess because of the lack of data. Drains will be mechanically constructed by the contractor.

Provision will also have to be made for windbreaks and fences (See the Agricultural Analysis). A network of interior feeder roads should be constructed to serve each Autonomous Irrigated Unit, providing access to all the collective installations. These feeder roads, specifications for which will be laid down in the plan, should be useable in all weather conditions. Reverse siphons or simple culvert piping should be planned at crossover points.

I. Financial Implications

In the absence of any detailed plan for this perimeter and especially in the absence of evaluative data of any kind, the estimate of construction costs is based on construction costs for comparable perimeters and on price indices given by GERSAR. The quantity of work and survey figures used are also approximate.

1. Unit Prices

- Dike Construction

Using the plan of a dike 2 meters high, 4 kilometers long, and with a cross-section identical to that of the Podor dike, the resulting quantity survey volume will be 60,000 cubic meters at a cost of 900 CFA per cubic meter. As in the case of the other contractor costs, this figure would be increased by 10 percent to cover equipment transportation costs. Therefore, the total is 60,000 x 990 = 59,400,000 CFA.

- The Pumping Station

Below are suppliers' prices for a modular unit comprising a pump, motor, coupling frame, intake assembly, a Ø 250 reserve flow PVC pipe for a strainer, estimated length 200 m (150 m fixed and 50 m articulated), a metallic floating platform filled with polyurethane foam, and a reverse flow ball valve:

Unit price, including transportation and on-site installation	10,000,000 CFA tax-free
Price of a spare motor, pump, and floating platform	7,220,000 CFA " "

Total price of four operational plus one spare pumping station	47,000,000 CFA tax-free
Water control equipment and installations: 2 NEYRPIC-type gates (e.g. 71/80 and 50/60) installed	20,000,000 " " "
TOTAL	67,200,000 " " "

2. Network Infrastructure

List prices for the improvement scheme updated to 1982 levels.

Irrigation canals 1, 2, and 3	150,000 CFA gross
Mains 1, 2, and 3	70,000 " "
Civil engineering construction work on the networks	175,000 " "
Main roads	345 CFA/m unit
Secondary roads	285 " "

Total of the above to be increased by 10% to cover heavy equipment transportation costs.

Improvement work on plots to be done by the farmers' groups: tools, materials, windbreaks, minor equipment, at 400,000 CFA per net hectare.

Technical assistance personnel provided by the IDP will be responsible for the engineering design and supervision of construction.

3. Cost Summary

	(10^3 CFA)
Dike construction	59,400
Pumping Station: pumps	47,220
supplementary equipment	20,000
Network infrastructure (for 250 gross ha/ 200 net ha)	211,300
SUB-TOTAL	337,920
Contingencies and Inflation (about 10%) after 1st year	32,080
TOTAL contingencies	370,000

Equivalent(at an exchange rate of $1= 300 CFA) : $ 1,233,000

In effect, construction costs in 1983 US $ work out as follows:
$4,930/gross hectare
$6,160/net hectare

4. Financial Charges - Collenga Construction Program

Figures in thousands of 1983 U.S. $
Exchange rate: $ U.S. x 1 = 300 CFA

IDP	Year 1	Year 2	Year 3	Year 4	Total
Study and Project	PM	PM			PM
Dike	198				198
Equipment for Pumping Station	168				168
Engineering Work	56				56
Networks	200	504			704
Supervision	PM	PM			PM
Contingencies 10%	62	50			112
TOTAL: 1983	684	554			1,238
Inflation at 8% per year	55 (1.08)	94 (1.17)	(1.26)		149
TOTAL	739	648			1,387

5. Operation and Maintenance

Funding for construction of Collenga and Bakel should not be released until adequate organization for operation and maintenance has been set up, covering both the original perimeter and its extension.

It is likely that SAED technicians will have to play an integral part in the implementation of this organization and serve as technical consultants for the first few years of operation. However, if SAED should undertake any substantive maintenance work, the full cost of the work should be paid by the farmers groups. Senegal has a private sector capable of this work if it is not in competition with government-subsidized construction.

3.2.5. Development of Small Basins

3.2.5.1. Description of Small Basins

These small basins can generally be defined as low-lying, relatively level areas situated at some distance form the river bank and collecting rainfall run-off from surrounding high land (watersheds) and occasionally the overflow from river flooding or from marshes. The water in these areas is usually stagnant, although occasionally flowing. These areas are generally elongated and in some cases branched.

This definition is characteristic and by no means descriptive.

3.2.5.2. Concept of the Set-Up

The different methods for developing a small basin are a function not only of its configuration, but also of the end goal of its development. In this project, socioeconomic criteria will be preponderant in determining the degree of sophistication of the system.

To the extent possible, the project should attempt to adhere to a system based on the farmer groups and their subperimeters of 15 hectares. Nevertheless, certain departures from this concept are to be expected due to physical constraints.

3.2.5.3. Techniques of Small Basin Development

3.2.5.3.1. Collection of Water

Specific study of each proposed site should evaluate the amount of rainfall, the amount of water from run-off, and the amount of water from the overflow from adjacent watercourses. Similarly, research should be conducted on the retention sites (topography, soil conditions) and water retention sites.

The correlation between these alternatives and the amount of flow required by the cultivation envisioned (generally rice) will define the optimum irrigation system. Sometimes, two complementary types of systems will be selected. An analysis of the costs of investments and of its operation will be the determining factors.

This project proposes the following alternatives: See Figures 16 A, B, and C, Appendix D11-D12.

A. A retention dam with reservoir situated upstream to supply all or a part of the perimeter and equipped with a valve for gravity flow irrigation. The capacity of the reservoir should be based on the volume required to compensate for prolonged

deficiencies in rainfall (Figure 16 A).

B. A dike protecting a flood plain, equipped with an intake gate and a controlled outlet, and a security overflow to avoid flooding by water from the adjacent watersheds (Figure 16 B).

C. Pumping from the river and gravity flow by canal to the distribution network (Figure 17 C).

D. A combination of one or more of these systems.

3.2.5.3.2. Distribution System

In alternatives (a) and (c) (retention dam and pumping), the water for irrigation will be pumped to the highest level of the perimeter. A collective distribution system will transport it up to each intake for use by the farmer group for each subperimeter. If there are two complementary systems of water supply, the system should be interconnected to avoid dividing distribution into two separate canals. Junctions would most often be distribution basins as well. The types of canals and gates and drains and other works should be similar to those used on the medium perimeters described earlier.

3.2.5.3.3. Protection from Floods in the Perimeters

The drainage system will collect the excess water generally at only one point from which it will be drained out by gravitation and outside of the perimeters by adequately sized drain piping. If the perimeter is subject to river flooding and is to be protected by a dike, the drainage area will pass under the dike and be fitted with a one-way valve designed to avoid back-flow into the perimeter from the river of marshes (Figure 18). This system must take into account the risks involved in prolonged flooding if the level of the river does not allow draining by gravitation. It should be noted that in the upper valley, flood peaks are generally of short duration.

In certain cases where the risk of prolonged flooding is greater, a pumping system should be installed for drainage, which would be the same as the irrigation pump (see basins in Kounta and Farakorossou).

On the other hand, a perimeter dike would normally protect the area against run-off from the adjacent watersheds on either side.

3.2.5.4. The Mauritanian Perimeters

As presented in Tables 1 and 2 (Appendix B), a total of 600 hectares of medium-sized perimeters are planned in the Kaedi Sector during phase two. These perimeters will be composed of approximately 300 hectares each

and be located near the villages of Winding and Dirol. Small dams will be constructed at both sites to establish seasonal reservoirs in low-lying basins from which water for perimeter irrigation can be pumped. SONADER will be responsible for contracting for the final design and construction of these perimeters, for supervising farmer participation in the construction, and for monitoring the construction contractor. The irrigated area will be divided into sections of approximately 15 hectares each, so that independent farmer's associations will be responsible for tertiary canal construction and all agricultural production activities as with the small perimeters. AID will finance the construction costs and provide engineering technical assistance and operating support to SONADER for this medium-sized perimeter construction program. Because of the additional earthworks involved, including the small dam, the per hectare cost of the medium-sized perimeters is $4,500. This is considerably above that of the small perimeters but still economically justifiable, particularly with the animal traction program and other labor-saving and productivity-increasing measures that will have been introduced by the project during phase one.

3.2.5.4.1. Winding

This site is situated along a very deep creek that enters the Senegal River just below the village of Winding. The development of the site requires that a small dam be built near the mouth of the creek. The site includes three hundred hectares along the banks of the creek. The farmers will come from the village of Winding and several small neighboring Peul villages.

SONADER has undertaken technical feasibility analyses of the site, including topographical and soils studies and a socioeconomic study. 1/ The development plan and costs for the Winding medium perimeter are taken from the SONADER analysis. THe population of the area is sufficient for the development of the perimeter, although animal traction and some other labor-saving technologies should be introduced in order to fully exploit the area. The socioeconomic analysis uncovered some potential difficulties concerning land ownership. These will have to be carefully addressed during the early stages of farmer orientation and organization to assure proper development of the site.

3.2.5.4.2. Dirol

This site is on a flat natural plain with heavy alluvial soils which is cut by the Dirol creek. The plain is flooded annually by rainfall runoff draining into the area. In years of good rainfall, about 2,000 hectares in the plain are cultivated with millet and sorghum. The total surface area of the plain is about 8,000 hectares. There are eight Tukulor villages in this area, with a population of over 8,000. These include Oualom Atar,

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Etude des Périmètres dans les Secteurs Kaedi et Gouraye, SONADER, December 1981, Chapitre II - Identification des Sites, Chapitre III - Evaluation des Problemes d'ordre Sociologique.

Foundou, Abdalaye, Doubel, Bagoudine, Niabina, M'Bahé, Feralle, and Diawalel.

The development proposed by SAED is similar to that for Winding. A small barrage will be built to retain water in the creek that will be used for irrigating approximately 300 hectares along its banks. The socio-economic study of SONADER revealed that interest in this type of development was high among villagers but that they did not want heavy outside involvement. The development plan should follow the network plan for new perimeter development (see the Social Analysis, Volume III, Section 2.0.) to fully insure participation by the villages involved. The project will fund the development of 300 hectares at this site. This could later be expanded, since there is a large irrigable area at this site.

3.2.5.5. The Malian Perimeters

3.2.5.5.1. Goumbaye

The Engineering Division of the Ministry of Rural Development (GR) proposes a first phase consisting of a 130-hectare basin which at present is partially cultivated with rice (30 hectares) and one 25-hectare vegetable gardening perimeter. A reservoir with a capacity of 2,000,000 cubic meters in the Sambage basin is contained by an earthendike equipped with an overflow 10 m wide and an intake of 2 cubic meters per second.

The anticipated water supply in August-September is 2,500,000 cubic meters for 8.0 frequency and 12,000,000 cubic meters for 0.5 frequency, and should be sufficient for irrigating a 130-hectare area of rice in the basin. The GR likewise proposes to increase the area cultivated in Phase 2 to 220 hectares of rice paddies and 25 hectares of orchard and vegetable crops. Since reservoir capacity is not sufficient, the GR is planning to install a 185 HP pumping station interconnected by a distribution system, which will also allow double cropping. The reservoir supplies the system from an outlet as shown in Fig. 18. The pumping station through the distribution basin (B2), supplies the Phase 1 system via C4 and C5, the vegetable gardening perimeter through C3 and the second phase by C6 and C7. The orchard will be supplied by C7.1.

Three important issues may be drawn from this discussion:

A. The expected capacity of the reservoir and its supply are greater than what is neeeded for the additional 130 hectares of rice paddies (whose needs are estimated 120,000 to 130,000 cubic meters per hectare). If this first phase could be completed, one could envision greater extension of the cultivated areas.

B. The pumping station is only justified if the Senegal River level is high enough to allow cultivation during the dry season. It would be advisable to verify if this is actually the case at present. If not, it will be necessary to wait until the river

flow is regulated by the Manantali Dam which, again, will substantially raise the river level at the pump and allow for optimizing investment costs and the station's operating costs.

Nevertheless, the requirements for flooding the rice fields are high due to the high permeability of the soil (7mm/day). It would be wise to study this problem more thoroughly. If this system were adopted, operating costs would be very high in the dry season, when all the water would have to be pumped in for irrigation. Conscientious selection of the crops and of the pumping system is mandatory.

In other respects, the pedological study reveals that in addition to the high permeability in the basin, there is an uneven micro-relief that will require leveling. Also, topsoil is very thin in places and the drainage is poor.

The planned drainage will be directed for phase one into the Goumbaye marsh, which crosses a drainage outlet situated under the southern dike. In the second phase, similar to runoff from the perimeter dikes, drainage will be directed north of the river. The elevations of the outlets allow gravitional drainage in both cases. Protection against river risings similarly seems to be secured by high ridges along the river banks. The centenial flood, estimated at 42.80 meters, is no higher than the lowest-lying ground. Protection against the neighboring marshes will only require a small amount of diking.

The Government of Mali (GOM), in its estimates completed in 1982, expects to complete the first phase under contract works equipment and structures (pumping station, connections, and all associated works in the system). Cost : 415,122,000 MF. Total Cost : 734,000,000 MF or $1.22 million (approximately $7,870).

Completion of Phase two under contract (220 hectares of rice and 35 hectares of vegetable gardens) would cost 403,000,000 MF. Earthworks and structures, etc. would cost 403,000,000 MF. Equipment and structures (distribution, water intake and all construction works in the system) would cost 141,750,000 MF. Total cost : 544,750,000 MF without engineering supervision, i.e., approximately $0.91 million (about $ 3,762 per hectare) Overall costs for the two phases is $5,200 per hectare, if the pumping station is installed during phase one or phase two.

3.2.5.5.2. Kounta

The Government of Mali also proposes two phases for the development of a basin crossed by marsh. 8.4 hectares are available on the Kounta side and 15.3 hectares on the Farakotossou side of the marsh. Both sides can be double-cropped in rice.

A dike to protect against the hundred-year river floodings has been planned for a total length of 2.9 km. These dikes will be connected to the reservoir dam on the stream separating the two perimeters (Figure 21, D14).

Water will be supplied by two outlets in the dam, one into each of the two zones. The additional water collected during the rainy season and all water supplied during the dry season will be handled by two motor pumps located on the dikes. However, the GOM seems to prefer an alternative that would eliminate the construction of a dam, and has drawn up a preliminary plan (Fig. 20). Among the disadvantages of contructing a dam are that it would be quite expensive, even though reservoir capacity is low; that maintenance costs for preventing silting of the canals caused by the runoff would be high; and management of the whole operation would be too complicated.

In the alternative solution proposed by the GOM, irrigation would be achieved by pumping during the rainy season as well as the dry season. On the other hand, it differs from irrigation for the small perimeters in that dikes are necessary and require the removal of excess water by pumping. The development would include a network of canals equipped with on/off valves and security overflows. Two motorpumps would handle the pumping - one with 9 HP and 40 m of piping and the other with 13 HP and requiring 100 m of piping. (see Fig. 19, 20, 21, Appendix D14).

Because of these factors, the development cost per hectare is relatively high, notably for Kounta. Below are estimates completed by the GOM in 1982 for completion of phase one under contract (Kounta : 8.4 hectares).

Dike	8,507,000 MF
Canals	12,090,000
Drains	5,359,000
Structures	8,373,000
Pumping Station	5,153,000

Total Cost of Construction: 39,500,007 MF or about $65,800, which would cost $ 7,830 per hectare.

The second phase is independent of the first. The cost of construction at Farakotossou would be 56,800,000 MF, which equals $6,200. These perimeters should be studied carefully as non standardized pumps would be used to irrigate only a very small area.

3.2.4.5.3. Dioumékou

The site on the right bank of the river is upstream of the falls at Felou and includes the areas of Dioumékon and Soukoutalé, as well as an existing 12-hectare perimeter. A pre-project has been undertaken by the GOM, based on development allowing recession cultivation of sorghum or maize. These basins are flooded annually. This alternative is displayed

in Figure 22, D14.

Dikes protecting against centennial river floods are equipped with distribution valves and overflows. A central drain is planned in the Dioumékon basin. Rising of the river in eight years out of ten years allows the flooding of 35 hectares in Dioumékon and 40 hectares in Soukoutalé. These basins can also be flooded by the runoff from their interior catchment basins.

The first phase will involve development of Soukoutalé, while the second phase will include the development of Dioumékon and the extension of the truck-garden perimeter and of another 8-hectare irrigated perimeter. GRM costs estimates for works during phase one as of 1982 are as follows:

-execution of Phase one under contract Soukoutale 40 ha

. Dike and Inlet Canal	12,820,000 MF
. Engineering Works and Equipment	22,080,000 MF
. Total Without Supervision of Work	34,850,000 MF

Or approximately $US 58,000 at about $US 1,450 per hectare.

Extension of the small (8 hectares) perimeter in Dioumékon is estimated to be 21,600,000 MF ($36,000), while the estimated cost for the Dioumékon basin (35 hectares) is 38,400,000 MF ($64,000).

3.2.5.5.4. Other Basins Identified in Mali

A. Dakandakpé - Two basins have been proposed : one from 3-4 hectares in size, located 1.5 km from the river, and the other from 6-7 hectares in size, located 1 km from the river. Both have been designated for rice cultivation. No plan or report providing details on this proposal has been made available to us.

B. Walinékane - This is an elongated basin 200 m wide at the most, which is located 350 m from the river. A survey map on the scale of 1:2000 allows the estimation of 40 hectares of arable land for rice paddies.It will be necessary to make pedological, hydrological, and topographical studies of the environment to determine the feasibility of developing this basin. No data has been received on this basin aside from the 1:2000 scheme.

C. Gakoura II - This is a very narrow basin 300 m from the river. In the absence of map or other documents on this proposal, it can only be estimated that the total area of the surfaces wide enough to be developed would be between 80 and 150 hectares.

D. Sobokou II - This small basin is located 1.5 to 2 km from the river and has an area about 100 hectares suitable for rice paddies.

3.2.5.5.5. Program and Budget

Approximately 933 hectares of perimeters and basins have been identified :

Name of the Basin	Area	Name of the Basin	Area(ha)
Goumbaye (1st Phase)	155 ha	Soutounkolé	40 ha
Goumbaye (2nd Phase)	255	Dakandakpé	11
Kounta	8.4	Walinékane	40
Farakotossou	15.3	Gakoura II	115
Dioumékon	35 + 8	Dramane-Sobokou	150
		Sobokou II	200

The existing plans are preliminary. Some regions have not been identified on site by OVSTM personnel. Numerous and important investigations ranging from a master map to pedogical, hydrological, and socio-economic studies are necessary in order to justify any construction for development. This research will be undertaken in the context of the upper valley development plan financed under the regional program of the IDP. This study will allow the identification of other areas that could be developed. In this connection, one should note that most of the areas identified to date are situated on the left bank of the Senegal River; it is hoped that suitable land will likewise be identified on the right bank.

During year three of the program, it will be possible to prepare a realistic program of development. At that time, a construction model can be designed so that construction can begin in the fourth year.

Since it is not possible to define the area or the model of construction at this point, the following program may be only indicative, based on the average cost of construction developed above.

Mali - Development of Small Basins

Year of the IDP	1	2	3	4	5	6	7	Total $US
Irrigated areas (net area)	-	-	-	566	184 ha		-	750 ha.
Constructions	-	-	-	1,530,000	497,000		-	2,027,000
Commodities 1/ (pumps)	-	-	56,000	56,000	57,000	-	-	169,000
Total 1982 $US	-	-	56,000	1,586,000	554,000			2,196,000

3.2.5.5.6 Payment for Rehabilitation

In general, the cost of rehabilitation should be charged to the farmer's groups, who will be called upon to provide a significant volume of labor that has not been included in the above figures.

It is recognized that many of the present problems have resulted from RDA shortcomings in terms of inadequate site selection, perimeter design and layout, and construction control.

It is recommended that the required works be considered on a case-by-case basis. The IDP would finance any rehabilitation efforts necessitated by construction errors and poor terrain. Works undertaken for the convenience of the farmers' groups or to improve poor maintenance would be charged to the groups who would have access to credit.

1/ Commodities will be purchased by farmers' associations using credit made available by the project for this purpose.

3.2.6. Discussion of Fundamental Options

The several schemes of irrigation works presented above are concious choices made after comparing alternate possible development scenarios.

A. No development

To refrain from any irrigation investment is a valid possibility. However in light of the irreversible deterioration of land in the middle valley, due both to drought and a continuing dry cycle, population growth, and the demonstrated low carrying capacity of the land in dry years, it seems that the investment committed to major dams should be valorized by irrigation, which could increase the productivity of land in the middle valley by a factor of 20 or more.

In the upper valley, the abondant rainfall in an average year provides a real alternative to irrigation, yet the level of interest of villages in developing perimeters indicates that there are advantages to intensive farming with modern methods.

B. Large Scale Mechanized Agribusiness

As discussed earlier, the three nations concerned have decided that food production through local labor is a key goal of development (with the possible exception of lands in the Delta, which are amenable to mechanization if other technical problems can be solved, and where there is limited population). Once again, methods must be found to introduce profitable irrigation.

C. Small Perimeter Versus Large Perimeter

These two types of perimeters are not mutually exclusive alternatives. Both should be developed and used for different purposes.

While there have been problems with large perimeters in the past, some of their causes are known, and strategies have been developed to avoid them in the future. The investment required in large perimeters is high, both in per hectare costs and in the concentration of investment in one area. These costs are largely due not so much to the size of the perimeter as to the less favorable location of large perimeters.

In recent years, small village perimeters have spread rapidly throughout the valley. According to the available production records, many of these perimeters have been successful in producing food and in mobilizing the village human resources and have required limited external cash investment.

By definition, small perimeters are located on high banks at the river's edge, thus avoiding the necessity of flood protection dikes and long water conveyance canals. Because they are small, drainage works are rudimentary and internal roads are not essential. Perhaps most importantly, the organization required to build, operate, and maintain small perimeters does not preclude unsophisticated village size units.

In spite of these advantages, the potential for developing PIV's is geographically limited to a narriw strip at the immediate edge of the river, generally on less fertile though arable soils. Because the small perimeters are isolated, they require considerable investment in roads to make them accessible to vehicular traffic year round, and lower the efficiency of extension and training workers, pump repair, contract farm operations, credit evaluation, and any activity that is beyond the immediate village level.

As irrigation is expanded beyond a strip of no more than a few hundreds of meters wide, the monetary and social investment in large perimeters becomes justified.

The IDP design team guidelines will be set out for Podor and Collenga to help develop models for effective physical and organizational design of large perimeters.

D. Water Lifting Systems

For more than a decade, hundreds of small pumping units have been installed along the Senegal River to irrigate village perimeters. Experience in the three countries has led technicians to set a standardized optimum unit to supply a 20-hectare (15 useful hectare) perimeter which should satisfy the following criteria:

- Provide a discharge of at least 75 liters per second (270 m3/hour). This is a nominal flow needed for 20 hectares of paddy rice, against a total head ranging from 3 to 19 m depending on river stage and location. This solution requires up to 17 theoritical horsepower, not taking into account losses due to pump inefficiency and friction loss;

- Accomodate floods that can raise water levels 10 m or more above low flow levels;

- Have an intake that will not clog due to siltation as bed load moves along the bottom of what is frequently a shifting channel;

- Be inexpensive to purchase and operate, reliable, easy to repair, and non-polluting.

The preferred standardized unit is a diesel-engine powered horizontal rotodynamic "groupe moto-pompe", referred to as GMP. This unit is placed on a floating raft,discharging through a combination of flexible hoses and

quick coupling irrigation type pipes.

Various other methods of lifting water have been considered. Controlled flooding during the annual flood which is practical in low lying basins and is used presently, is included in the IDP. However, this system depends on the vagaries of the flood and can be applied in only a few favorable areas; in any case, it can provide only one crop a year. Upstream diversion is impractical, given the very shallow drop of the river, the high banks, and the size of the annual floods; diversion canals would have to be tens (or hundreds) of kilometers long in step and unstable banks subject to scour in every flood season.

Any pumping system requires an intake at water level, and this water level moves up and down with the flood as well as laterally for considerable distances. The following possibilities should be considered:

- Placement of a well driven to below river water level. Soil permeability is such as to require many wells to irrigate one 20 hectare perimeter unless a pipe at an elevation below low water is laid to the low water channel. Intake in this channel could be completely inacessible during the flood. Vertical shaft pumps are considerably more expensive than horizontal. This solution is valid only for either large installations or very small ones that would not excessively draw down seepage flow.

- Placement of a movable pump placed on the bank at the water's edge. This solution is being used for diesel pumps in Mauritania and is not regarded as satisfactory. The GMP's are unwieldy on the steep banks, are seldom set level, and water and oil spillage make for an unsuitable platform for operation and particularly for repairs. Installation could be improved by providing concrete platforms at vertical intervals of 2 meters, or an inclined ramp of concrete or steel truss sections on concrete bases; this solution will be tried at Bakel (the solar pump) and will furnish useful data on costs and on problems that may arise from river flow and scour during flood.

- Installation of a screw conveyor, with its motor on the bank, which could descend below low water levels and thus avoid all problems with fluctuating river water levels. The screw would have to be about 30" (76 cm) diameter, however, and the length of 17 m (55') is near the maximum size presently built. The lower bearing would be submerged (under 10 m of water during floods). The motor would have been either inclined or connected through an angle drive. The foundation for either an enclosed or an open screw would be massive, subject to scouring in the river channel. These pumps are usually specified either for lifting water with a high solids content or for low lifts (a meter or two) of clear water.

- Construction of a floating raft with a GMP is another solution which, except for the high costs of the raft, poses problems. River velocity is not high, even during flooding (order of 1 to 1 1/2m/s max). Mechanics have not complained of the comparatively restricted working space.

Sources of energy other than diesel engines have been considered. The general comparatively high lift required during most of the year effectively eliminates most of these, as power requirements become high, particularly with the high water demand of paddy rice in the dry season. Among the energy sources that were rejected are the following :

- Manpower can be developed at the rate 0.067 HP at a steady rate. to replace one 15 HP engine would require 225 workers, at least 450 to be able to work in 2 shifts, with presumably at least 50 individual pumps each with its own intake problems. This is a region where lack of manpower is already a major constraint to the spread of irrigation .

- Animal power, specifically oxen, can be developed at 0.3 to 0.5 HP for a period of few hours. To be able to work two shifts (pumping during a full irrigation day), some 30 to 50 wells would be required to replace one 15 HP motor. Some 10 wells would be required to replace one GMP, each with its own water lifting device and its own driver for the animals.

- Water power is available only from the flow of the Senegal River. During most of the dry season, at present, flow is negligible or nonexistent. Even after the construction of Manantali, with a minimum flow of 300 m3/s maintained at Bakel, flow velocities will be low, less than 0.5 m/s. To develop power from this source would require large paddle wheels on unwieldy barges anchored in the fastest moving current (15 HP would require 7 m3 of area in each paddle if a current velocity of 0.3 m/sec and efficiency of 40 percent are assumed, both high. With a 3 m radius of the paddle wheels, rotational velocity would be on the order of 0.015 rpm, requiring gearing for a roto-dynamic pump). There would also be problems with the flexible piping to shore.

$$(HP = \frac{pW \; Ap \; Uw3}{K}$$ K = 550 in foot-pound units, P is mass density of water, Ap area of paddles and Uw the velocity of the water).

- Wind power is not a viable possibility. Reported wind velocities at at Matam are: 2 2 mph - 55 precent of the time; 2 - 10 mph, 36 percent ; 10 - 14 mph, 6 percent and 14 to 30 mph, 3 percent. Average velocity is only 4.2 mph (to generate only 5 HP would require a blade diameter of 100 feet at 40% efficiency in a wind of 6 mph).

($HP = K\ Aw\ Uw^3$, where $K = 7.1 \times 10^{-6}$ if Aw, area swept by the blades is in ft^2 and velocity Vw is in miles per hour).

- Solar energy, although it has no operating costs, has not proven economically feasible with the presently applied technology (Bakel solar pump). Two solar-powered pumps are being installed in the SRB, one each in Senegal and Mauritania. Several years of work and considerable expense have not helped render either of them functional as yet. Further advances, particularly inexpensive and reliable photo-voltaic cells, may change this picture in the next decade. Insolation in the SRB is plentiful and reliable, but this technology has not yet been developed.

- Electric power offers many advantages. It is clean, requires no fuel to handle at the pump site, needs minimal maintenance, causes little wear, and starts easily. A major disadvantage in the small perimeters however, is that electric power is not available at this time above Richard Toll. A few towns have intermittent or irregular power, and new generation capacity is planned for the near future in several places. Even when these are built, however, the cost of distributing the few kilowatts needed by pumps is uneconomical among the widely scattered villages with average distance of 10 km or more between them. In some areas with a concentrated number of perimeters, constructing central generating plants may be economically feasible. Such plants could increase efficiency and reliability of larger well maintained engines, reduce maintenance needs, and promote smooth operations. Though this investment cannot be justified at this time, as the local village social structure is not ready to support such endeavours, this option should be considered in the future.

- For international combustion engines, diesel energy is less expensive than gasoline, and natural gas is not available.

Diesel driven GMP's, on rafts, are at the present time unquestionably the preferred water lifter for village perimeters, both technically and socially. Purchase, operation, and maintenance are within reach of the evolving village group, particularly as private mechanics begin to phase out RDA support.

Of the various motors and pumps that have been tried, the best experience has resulted from LISTER HR series diesel engines, which have acquired a reputation for sturdiness. Mechanics are familiar with them and stocks of spare parts are available.

Pumps should be carefully chosen matching performance curves to lift conditions and engine characteristics. Each reach of the river, for a given bank height, will have its own specific requirements.

Few measures have been taken to date either to verify GMP performance or to adjust water delivery rates, variable with river stage, to predetermined water demand. Unquestionably, there has been over irrigation and water waste. The irrigation engineer will spot check pump performance during the year, using overflow weirs or stream gauging with micro-moulinet. He will thus be able to advise extension personnel as to optimum operation conditions around the crop and river stage cycles. Recommendations can be made as to the most economical pump speed settings and hours of operation, and discussions held with farmers to explain to them the most economical pump operation to satisfy crop needs.

Appendix A 1

IRRIGATION SCHEDULING AND WATER REQUIREMENT APPLIED TO SMALL PERIMETERS

This proposed irrigation scheduling is derived from weather data, crop data, and pumping data. It is strictly applied in small perimeters, where a normal scheduling cannot be applied.

Scheduling is made based on the following conditions (which are the cases found in small perimeters):

1) Pumps always run at optimum speed and discharge will not be variable.

2) To meet water demand for plants a fixed pump running-time is calculated .

3) Only one irrigation block is irrigated per day. This is applied for both rice crop as well as corn or mixed crop.

4) Field is derived into irrigation blocks (2.5 ha net for rice and 3 ha net for corn and mixed crop).

Application

When the schedule is made, farmers only need to know pump running time during the day that irrigation takes place. This pump running time is almost constant. Farmers or irrigators need to have a watch to keep track of the time to run the pump. If this scheduling is respected,water satisfaction is 100% and optimum yield variation of pump running time of ± 15% can be accepted depends on efficiency of water distribution system, then fluctuation of water level in the river and the performance of the Group Motor Pump.

APPENDIX A 2

IRRIGATION SCHEDULING AND WATER REQUIREMENT FOR CORN - RAINY SEASON - BAKEL - 96 DAYS CROP CYCLE

BASIC DATA

- Q = varies from 250 - 320 m³/hr - HR2
- Irrigation cycle (interval) varies from 7 - 10 days
- Water application rate 300 m³/ha for small corn - 400 m³/ha for ig corn
- Pump running time fixed : 5.8 hr/day except during last month : 7.4 hr/day
- Irrigation plot of 3 ha is irrigated/day
- Irrigation efficiency 65%
- No beaching requirement

Q m³/hr	250				320					250			
MONTH	JULY			AUGUST			SEPTEMBER				OCTOBER		
DAY	0	10		24	30	40	50	60	70		80	90	100
	0	7	14	21	28	37	46	55	62	69	76	86	96
STAGE	Seedihg							Flowering			Mature		Harvest
SECTOR IRRIGATED													
Water application cm	3	3	3	3	4	4	4	4	4	4	4	4	
Pumping Vol m³/plot	1385	1385	1385	1385	1846	1846	1846	1846	1846	1846	1846	1846	
Pump running time hr/day	5.6	5.6	5.6	5.6	5.8	5.8	5.8	5.8	5.8	5.8	7.4	7.4	
Fuel consumption Liter/day	26	26	26	26	27	27	27	27	27	27	34	34	Total 334ℓ/3ha = 111ℓ/ha(without rain)
Irr. Intervals(days)	7	7	7	7	9	9	9	7	7	7	10	10	

WITH RAIN : ℓH rainfall 300 mm

Water deficit 420mm - 300 mm = 120 mm = 1200 m³/ha

Pump running time $\frac{1200}{350}$ = 4.8 hr

Fuel consumption 4.8 x 4.65 = 22 l/ha.

APPENDIX A 3

Irrigation Scheduling and Water Requirement for
Corn Crop - Off Season - BAKEL - 112 days crop cycle.

- Q = HR2 250 m³/hr constant
- Irrigation cycle: varies from 6 - 8 days.
- Water application - 300 m³/hr for small corn.
  - 400 m³/hr for big corn.
- Pump running time = 8.4 hr/day except during imbibition and flooding period: 6.3 Hr/day.
- Plot: 3 Ha net - one sector is irrigated per day.
- Irri efficiency: 65 %.
- No leading requirement.

Q m³/hr	250 m³/hr															
MONTH	JANUARY				FEBRUARY			MARCH				APRIL				
DAY	0 8	10 16	20 24	30 32	40 40	50 48	56	60 64	70 70	76	80 82	88	90 96	100 104	110 112	120
STAGE	Seeding							Flowering					Mature		Harvest	
SECTOR IRRIGATED days	1 2 3 4 5 6															
Water application cm	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	
Pumping Vol m³/plot	1385	1385	1385	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	
Pump running time Hr/day	6.3	6.3	6.3	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	
Fuel consumption L/day	30	30	30	39	39	39	39	39	39	39	39	39	39	39	39	
Irr. Intervals day	8	8	8	8	8	8	8	8	6	6	6	6	6	8	8	

27,295 m³/3Ha

Fuel consumption = >186 L/Ha

APPENDIX B

Table 1

Existing and Planned Perimeters in the Kaedi Sector

Kaedi Sector	Existing Ha	FED Project	USAID/WORLD BANK PROJECT Phase 1	Phase 2
Youmane Yire	15	20	50	-
Cive	40	20	60	-
Tokomadji	11	-	40	-
Koundel Reo	15	20	80	-
Guusel Gubi	-	20	-	-
Aere Dindi	13	-	30	-
Tetiane Patoukone	-	-	20	-
Pjawo	89	40	100	-
Palel Guiraye	-	-	20	-
Sintiou	15	-	40	-
Nere Walo	15	40	160	-
Roufi Aoudi	-	40	-	-
Dirol	-	-	-	300
Dawalel	-	-	40	-
Dabbe	-	-	40	-
Winding	32	-	20	300
Sori Male	36	-	80	-
Abdehah	-	40	-	-
Kaedi Gattoya	-	60	-	-
TOTAL	281	300	780	600

Table 2

Existing and Planned Perimeters in the Gouraye Sector

Gouraye Sector	Existing HA	USAID/WORLD BANK PROJECT Phase 1	Phase 2
Khabou Guidimaka	35	140	-
Soulou	30	75	80
Diagountourou	70	100	-
Moulessimou/Diaguili	62	140	-
Liradji-El Salam (Mercel)	-	20	-
Woumpou	35	50	-
Sagne	9	45	-
Toulel	33	60	-
Wali	53	80	-
Benenki	19	20	-
Synthiane	12	20	-
Pimbo Paliba-Toulel	15	40	-
TOTAL	373	790	80

Phase 2 will also include the upgrading of 190 hectares of existing perimeters. That will be selected jointly by SONADAR and the Tech. Assist. Irrigation Engineer.

Table 3

I. Senegal

A. Bakel	Existing Perimeters	Ha. to be Upgraded	New Perimeters (gross ha.)
Gandé	8	8	(ext.) 12
Galladé	8	8	(1) 20
Moudery	45	28	(2) 40
Diawara	46	20	(2) 40
Yellingara	7	-	-
Manael	8	-	-
Tuabou	12	-	-
Gassambilakhé	26	26	(2) 40
Collenga-Bakel	--	-	244
Kounghani-Marabout	4	4	(Ext) 13
Kounghani-Village	30	30	(2) 30
Golmy-Marabout	5	-	-
Golmy-Village	-	-	(1) 15
Yafera	62	62	(4) 80
Aroundou-Emigré	10	-	-
Aroundou-Village	49	20	(2) 40
Ballou	109	-	(6) 120
Sebou	30	30	-
Debekhoule	20	20	(1) 20
Djimbe	15	15	-
Dialiquel	10	10	-
Sinthiou-Dialiquel	7	-	-
Ouro-Imadou	10	-	-
Seling	15	-	-
Kidira	33	-	-
Naye	9	-	-
Guitta	15	-	-
Senédébou	18	-	-
Total Bakel	611	281	714
B. Podor			
Podor-Sector C1	-	-	294
Podor-Sector M1	-	-	214
Podor-Sector C2	-	-	173
Fondé As	20	-	60
Dado	-	-	60
Guia	-	-	60
Doué	20	-	60
Goumel	-	-	60
Kodité	18	-	82
Total Podor	58	-	1,063
Total Sénégal	669	281	1,777

Table 4

III. Mali

Perimeters in the Kayes Sector

Perimeter	Existing Hectares developed Cultivated in 82 off-season	Ha to be renovated	1/ Possible new Perimeters
Maloum	26	26	--
Fanguène	15	15	--
Gumbaye	50	50	(1) 155 (2) 255
Sapou	15	15	--
Dioumekon	12	12	35 ≠ B
Mousa Goya	9	9	--
Kamankole	40	40	--
Samankidi	20	20	--
Moussala	20	20	--
Gakoura	25	25	155
Sobokou	50		100
Kounta	--		8,4
Farakotossou	--		15,3
Soukoutale	--		40
Diakandape	--		11
Walinkane	--		40
Drame-Sobokou	--		150
Total	282	232	933

1/ These are to be reviewed within the project financed planning ans feasibility studies for the Kayes Region; financing is planned for approximately 750 hectares.

Appendix B

MONTHLY WATER REQUIREMENTS IN CUBIC METERS FOR BAKEL AND GOURAYE

Table 5

RICE	J	F	M	A	M	J	J	A	S	O	N	D
BAKEL AND GOURAYE	4400	2948	4807	5940	2486	-	2805	-	902	3377	1408	-
MIXED CROPS IN BAKEL	495	-	-	-	-	29	1148	58	300	1104	2093	2668
MIXED CROPS-GOURAYE	1499	1284	1675	1043	-	58	2262	115	173	636	1786	2078

Table 6

MONTHLY WATER REQUIREMENTS IN CUBIC METERS

FOR KAEDI

Kaedi	J	F	M	A	M	J	J	A	S	O	N	D
Rice	4,600	3,082	4,577	5,704	5,202	-	3,576	356	1,587	3,760	1,483	-
Mixed Crops	1,227	1,284	1,526	951	-	234	1,387	264	985	889	1,786	2,250

Table 6

MONTHLY WATER REQUIREMENTS IN CUBIC METERS FOR KAEDI

Kaedi	J	F	M	A	M	J	J	A	S	O	N	D
Rice	4,600	3,082	4,577	5,704	5,202	-	3,576	356	1,587	3,760	1,483	-
Mixed Crops	1,227	1,284	1,526	951	-	234	1,387	264	985	889	1,786	2,250

Table 7

SMALL PERIMETER CONSTRUCTION COST IN SENEGAL

	Unit	PU 10^3 CFA	Number	Total in $ (1982)
A. Topo & Soil Studies	u	18	1	6,000
B. Pump Equipment				
Motor Pump Accessories	u	4,950	1	16,500
C. Construction Materials				
Stilling Basin (Back-bed)	u	170	1	570
Entrance Works	u	57	1	190
Trapezoical Earthen Canal	u	p.m.		p.m.
Weir-Cement Canal	u	2	3	20
Weir-Earthen Canal		26	3	260
Sand & Gravel		p.m.		p.m.
Labor		p.m.		p.m.
D. Equipment				
Metal Gate	u	21	8	560
Piastic Siphons	u	12	30	1,200
Cistern (3,000 1)	u	300	1	1,000
E. Topographical & Hydrological Material	u	p.m.		p.m.
Block Molds	u	40	2	
Shovels	u	3	30	
Picks	u	3	30	
Hoes	u	3	30	
Hand-Tampers	u	4	10	
Wheedlbarrows	u	25	10	
Wood for Formwork	m^3	200	0.5	
Small Hand Tools	u	750	2	
Subtotal				3,140
F. Contingencies (25%)				7,360
G. Total				36,800
H. Per Net Hectare				2,453
I. Per Geographical Hectare				1,840

TABLE 8

Estimates for a Model Small Perimeter in Mauritania (US $ - 1982)

	Units	Unit Price	Number	TOTAL-US $
A. Topo & Soil Studies	u	6,600	1	6,600
B. Motor Pump & Accessories	u u	17,000	1	17,000
C. Construction-Material				
Stilling Basin	u u	620	1	620
Entrance Works	u u	210	1	210
Trapezoidal Earthen Canals		p.m.		p.m.
Weir-Cement Canal	u	8.	3	24
Weir-Earthen Canal	u	95.	3	285
Sand, gravel		p.m.		p.m.
D. Equipment				
Metal Gate	u	76	8	608
Plastic Siphons (4m)	u	44	30	1,320
Cistern (4000 l)	u	1,700	1	1,700
E. Tools				
Block Molds	u		2	
Shovels	u		30	
Picks	u		30	
Hoes	u		30	
Hand Tampers	u		10	
Wheelbarrows	u		10	
Formwork Lumber	m^3		0.5	
Misc. Small Tools			1	
Subtotal				3,600
F. Contingencies (35%)				7,992
G. Total Type A Perimeter Plus Heavy Equipment Work				$17,500
H. Total Type B Perimeter				$57,459
I. Per Geographic Hectare - Type A				$ 1,998
J. Per Gepgraphic Hectare - Type B				$ 2,873

TABLE 9

COST ESTIMATES FOR SMALL PERIMETER CONSTRUCTION
(U.S. $ - 1982)

	1983	1984	1985	1986	1987	1988	1989	
IDP Year	0	1	2	3	4	5	6	Total
Senegal - Bakel		210	160	43	-	-	-	413
Construction	-	-	-	-	-	-	-	-
Materials/Equip.	251	150	51					452
	251	360	211	43				865
Mauritania								
- Gouraye		252	588	641	150			1,631
Materials/Equip.	153	228	248	63				692
Total for Gouraye	153	480	836	704	150			2,323
Kaedi								
Construction	-	113	548	594	254	-	-	1,509
Materials/Equip.	68	204	221	153	-	-	-	646
Total for Kaedi	68	317	769	747	754	-	-	2,155
Total for Mauritania	204	747	1,538	1,409	367	-	-	4,265

TABLE 10

CONSTRUCTION COST ESTIMATES FOR THE PODOR PERIMETER

	(CFA 10^3)	($ 1,000[1/])
Dike Construction		
Phase I	197,400	658.0
Phase II	197,400	658.0
Pumping Stations	83,000	276.7
Civil Engineering for pumping stations	96,000	320.0
Supplementary Equipment gates and siphoning	80,000	266.7
Power Plants	200,000	666.7
Network Infrastructure	486,400	1,621.3
Work Supervision	91,500	305.0
Studies for Construction Plan	20,000	66.7
Small Perimeters	165,500	551.7
Sub- Total :	1,617,200	5,390.8
Contingencies 10%	161,700	539
TOTAL :	1,778.900	5,930

1/ $1 = 300 CFA

TABLE 11

Illustrative Perimeter Development Costs under IDP

for PODOR

IDP YEAR	1	2	3	4	5	6	7	TOTAL
Area developed (gross ha)		45	247	371	400			1,063
Area under Production (net ha)			36	226	504	810		810
	000 of U.S. $							
Design	66.7							66.7
Dike		658			658			1,316
Power plant eqpt.		330		116				446
Power station const.		20.2	100	50	50			220.2
Pumping station eqpt.		244	168.7	130.7	72			543.4
Pumping station, const.		16	152	80	416.7			320
Canals, drains, roads			698	507	416.7			1,621.7
Village Perimeters		70	142	165	175			552
Sub total (1983 $)	66.7	1,338.2	1,260.7	1,048.7	1,371.7			5,086
Construct. supervision at 6%	4	80	76	63	82			305
Contingency at 10%	7	142	134	115	145			539
Sub total (1983 $)	77.7	1,560.2	1,470.7	1,222.7	1,599.4			5,930
Inflation multiplier (at 8% year)	1.08	1.17	1.26	1.36	1.47			
Total, adjusted for inflation.	84	1,825	1,853	1,663	2,351			7,776

Table 12

OPTIMAL PUMPING STATION OPERATION

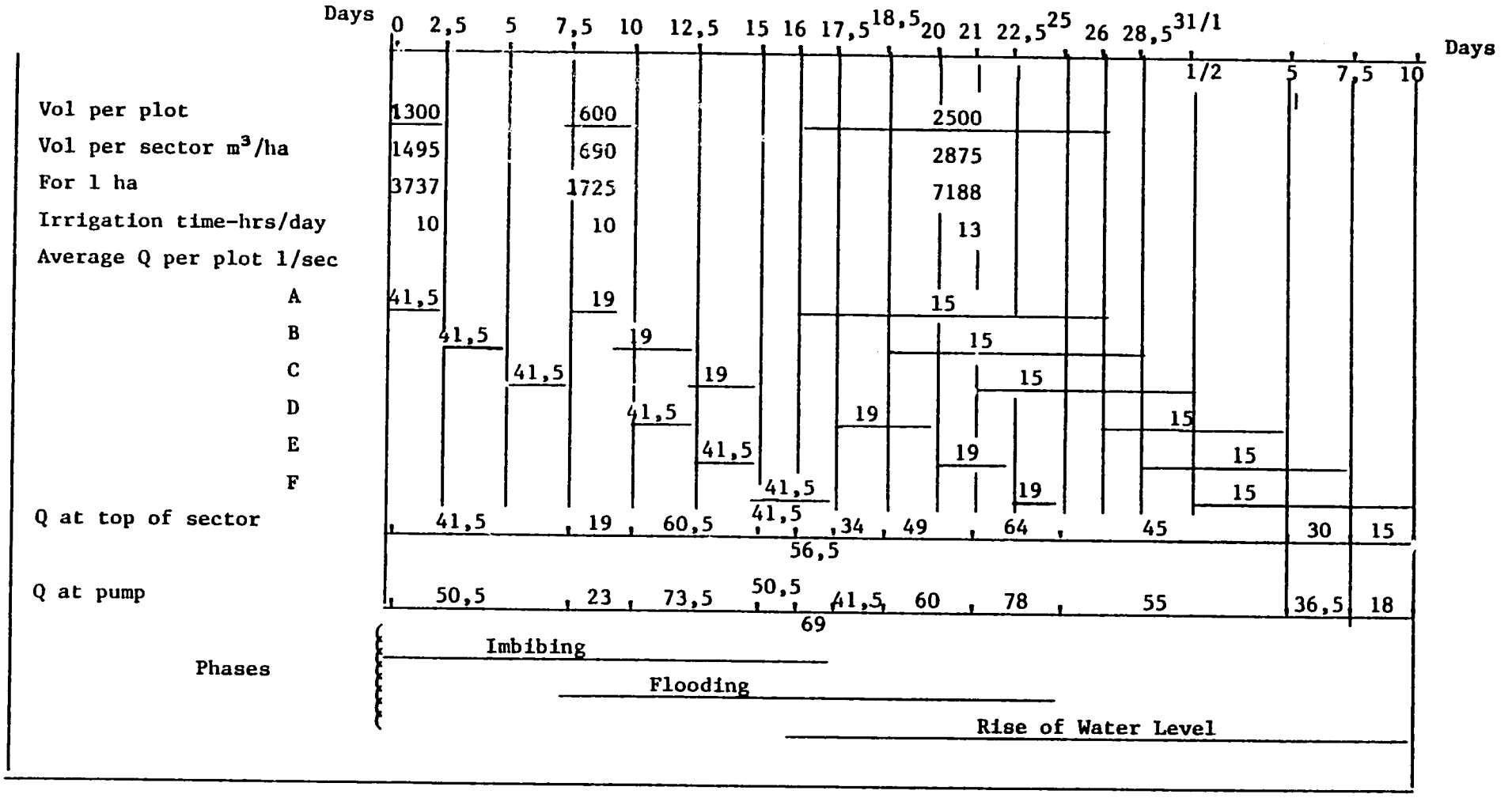


Table 13

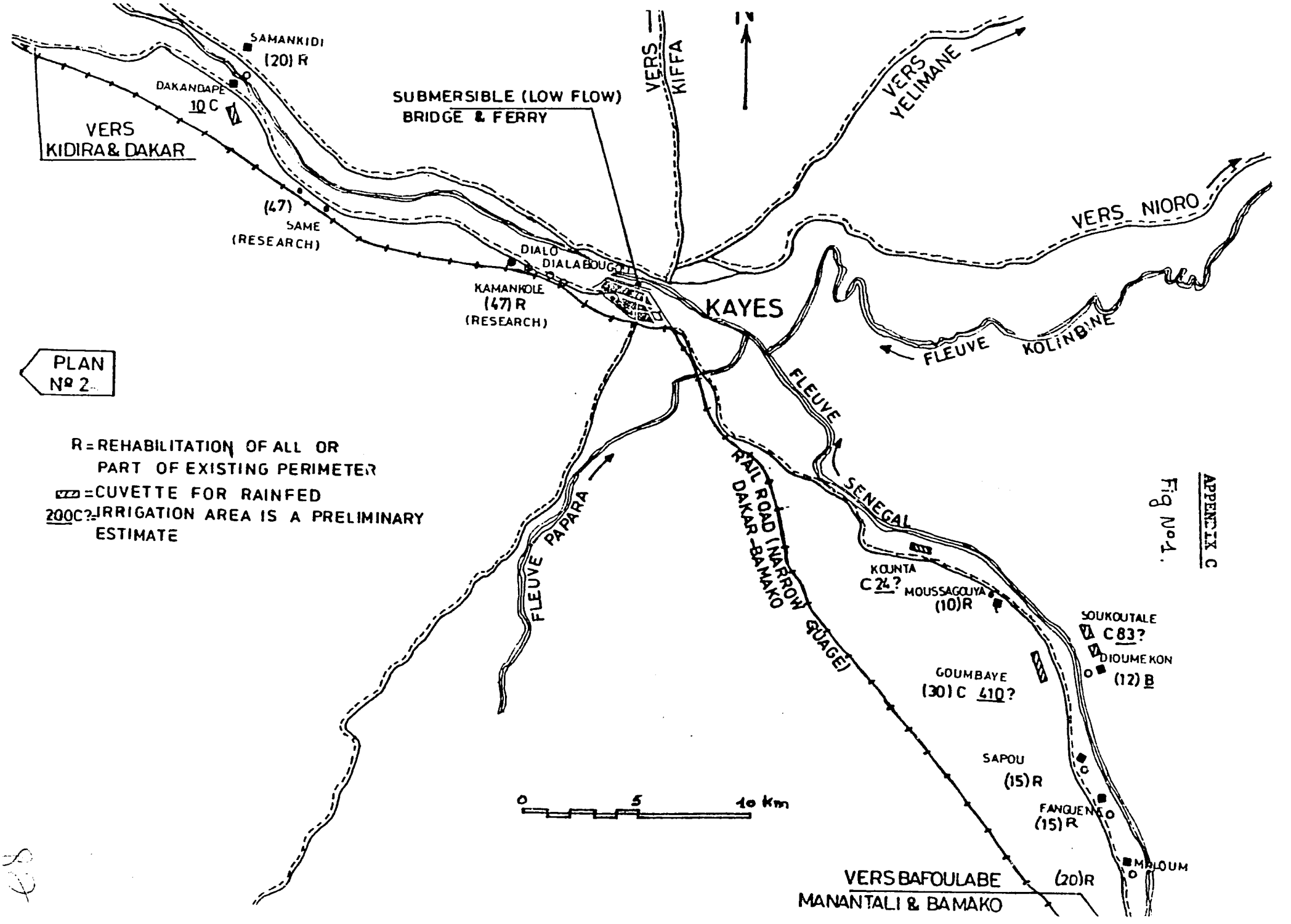
PROPOSED WORK PLAN FOR PERIMETER DEVELOPMENT UNDER IDP

for Podor Perimeter

Year	1	2	3	4	5	6	Notes
Dike 1	Design	Construction				Correct problems, improve existing perimeters, study for next phase.	
Small Perimeters (PIV)		Design & Construction (45 ha)	Design & Construction (100 ha)	Design & Construction (110 ha)	Design & Construction (128 ha)		At year 4 study the possibility and design necessary to convert PIV's to medium system (300 ha)
Pump Station and C1		Design, order equipment	Construction (147 ha)	(147 ha)			
E1		Design, order equipment	Construction equipment				
Pump Station and M1			Design, order equipment	Construction equipment (107 ha)	(107 ha)		
Pump Station and C2				Design, order equipment	Construction (173 ha)equip.		
Power plant C1 + C2 + M1 and E1		Design all order equip. for C, E1, M1	Construction equipment C1 + E1.	Construction & equip. M1 Order equip. C2	Construction & equipment C2		
Infrastructure		PIV	PIV - C1 E1	PIV - C1 E1 - M1	PIV - M1 C2		
Area		45	247	364	408		
Accumulated area		45	292	656	1,063		

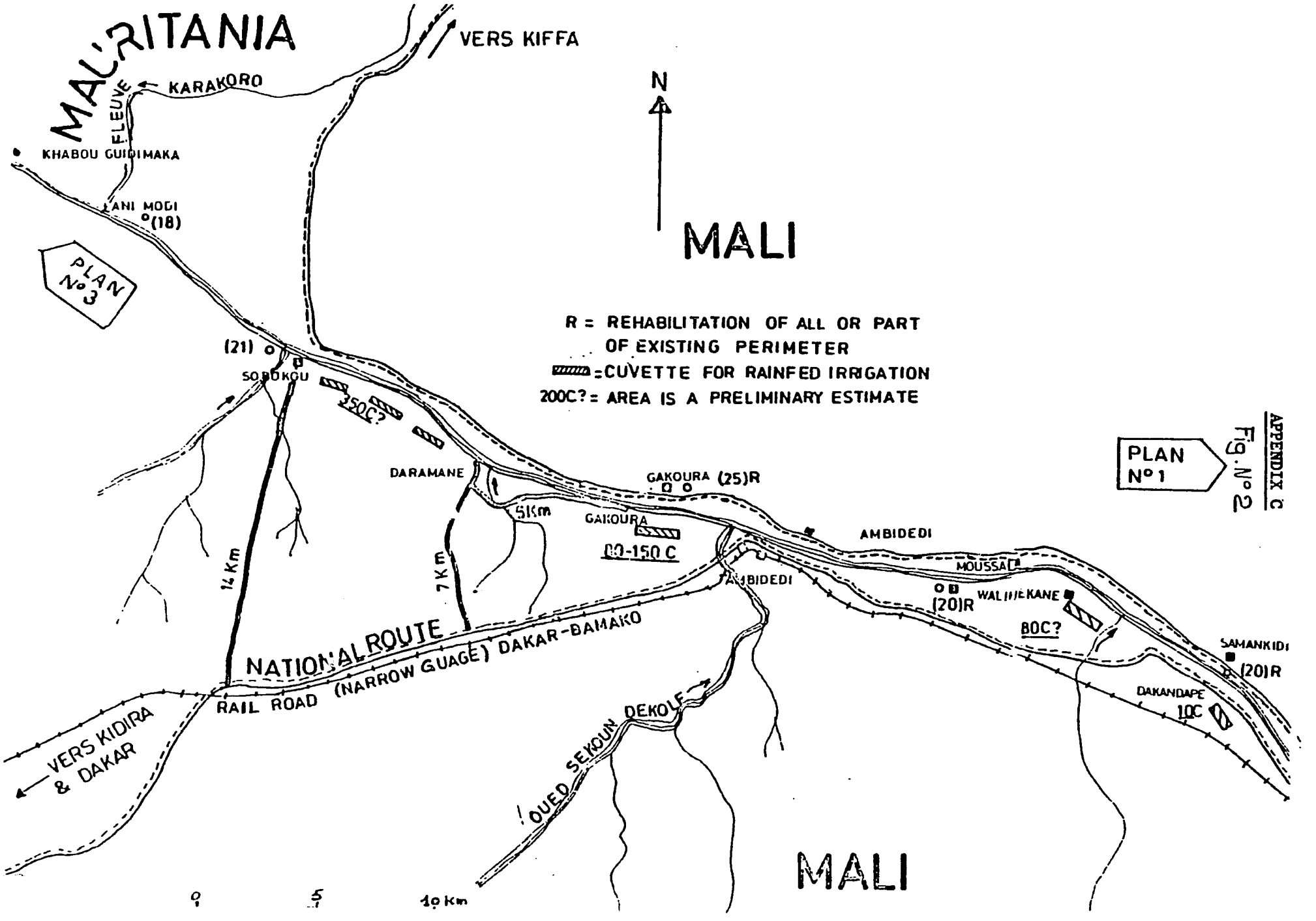
P L A N S

LEGEND		LEGENDE
EXISTING		**Actuel**
RIVER		FLEUVE
PAVED ROAD		ROUTE BITUMEE
(UNPAVED) ROAD		ROUTE AMENAGEE
EXISTING PERIMETER(S) AND AREA (Ha)	o (14)	PERIMETRE(S) EXISTANT(S) ET SUPERFICIE (Ha)
PROPOSED		**PROPOSE**
FEEDER ROAD		PISTE DE PRODUCTION
FEEDER ROAD IN FLOOD ZONE		PISTE DE PRODUCTION EN ZONE D'INONDATION
PROPOSED PERIMETER(S) AND AREA (Ha)	20	PERIMETRE(S) PROPOSE(S) ET SUPERFICIE(Ha)



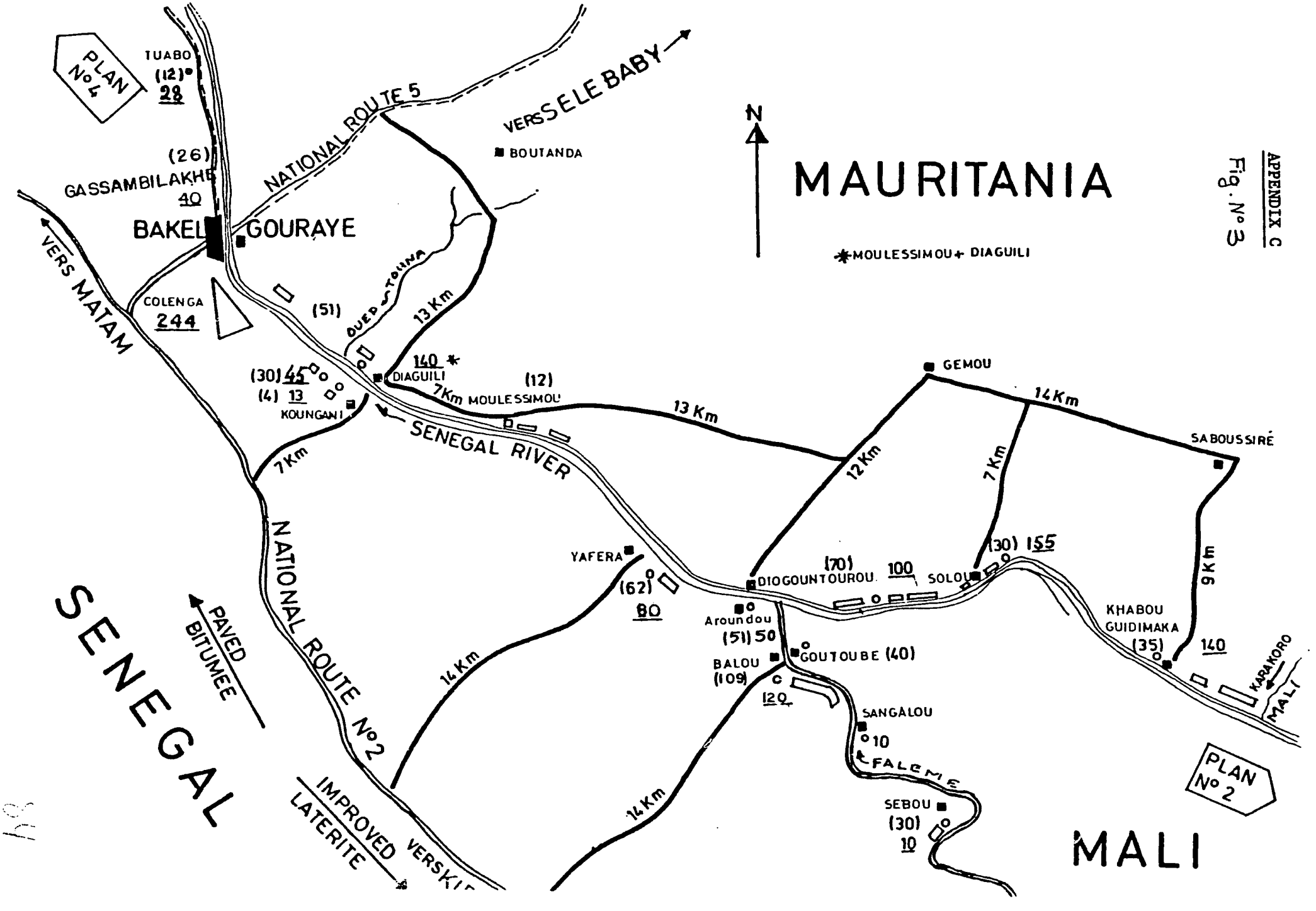
APPENDIX C

Fig No 1.


MAURITANIA
VERS KIFFA
KARAKORO
FLEUVE
KHABOU GUIDIMAKA
LANI MODI
(18)
PLAN No 3
N
MALI
R = REHABILITATION OF ALL OR PART OF EXISTING PERIMETER
= CUVETTE FOR RAINFED IRRIGATION
200C? = AREA IS A PRELIMINARY ESTIMATE
(21)
SOBOKOU
350C?
DARAMANE
GAKOURA (25)R
5Km
GAKOURA
00-150 C
AMBIDEDI
MOUSSA
(20)R
WALIMEKANE
80C?
SAMANKIDI
(20)R
DAKANDAPE
10C
PLAN No 1
APPENDIX C
Fig. N° 2
14 Km
7 Km
NATIONAL ROUTE
RAIL ROAD (NARROW GUAGE) DAKAR-BAMAKO
VERS KIDIRA & DAKAR
OUED SEKOUN DEKOLE
MALI
0
5
10 Km

APPENDIX C

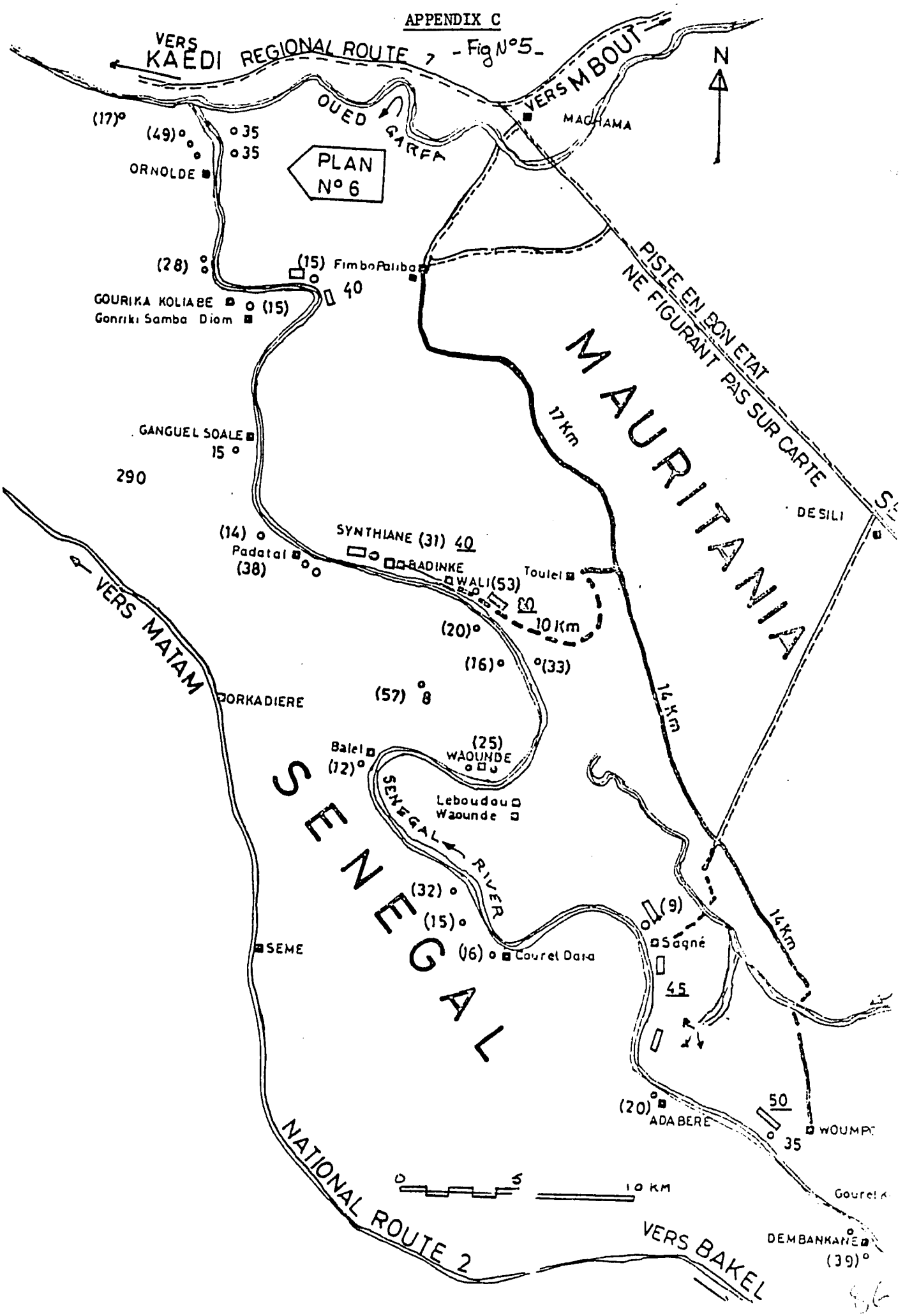
Fig. N° 3



APPENDIX C

Fig. N°4

APPENDIX C


VERS KAEDI
REGIONAL ROUTE 7
- Fig N°5 -
VERS MBOUT
N
OUED GARFA
MACHAMA
PLAN N° 6
ORNOLDE
(17)°
(49)°
35
35
(28)
(15) Fimbo Paliba
40
GOURIKA KOLIABE
Gonriki Samba Diom
(15)
PISTE EN BON ETAT NE FIGURANT PAS SUR CARTE
MAURITANIA
17 Km
GANGUEL SOALE
15
290
DESILI
(14)
Padatal
(38)
SYNTHIANE (31) 40
BADINKE
WALI (53)
Toulel
10 Km
(20)°
(16)°
(33)
VERS MATAM
PORKADIERE
(57) 8
14 Km
Balel
(12)°
(25)
WAOUNDE
Leboudou
Waounde
SENEGAL
SENEGAL RIVER
(32)
(15)
(9)
Sagné
SEME
(16)
Courel Data
45
14 Km
(20)
ADABERE
50
35
WOUMPE
0
5
10 KM
Gourel K
NATIONAL ROUTE 2
VERS BAKEL
DEMBANKANE
(39)°

APPENDIX C

Fig. N°6

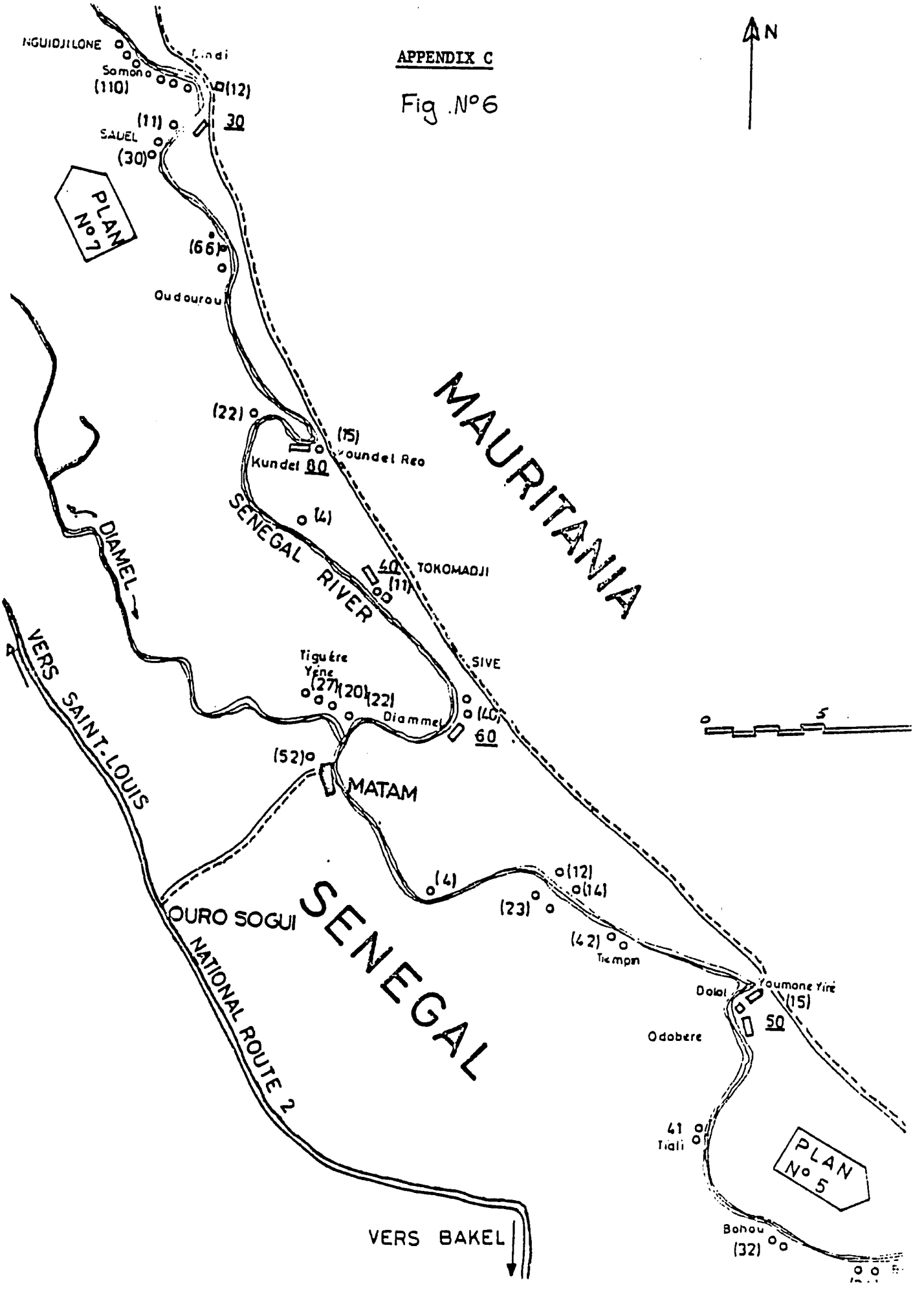
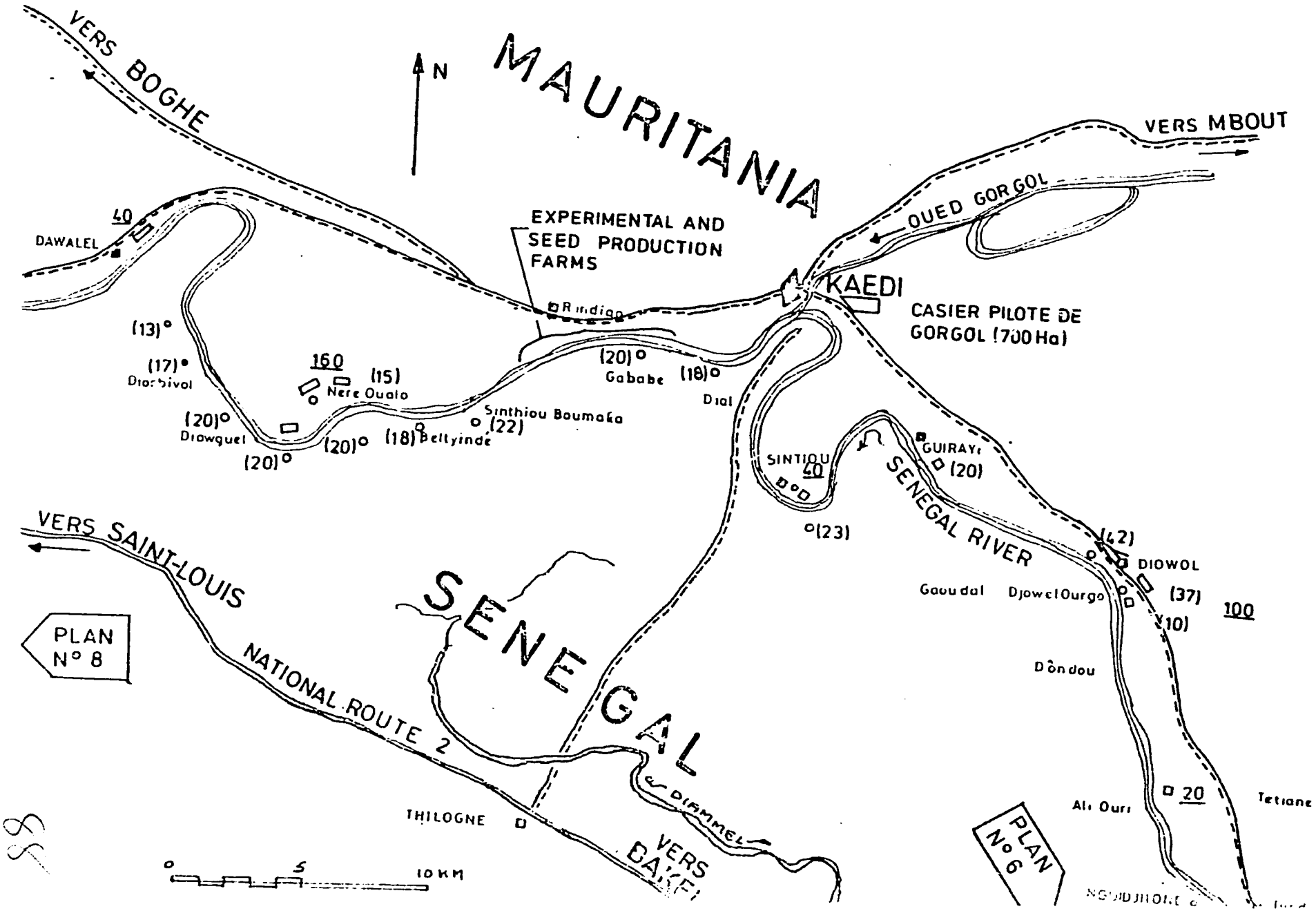
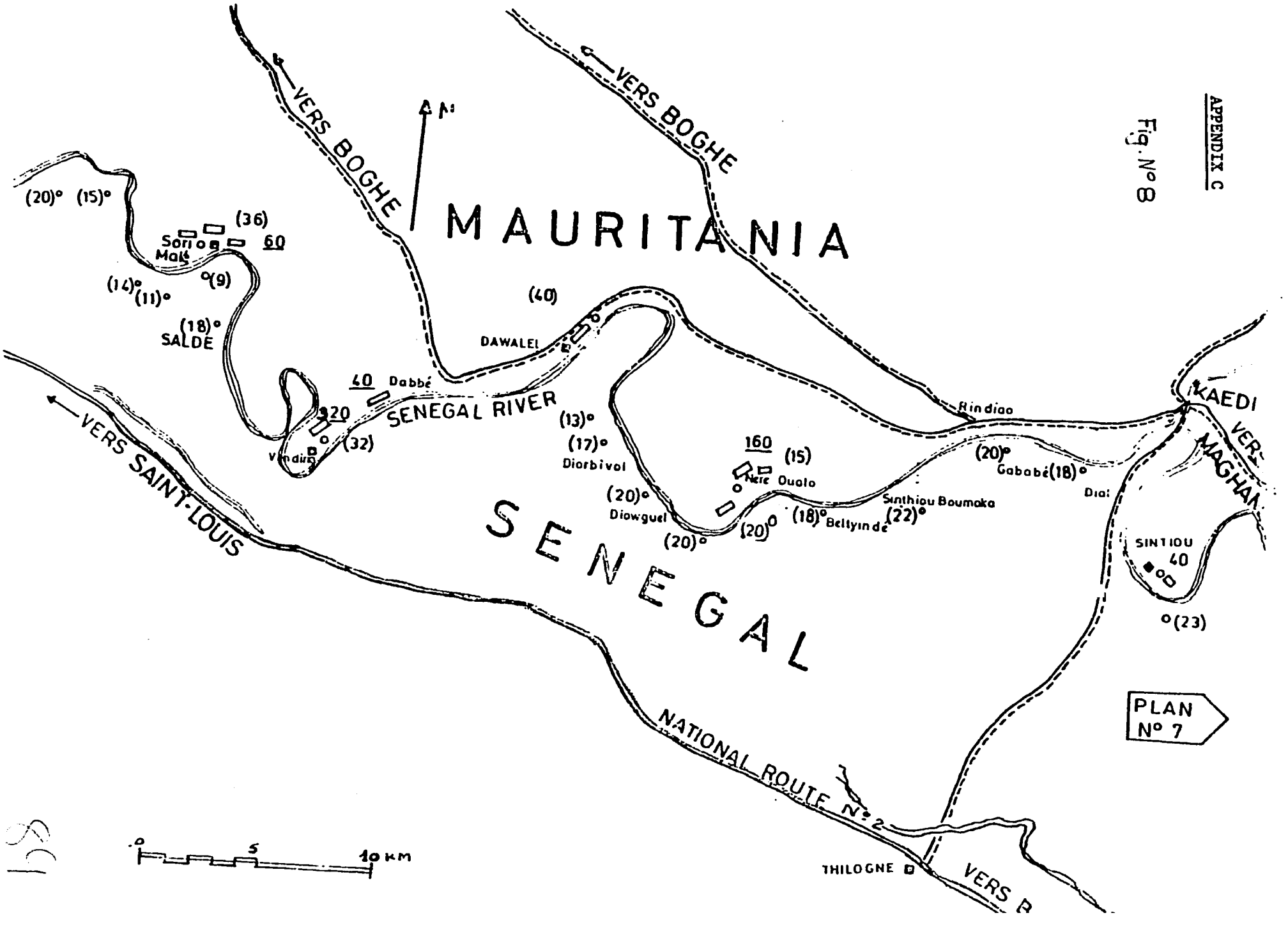


Fig. No 7.


VERS BOGHE
N
MAURITANIA
VERS MBOUT
OUED GORGOL
EXPERIMENTAL AND
SEED PRODUCTION
FARMS
KAEDI
CASIER PILOTE DE
GORGOL (700 Ha)
DAWALEL
40
Rindiga
(13)
(17)
Diorbivol
160
(15)
Nere Oualo
(20)
Gababe
(18)
Dial
Sinthiou Boumaka
(22)
(20)
Drawguel
(20)
(18)
Bellyinde
(20)
SINTIOU
40
GUIRAYE
(20)
(23)
SENEGAL RIVER
(42)
DIOWOL
Gaoudal
Djowel Ourgo
(37)
(10)
100
Dondou
SENEGAL
VERS SAINT-LOUIS
PLAN
N° 8
NATIONAL ROUTE 2
THILOGNE
VERS
BAKEL
0
5
10 KM
Ali Ouri
20
Tetiane
PLAN
N° 6

APPENDIX C

Fig. N° 8



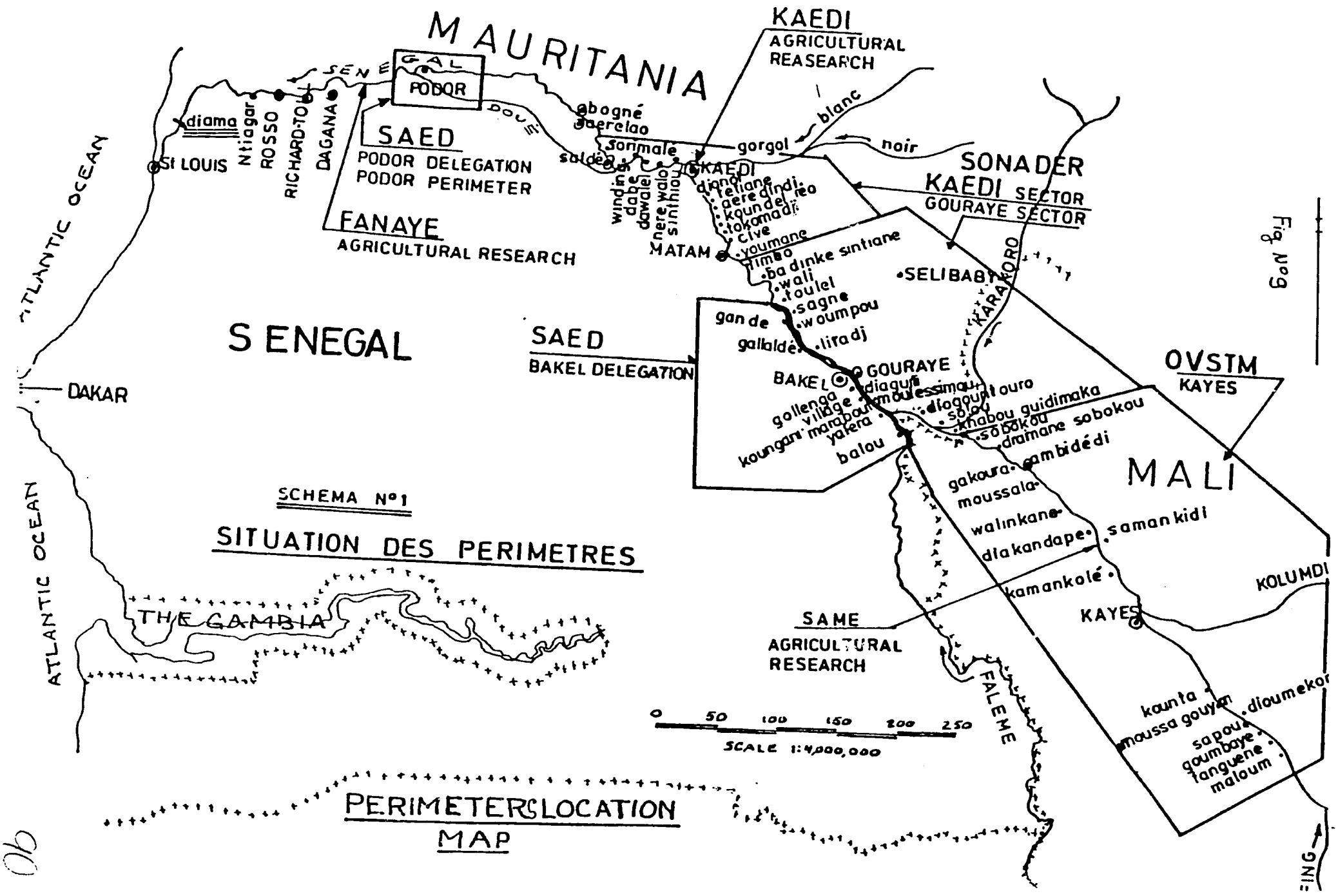

MAURITANIA
SENEGAL
PODOR
SAED
PODOR DELEGATION
PODOR PERIMETER
FANAYE
AGRICULTURAL RESEARCH
KAEDI
AGRICULTURAL
REASEARCH
SONADER
KAEDI SECTOR
GOURAYE SECTOR
SAED
BAKEL DELEGATION
OVSTM
KAYES
SAME
AGRICULTURAL
RESEARCH
MALI
SENEGAL
THE GAMBIA
ATLANTIC OCEAN
DAKAR
St LOUIS
Ntiagar
ROSSO
RICHARD-TOLL
DAGANA
diama
MATAM
SELIBABY
BAKEL
GOURAYE
KAYES
KOLUMDI
FALEME
KARAKORO
blanc
noir
gorgol
SCHEMA N°1
SITUATION DES PERIMETRES
0 50 100 150 200 250
SCALE 1:4,000,000
PERIMETERS LOCATION
MAP

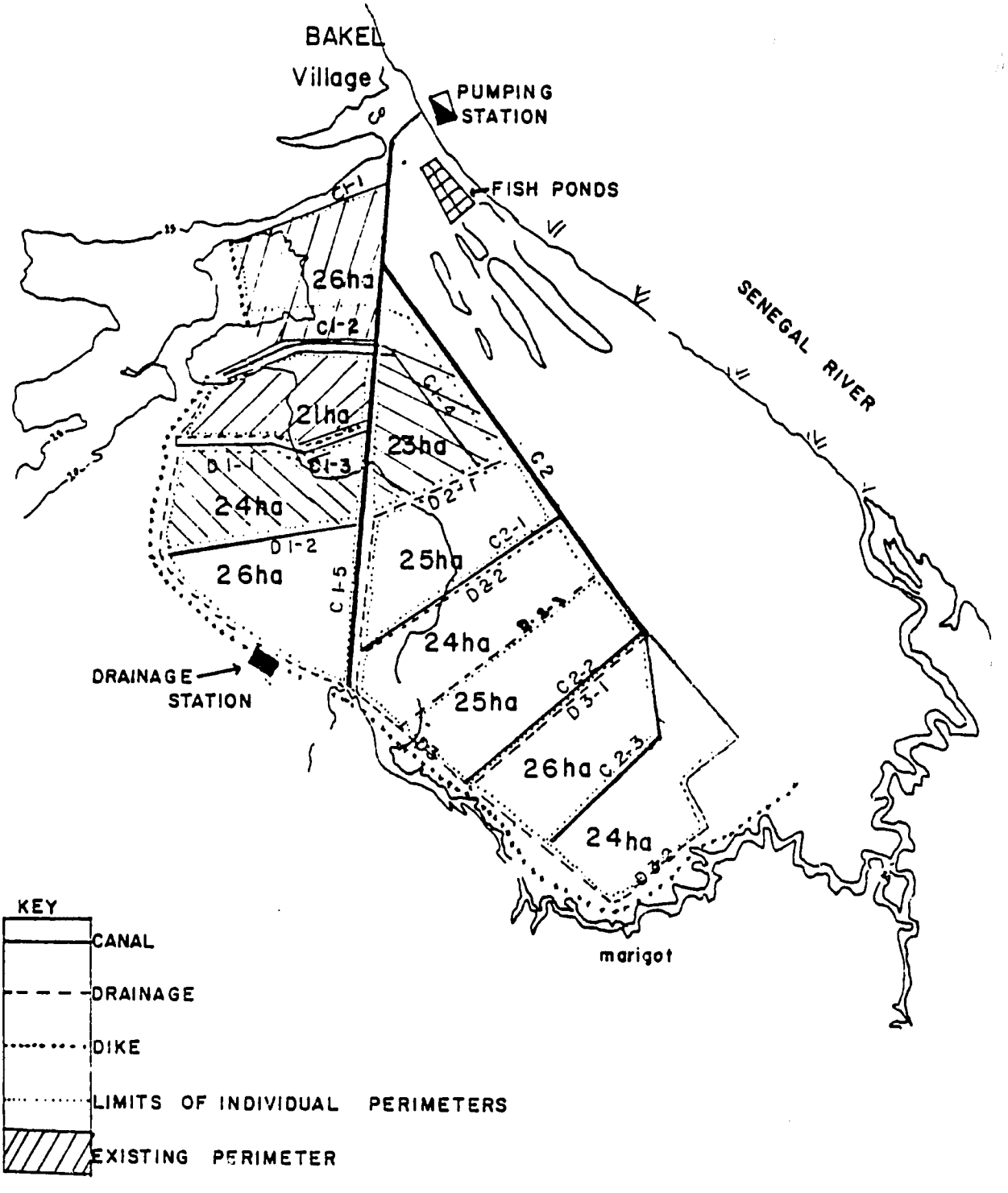
Fig No 9

90

COLLENGA PERIMETER
BAKEL

APPENDIX C

Fig N°10



Appendix D.1

Figure 1..

Irrigation Scheme for Rice and Mixed Crop Cultivation

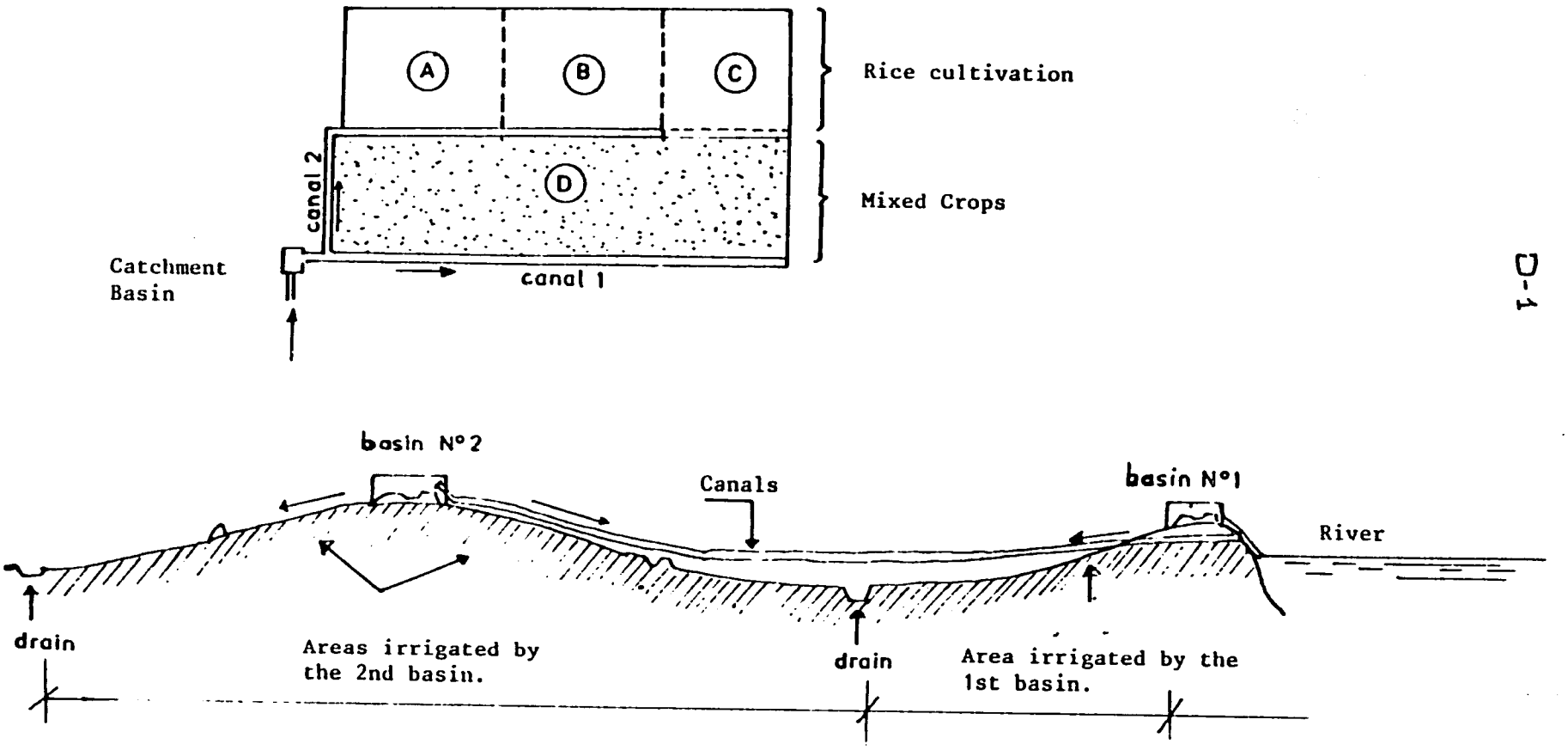
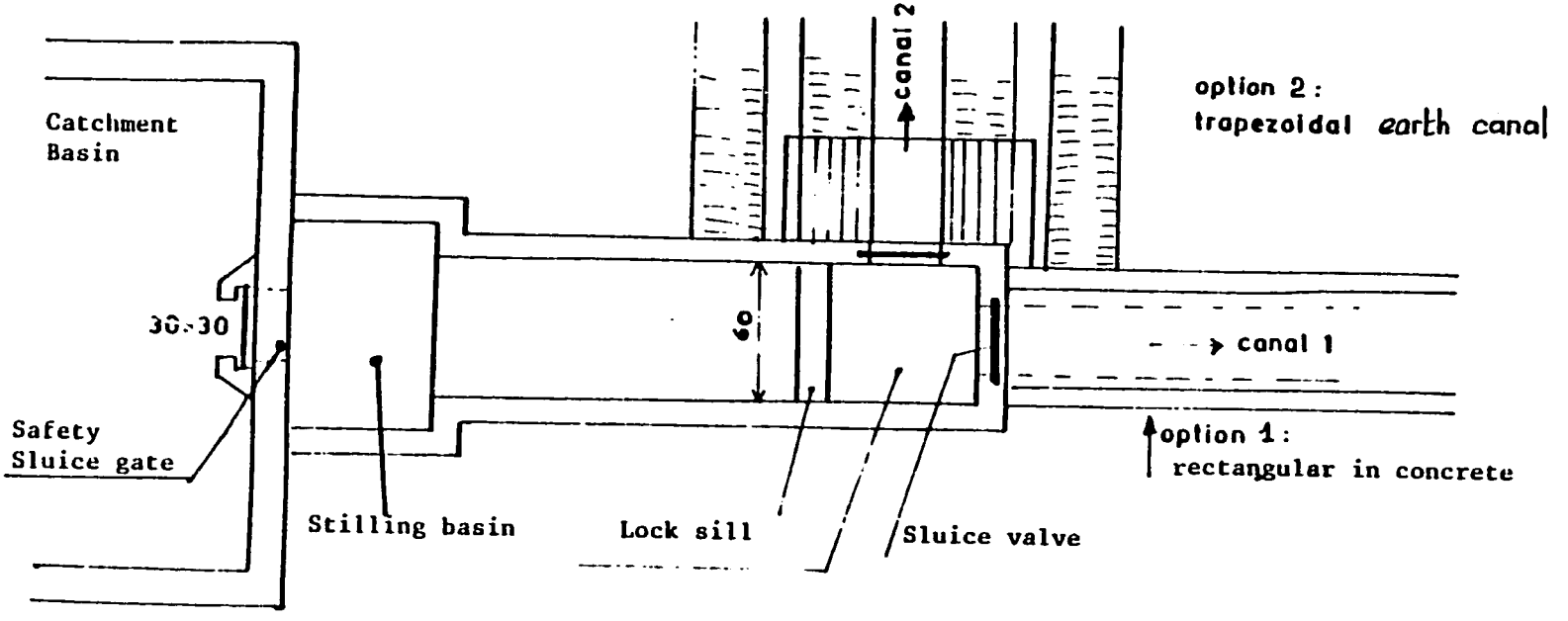


Figure 2

SKETCH MODEL OF IRRIGATION CANALS FOR PERIMETERS



IRRIGATION CANALS PROFILE

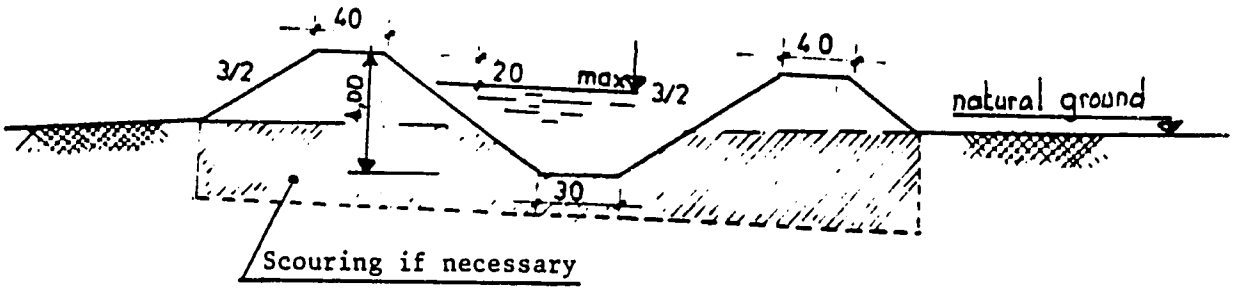


Figure 3.

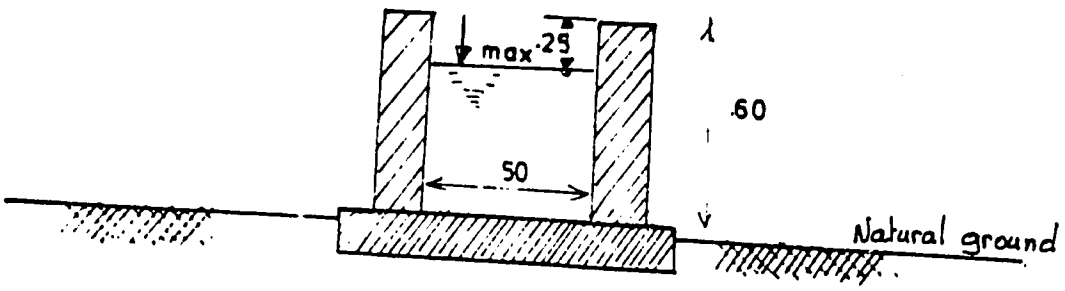


Figure 4.

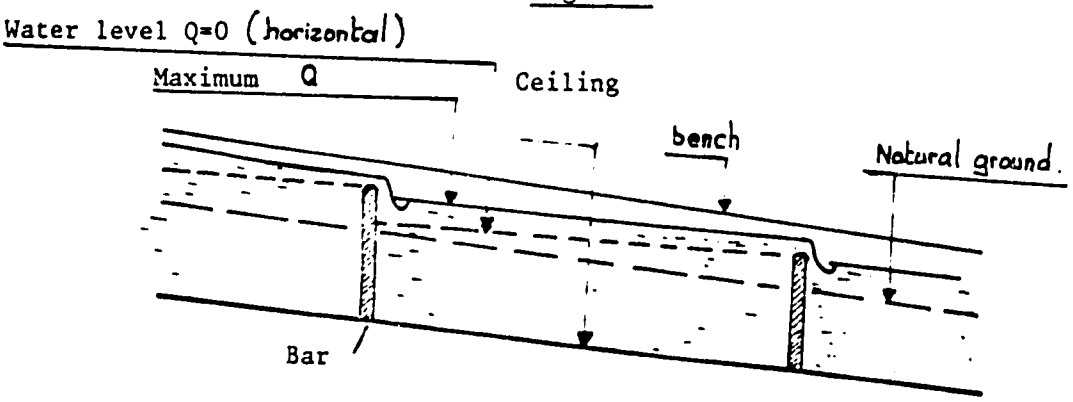


Figure 5.

Figure 6.

IRRIGATION CANAL PROFILES

Maximum and minimum water levels

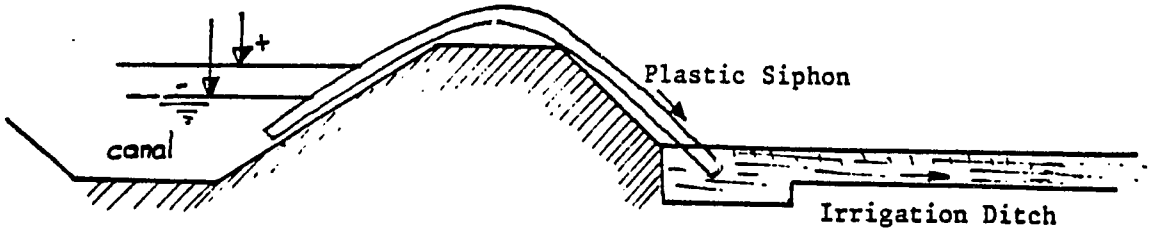


Figure 6.

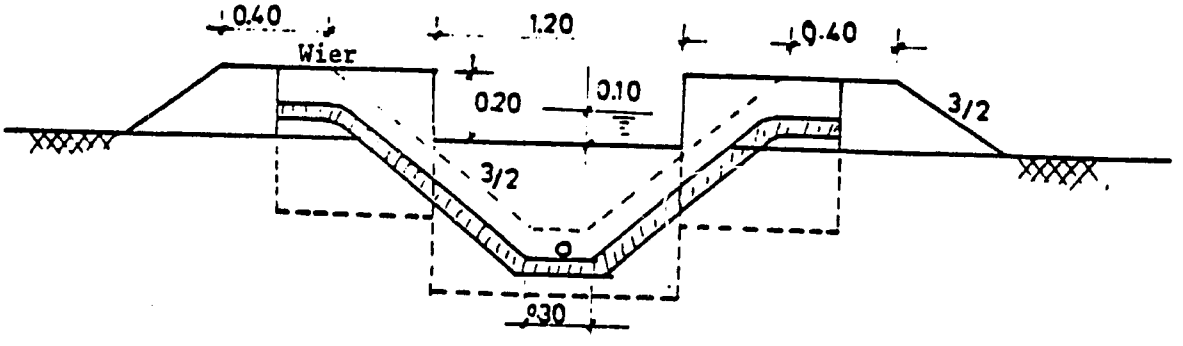


Figure 7.

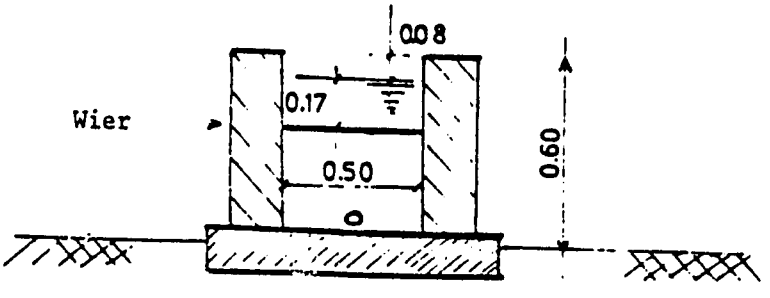
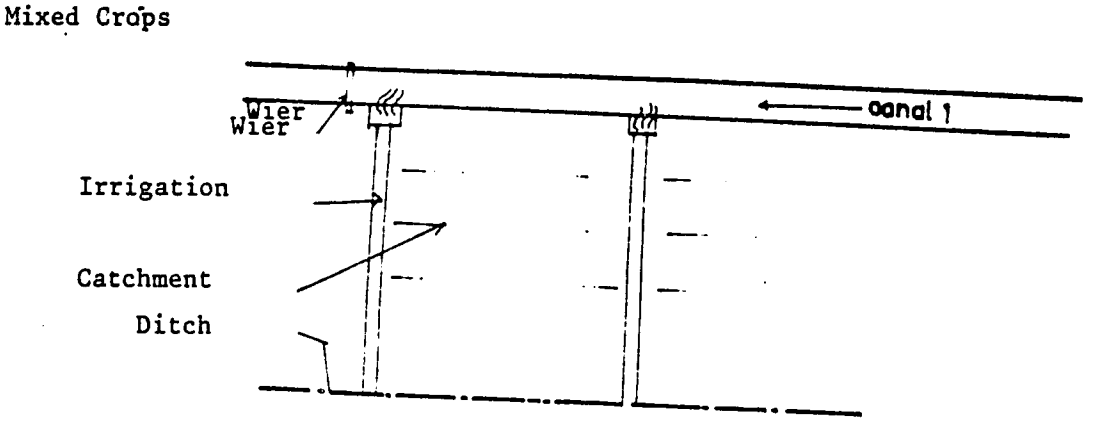


Figure 8.

Figure 9

IRRIGATED PERIMETER: MIXED CROPS



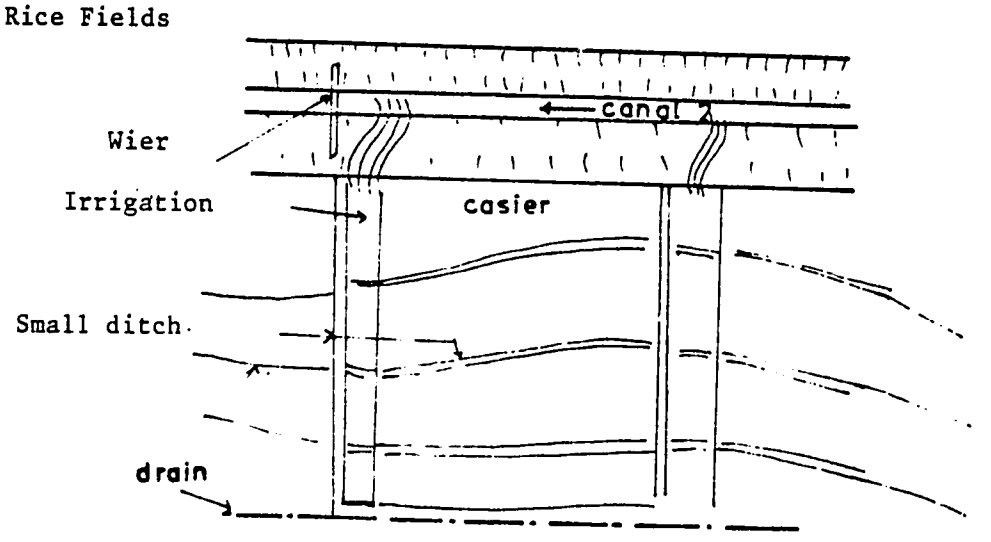


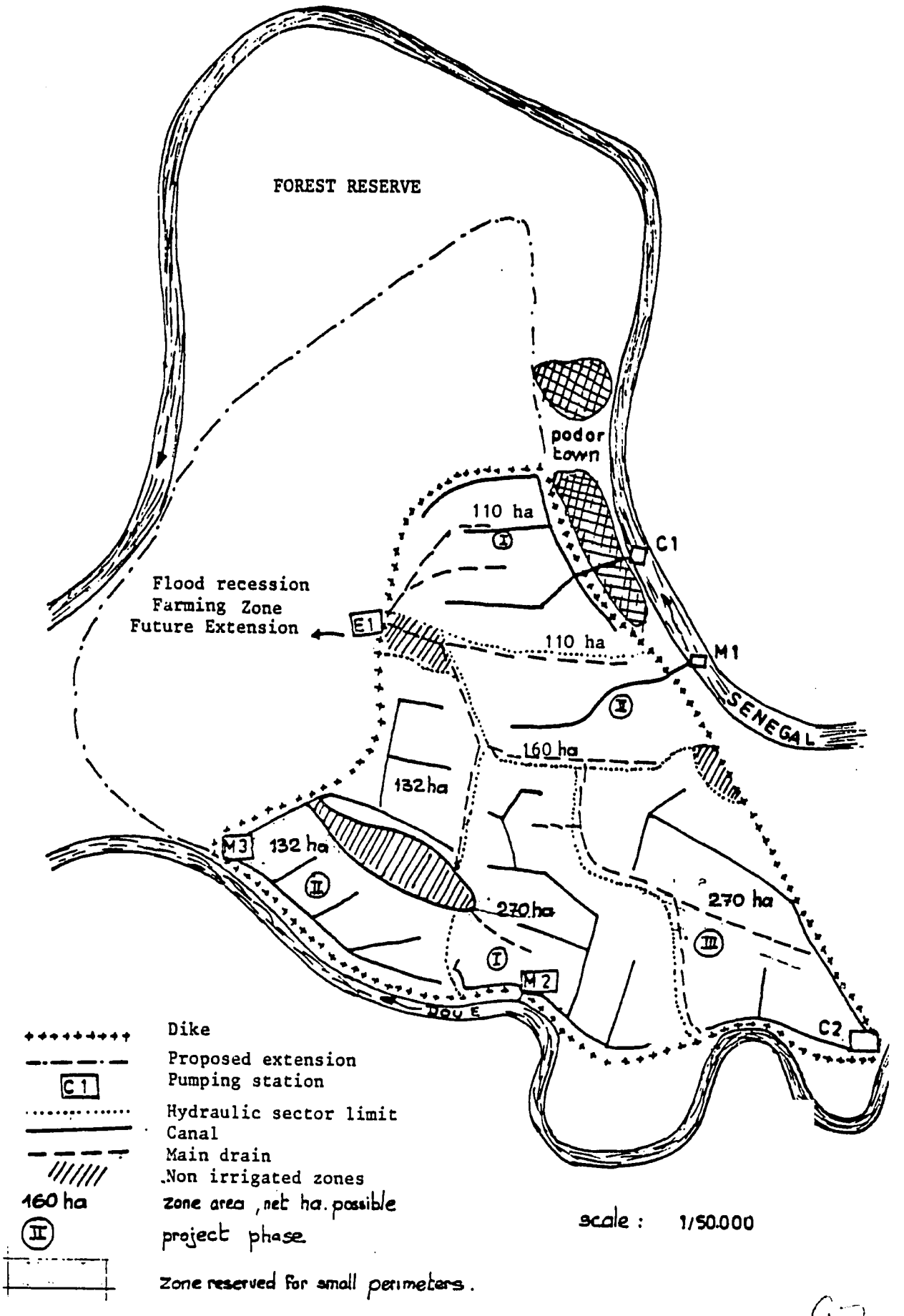
Figure 10

IRRIGATED PERIMETER: RICE FIELDS

Figure 11.

D - 6

PODOR PERIMETER



97

Figure 12

STANDARD CANAL RIGHT OF WAY

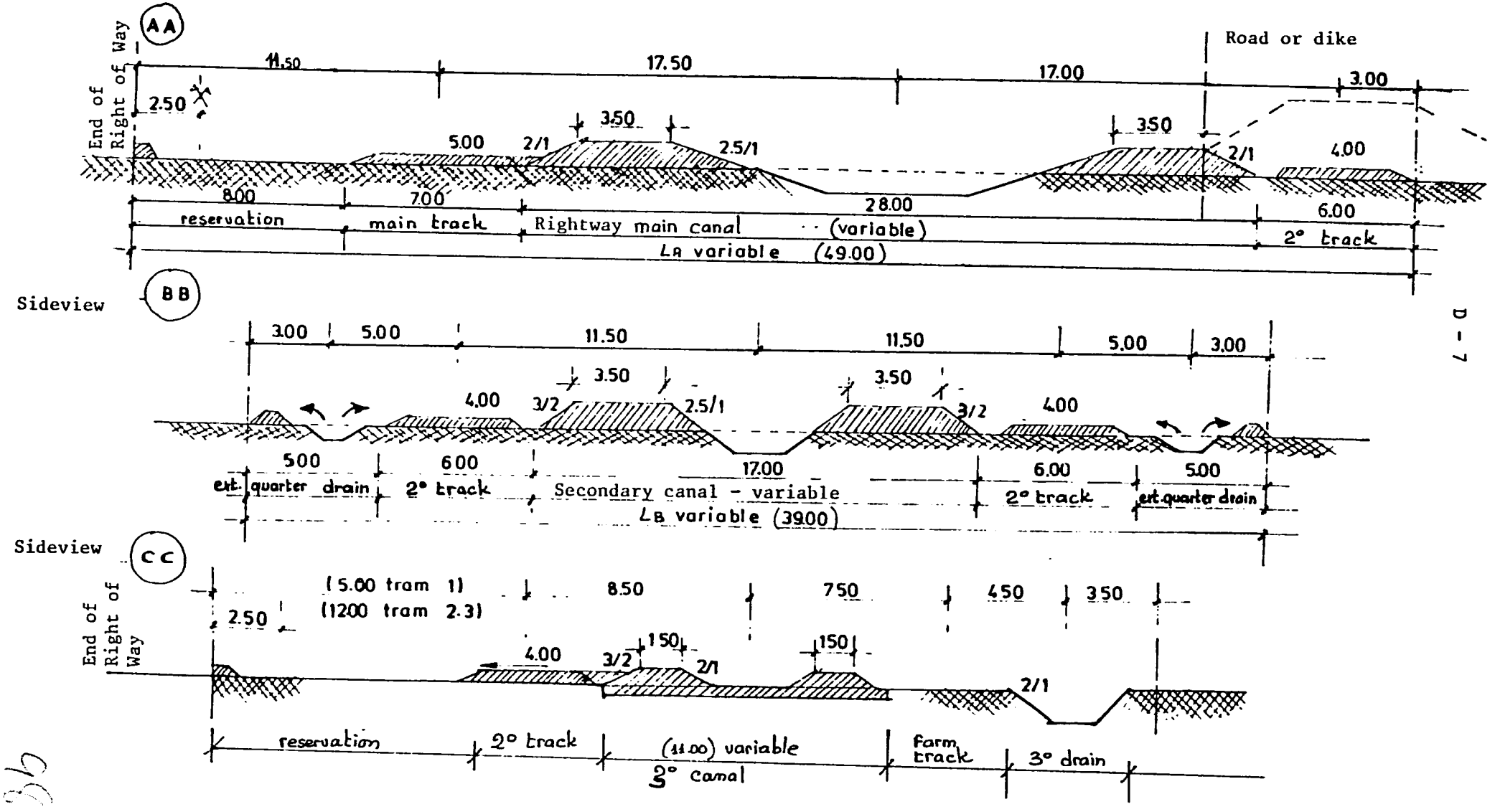


Figure 13.

HYDRAULIC WORK SCONDARY/TERTIARY CANALS

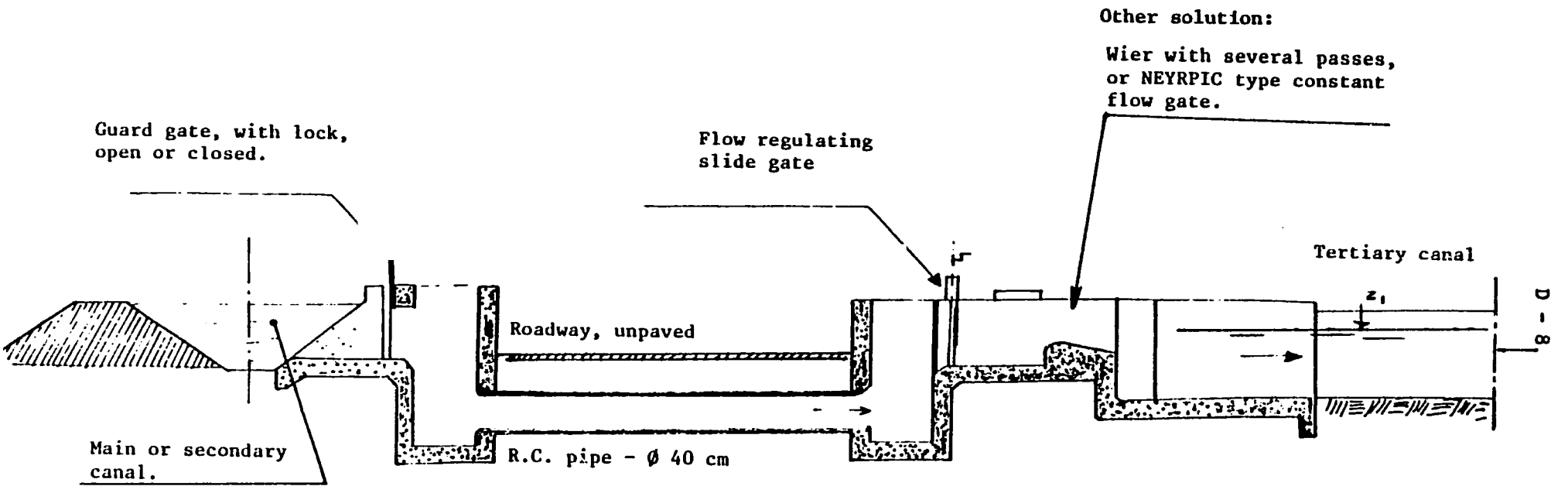


Figure 14.

INTAKE PUMPING STATION

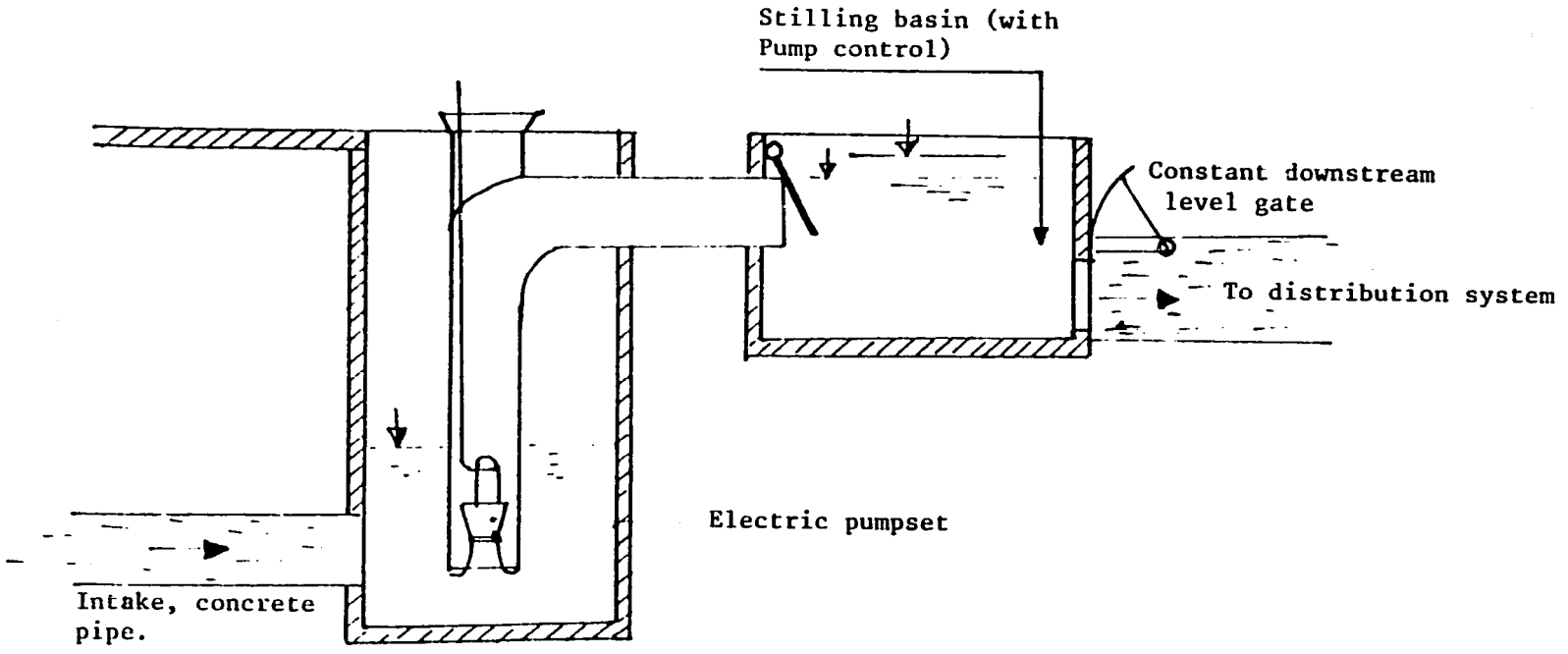
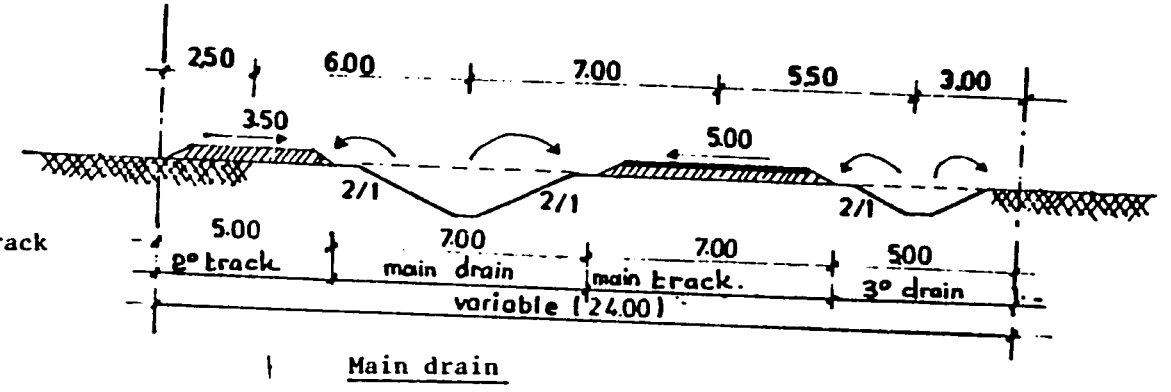


Figure 15.

STANDARD DRAINAGE RIGHTS-OF-WAY

Sideview (1)



Sideview (2)

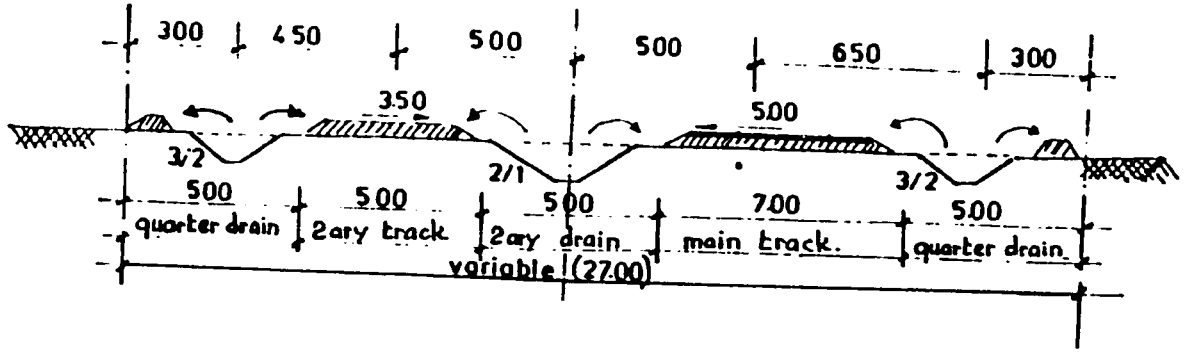


Figure 16.

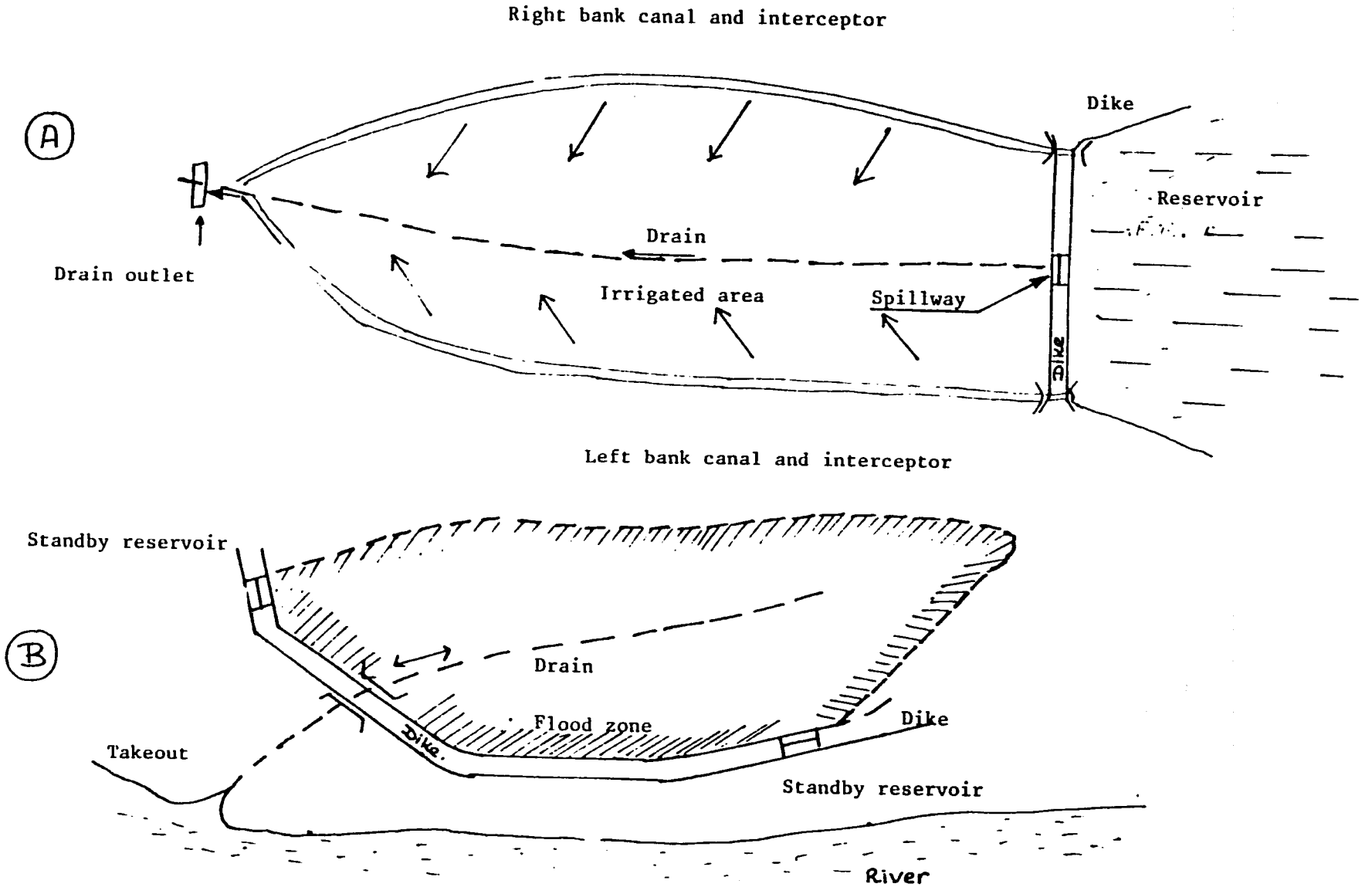

Right bank canal and interceptor
A
Dike
Reservoir
Drain
Drain outlet
Irrigated area
Spillway
Dike
Left bank canal and interceptor
Standby reservoir
B
Drain
Flood zone
Dike
Takeout
Dike
Standby reservoir
River

Figure 17

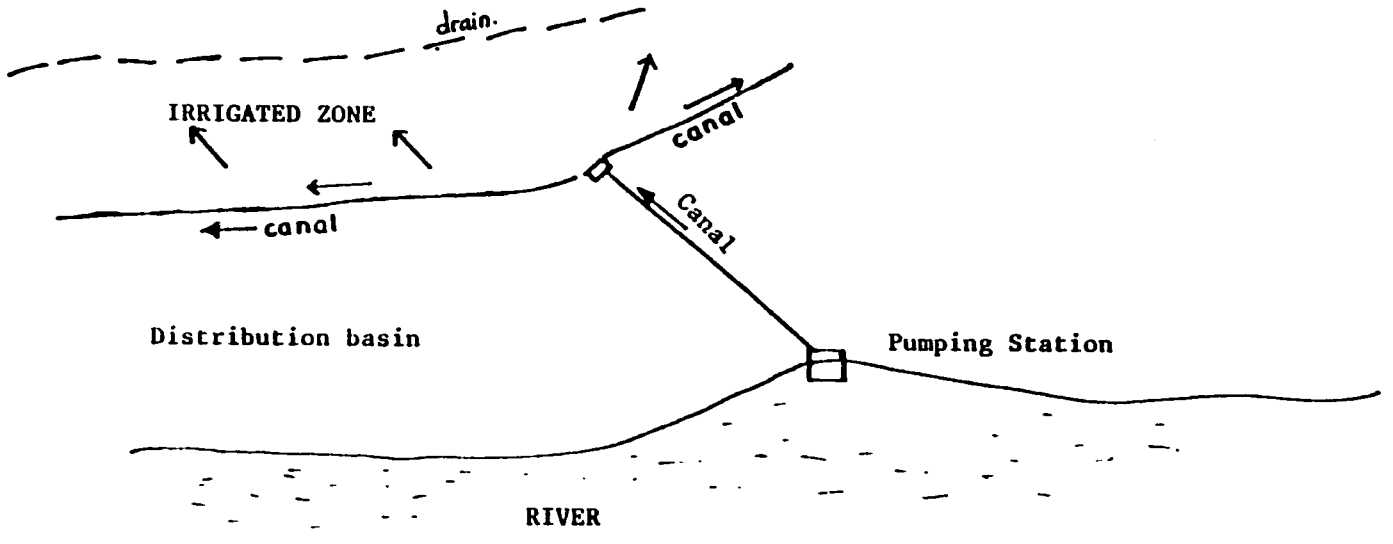
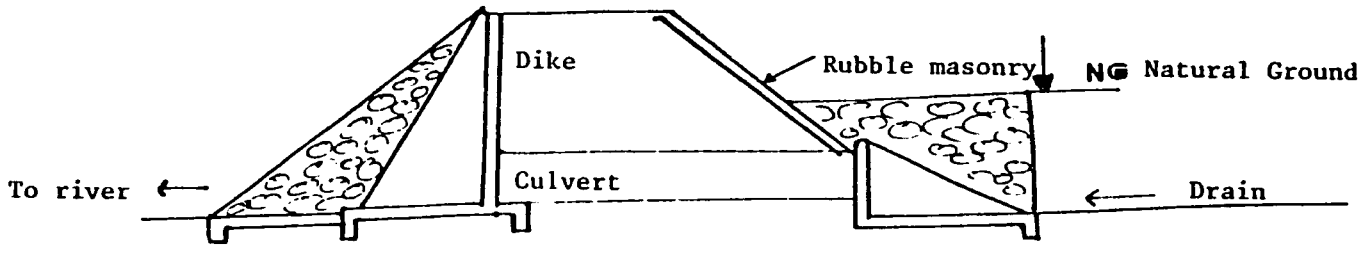

drain.
IRRIGATED ZONE
canal
canal
Canal
Distribution basin
Pumping Station
RIVER

Figure 18



SCHEMA N° 55

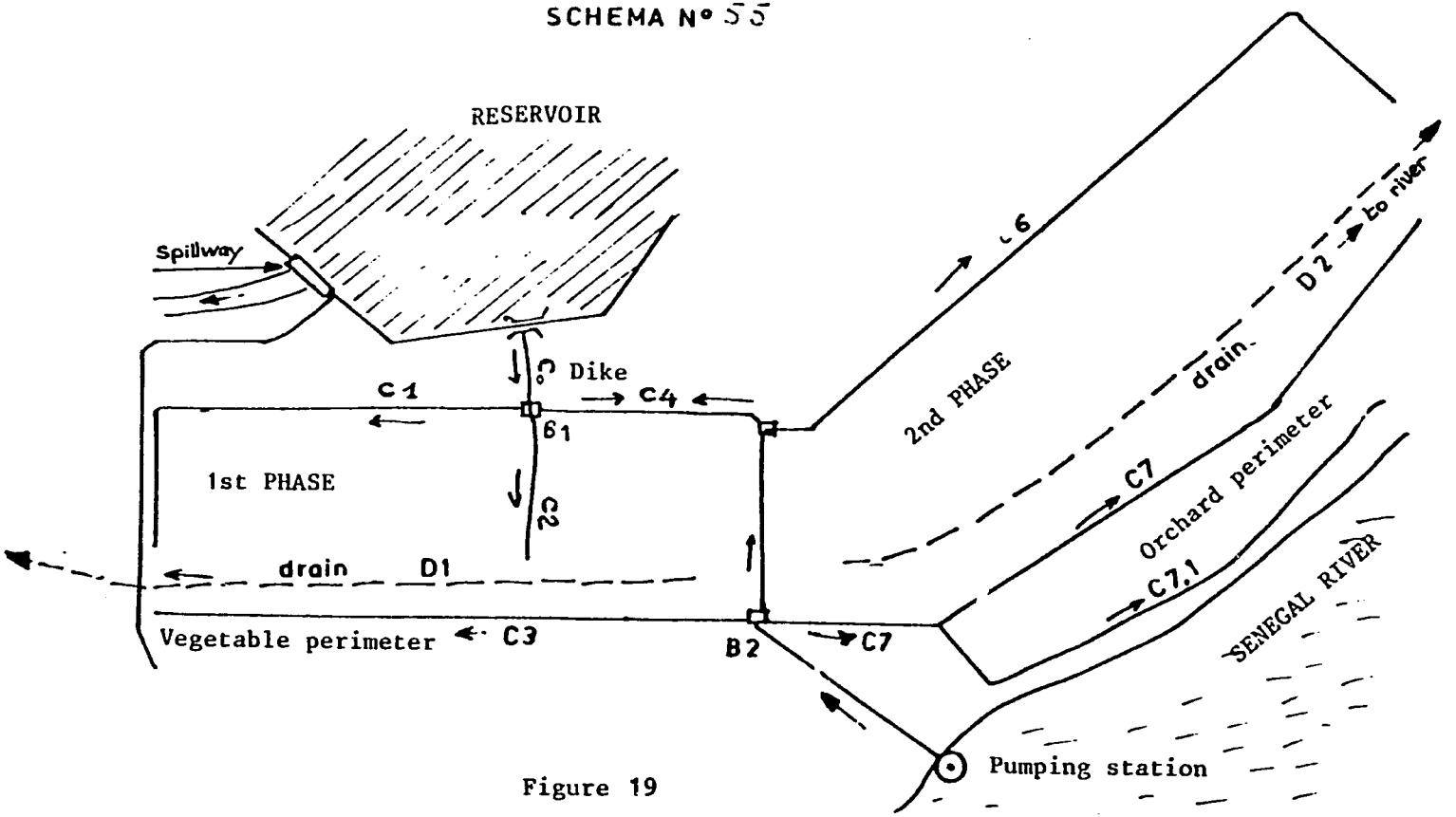
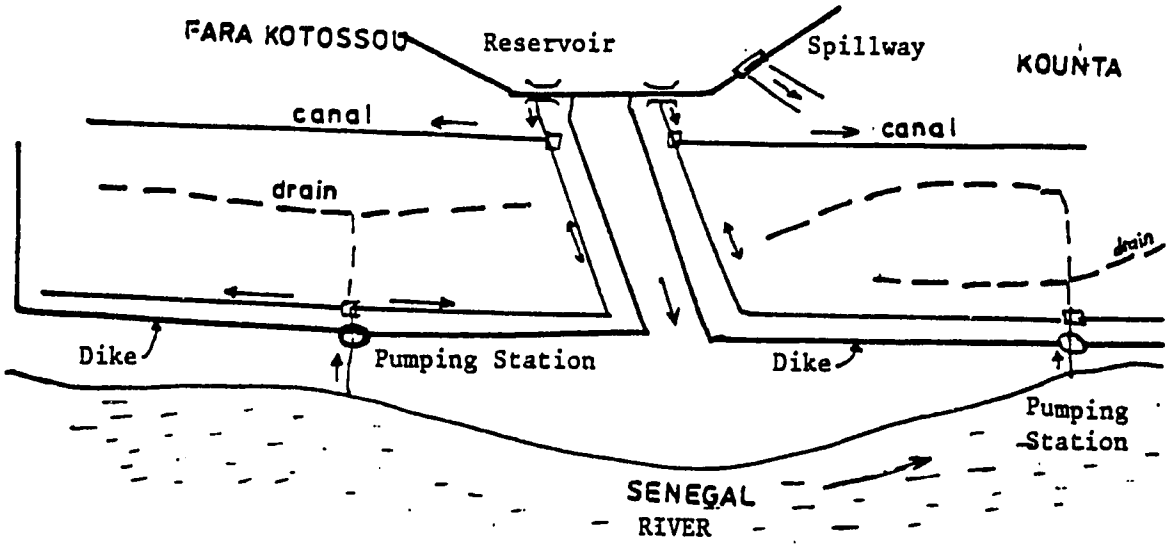
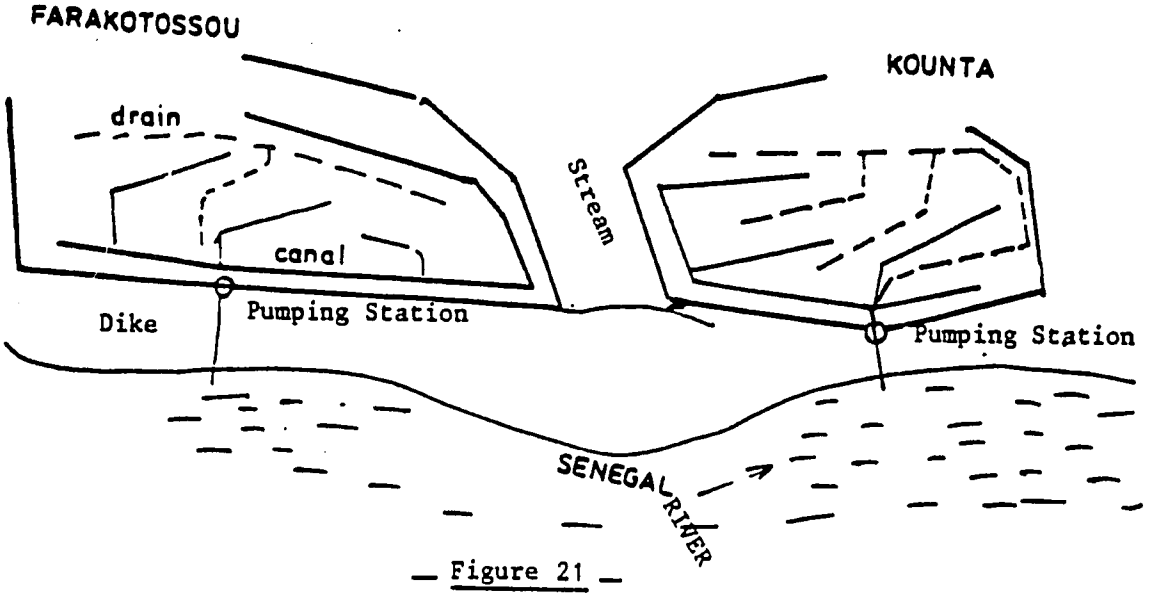


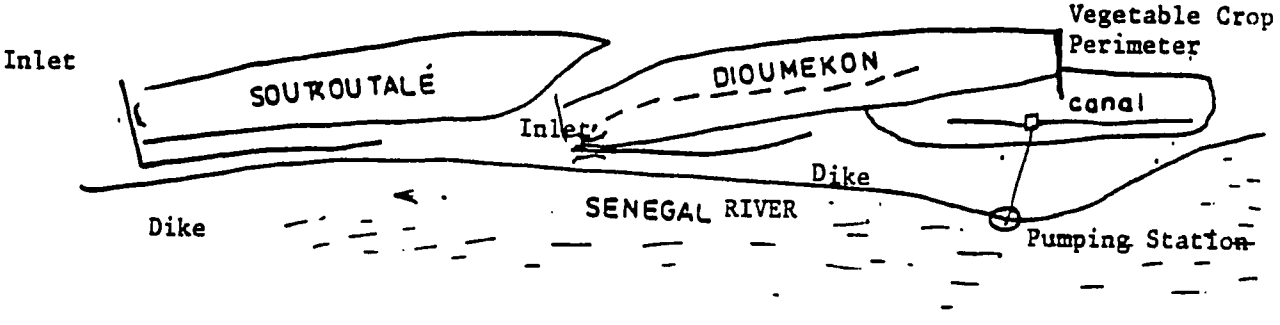
Figure 19



— Figure 20 —



— Figure 21 —



— Figure 22 —

Checklist for Preparation of Construction Site Plans

A. Land Information

Topographic Map - project area
(1:10,000 - 1:25,000 scale, 2 - 3m contours);

Detailed Soil Map - project area
(1:5,000 - 1:10,000 scale - soil families and soil series);

Refined bedrock geology map - project area

Expanded soil survey data - project area (physical components - slope, texture, structure, infiltration tests; chemical components - PH, ratio exchange capacity, electrical conductivity, sodium absorption ratio and amount of organic matter;

Natural drainage data - project area
(patterns, depth, rates);

Plan for monitoring soil changes.

B. Climate

Record of maximum minimum temperature - at project site;

Record of precipitation at project site;

Record of hours of sunlight at project site;

Record of evaporation, Class A pan at project site;

Record of hours and direction of wind at project site;

Record of relative humidity at project site;

C. Water

Map of project water resources;

Ground water map of project area;

Continued data on standing volume or surface flows;

Amount of sedimentation in surface sources:

____Continue water quality test data;

____Plan for monitoring post-project water quality.

D. Agriculture

____Crop water requirements for proposed crops;

____Water volume calculations for conveyance structures;

____Plan for pilot or demonstration farms;

____Estimates of area of cropland to be irrigated;

____Preliminary agriculture extension plans;

____Potential crop rotations;

____Plan for water distribution and management (water users associations);

____Plan for integrated pest management.

E. Public Health

____Design criteria for irrigation structures to minimize health hazards;

____Inventory of potential disease vector habitat;

____Design criteria for impoundments;

____Health criteria for water management;

____Design for domestic water supply;

____Design sanitation facilities;

____Design for related health facilities;

____Plan for public health education;

____Plan for migrant health control;

____Plan for monitoring post-construction disease status.

F. Flora and Fauna

____Prepare reports of field surveys with expression of relative abundance of plant and animal species;

____Report on extent of endangered species habitat;

____Plan for protection of natural areas;

____Develop reforestation or afforestation plan for watershed protection and erosion control.

G. Social and Economic

____Complete community profile;

____Plans for resettlement of human populations;

____Plans for irrigated land allocation or consolidation;

____Inventory of potential markets;

____Plans for agricultural credit for farmers;

____Plans for new or accessory transportation routes;

____Plans for accommodating migratory humans and livestock;

____Establish relief funds and supplies for farm families during project construction.

Appendix A 1

IRRIGATION SCHEDULING AND WATER REQUIREMENT APPLIED TO SMALL PERIMETERS

This proposed irrigation scheduling is derived from weather data, crop data, and pumping data. It is strictly applied in small perimeters, where a normal scheduling cannot be applied.

Scheduling is made based on the following conditions (which are the cases found in small perimeters):

1) Pumps always run at optimum speed and discharge will not be variable.

2) To meet water demand for plants a fixed pump running-time is calculated .

3) Only one irrigation block is irrigated per day. This is applied for both rice crop as well as corn or mixed crop.

4) Field is derived into irrigation blocks (2.5 ha net for rice and 3 ha net for corn and mixed crop).

Application

When the schedule is made, farmers only need to know pump running time during the day that irrigation takes place. This pump running time is almost constant. Farmers or irrigators need to have a watch to keep track of the time to run the pump. If this scheduling is respected,water satisfaction is 100% and optimum yield variation of pump running time of ± 15% can be accepted depends on efficiency of water distribution system, then fluctuation of water level in the river and the performance of the Group Motor Pump.

APPENDIX F - IRRIGATION ANALYSIS

SMALL PERIMETER DEVELOPMENT--RURAL DESIGN PROCESS AND CRITERIA

I. Present Development Problems

The IDP program for small perimeter development is based on the substantial experience that AID has had with Small Irrigated Perimeters in the Senegal River Basin with the Bakel Small Irrigated Perimeters Project (1978-83) in the Bakel region of Senegal, the AFRICARE OPG for Small Perimeters (1981-82) in the Gouraye Region of Mauritania, and the AIP for Small Perimeters (1978-79) in the Kayes Region of Mali. Evaluations of these experiences, most importantly the Bakel evaluation of November 1981 and the AFRICARE/Gouraye evaluation of October 1982, provide the basis for the IDP small perimeter design. This design was further enriched by the similar experiences of other donors working with small perimeter development in the SRB. 1/

The common problems and recommendations from these experiences are the basis for the IDP perimeter design criteria, and implementation strategy. The principal problems to date with small perimeters can be grouped into four categories: (1) pumping plants, (2) penstocks, (3) water distribution, and (4) irrigation application.

(A) Pumping Plants

Problems with pumping plants have been the most persistent and serious of the problems that have occurred with small perimeter irrigation in the SRB. These plants are Diesel-driven centrifugal pumps with a capacity to irrigate approximately 20 hectares. Experience to date has shown that small, low-speed, air-cooled, manual-start engines such as the two-cylinder Lister HR-2 are the most suitable. Experience has also shown that the pump/engine units need to be properly matched for the water lifting needs of each individual perimeter. At Bakel, pump lift requirements range from about 13 m at low river flow during the dry season, and 4 m at high flow during the rainy season, and existing pump efficiencies range from 66 to 88 percent during the dry season and 50 to 77 percent during the rainy season. Under these conditions the best combination of pumping plant has been found to be the Deloule pump (with 260 mm impellor) combined with a Lister HR-3 engine, or secondly the Gorman Rupp pump with the same motor. 2/ The Deloule HR-3 combination has an average efficiency of around 80 percent for both high and low river pumping lifts. However, in Bakel only 2 out of 50 pumping plants have this most efficient combination. 3/

1/ See the OMVS IDP design bibliography for a listing of reports on other donor projects that were used in the Project Paper design.

2/ Technical Report on Pumping Water for Irrigation, Bakel Small Irrigated Perimeters, Ni Vu Nguyen, January 1981.

3/ "Project Review for Bakel Small Irrigated Perimeters," USAID/Senegal Project No. 685-0208, prepared under Water Management Synthesis Project AID Contract No. AID/DSAN-D-0058, January 1982, pp. 58-60.

By systematically assuring optimal pumping unit selection for each perimeter fuel consumption can be reduced by about 15 percent in Bakel. 4/ In other areas like Kaedi and Gouraye where pumping efficiencies have been lower than in Bakel, the estimated reductions in fuel consumption are around 20 percent. Optimal pumping plant selection has not occurred to date because of the lack of adequate technical design for individual site plans for each perimeter and because of donor funding and administrative procedures that have favored large international tenders to buy low cost pumping units in large lots regardless of site diversity and site-specific irrigation needs.

A second problem with the pumping plants has been the design and cost of pump floats. For most perimeters the pumping unit is mounted on a float in the river. The existing floats are generally fiberglass-foam plastic floats or sealed metal floats that tend to shake apart under operating conditions. Many of the floats list at various angles and several tip over each year and literally down the engine. This situation makes routine maintenance more difficult and necessitates additional and more expensive maintenance. It is estimated that inadequate floats have increased maintenance and repairs by at least 25 percent in Bakel and have likewise reduced the engine life. 5/ The pump float problem is being addressed by research ongoing at Bakel to improve float design and develop low-cost locally built floats. IDP will also closely evaluate the need for pump floats at each site, particularly at sites with rock outcroppings suitable for rail mountings or sites with a gentle slope suitable for having the pump unit placed on the bank and periodically moved up or down corresponding to changes in water level.

The third problem with the pumping plants is the fueling systems. The current system in many perimeters is to store fuel in 200 liter drums, to siphon the fuel into open buckets, to carry it down the bank and to pour it into the engine. Throughout the fueling process there are numerous opportunities to spill or contaminate the fuel with dirt and water. It is estimated that fuel contamination is an important factor that leads to shorter engine life and excessive repair and maintenance and results in a 25 percent reduction in engine life and a 25 percent increase in maintenance costs. 6/ In several perimeters, particularly in Mauritania, storage tanks have been built at the perimeter site, but these have generally been provided because of insecurity in supply and have not been well designed to reduce fuel contamination. Under IDP, the perimeter site plans will include fuel storage and fuel contamination measures such as installation of storage tanks, and hoses or closed containers to carry the fuel from the tanks to the engines. These improvements will eliminate most of the contamination problems.

4/ "Project Review for Bakel Small Irrigated Perimeters," p. 60.

5/ "Project Review for Bakel Small Irrigated Perimeters," p. 61.

6/ "Project Review for Bakel Small Irrigated Perimeters," p. 61.

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The final problem with the pumping plants has been that of maintenance. The maintenance problems arise at the farm level because of inadequately trained pump operators who do not follow a systematic maintenance program. This compounds the repair problems which are further aggravated by poor repair services. The RDAs themselves are pooly trained, equipped and organized. For the success of irrigation in the SRB, the improvement of plant maintenance and repair services is imperative. The IDP include numerous activities to address these problems from several directions. Current approaches will be strengthened such has training for farmer operators and SAED mechanics, proper tools and service facilities, and incentives for both the RDAs and the farmer groups to maximize the life and performance of the pumping plants. New approaches will also be introduced through greater standardization, development of supply and service alternatives to the RDAs, and reduction of policy and administrative constraints to supply of parts and services in the SRB. In addition, substantial improvements will occur naturally as farmers and mechanics gain experience with Diesel-powered pumpsets.

(B) Penstocks

The pipelines which convey water from the pumps floating in the river to the canal head boxes at the top of the river bank are generally made of heavy plastic (PCV) pipe with flexible quick couples. Much of the pipe is improperly sized and misapplied. Thus, instead of lasting 10 or more years, it lasts only 2 or 3 years because of exposure to the sun and severe mechanical stress. Under IDP, these problems will be addressed in the site plans for each perimeter. Bolted galvanized steel tubing will be used for exposed sections with flexible joints and elbows as an option for discharge and suction pipes. The pipelines will be sized to assure that friction loss and velocities are not excessive and plastic pipe will be buried and long radius elbows used at sharp bends. It is estimated that with these improvements the life expectancy of the penstocks can be increased to 10 to 20 years and fuel consumption reduced by virtue of decreased head loss in the pipe.

(C) Water Distribution

Each perimeter must include an appropriate conveyance and distribution system for delivering the required quantities of water to respective irrigation blocks at scheduled times. Existing canals are quire good in some perimeters, but very poor in others. It is estimated that the best canals in Bakel have water losses in the neighborhood of 25 percent and that the worst have losses of 50 percent or more. 7/ Canal construction appears in most locations to be a major labor requirement and bottleneck for the farmer associations. In addition to constructing the canals, the farmers must clean them and periodically rebuild the drop and outlet structures. Incomplete construction has often compounded maintenance problems in canals. With IDP, greater attention will be paid to design and layout of water distribution systems. On relatively steep or sandy lands canals

7/ "Project Review for Bakel Small Irrigated Perimeters," p. 64.

will be either lined or pipe used. Attention will be given to properly dividing the perimeter into irrigation blocks of suitable size and shape for the terrain and for irrigation rotation and scheduling. Leveling and grading will be encouraged within the context of establishing distribution systems appropriate to the small land holding and labor intensive cultivation practices.

(D) Irrigation Application

Generally, flooded basin irrigation is being used for rice and basins with furrows or zig-zag furrows are being used for row crops such as vegetables, corn and sorghum. In terms of topography and soils, the perimeters are generally will suited for surface irrigation. However, for efficient surface irrigation considerable land shaping and/or levelling is required but often not done. On many small perimeters, farmers have been left responsible for all land shaping. The task has been impossible with the labor and limited hand tools available. For successful small perimeters greater emphasis on proper irrigation system design and improvement of irrigation practices is needed. For new perimeters financed under IDP, a site plan for perimeter land devleopment will be prepared, a detailed topographic survey and a soils survey will be made for each perimeter, and the design will include land shaping and canal layout plans for the irrigation system. Farmers will be assisted in levelling and development of irrigation blocks by the RDA or by contracted equipment. The IDP design team felt that the payoff to such improvement could be substantial. The evaluation team for Bakel estimated that the "combined effects of improved design and installation with good maintenance and service would double the average area irrigated for a given amount of diesel fuel, practically double the area irrigated from a given pumpset, and triple (or quadruple) engine life. In addition farmers would be inclined to double crop." 8/

2. Master Plans

As of July 1982, approximately 32,000 hectares had been developed in the Senegal River Basin. This developed area is only 6.7 percent of the potential irrigable land in the SRB. 9/ In the IDP project zones the percent of developed land is even less than this. Since the small perimeters now being developed are in almost all cases only partial development of a larger potential site, and later perimeter expansion or contiguous site development is expected, a master plan for the eventual overall development of sites is extremely important. Such master plans will facilitate orderly development of sites and minimize the later redesign

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8/ "Project Review for Bakel Small Irrigated Perimeters," p. 74.

9/ "Bassin du Fleuve Sénégal, Périmètres Irrigués Aménagés en Maitrise de l'Eau, Situation au 1er Jullet 1982," Direction du Développement et de la Coordination, OMVS, January 1983.

and restructuring necessary for extension and contiguous plot development. So far in the SRB master plans have been prepared for the left bank in Senegal up to Matam 10/ and for the right bank in Mauritania up to Kaedi 11/ each of these studies has been complemented by further detailed studies for new perimeters and rehabilitating existing perimeters. For instance, the right bank master plan has been supplemented by a perimeter idenfitication study that included sites in the Kaedi and Gouraye 12/ zones, by a project identification study for the Kaedi and Gouraye perimeters, 13/ and then by two project feasibility studies for the perimeters financed by the IDP 14/ and the World Bank 15/. Similarly, the Podor perimeter was part of the left bank master plan and then a detailed feasibility study was prepared 16/ and this study was evaluated and modified by the IDP design.

The only area of the SRB that is not presently covered by irrigation master plans is the upper valley, including the Gouraye, Bakel and Kayes regions. The master plan for this area will be part of the Development Plan for the Upper Valley being financed by IDP. However, even though the master plans are not complete, plans for certain areas and site plans for irrigation development in those areas have been prepared. For all the perimeters to be financed by IDP in these areas, site identification and site feasibility studies have been prepared. The available studies are sufficient to move ahead with the IDP financed perimeter development program, but additional planning is needed for the next phase of expansion after that.

10/ "Schéma Directeur d'Aménagement, Etudes de Réhabilitation, de Factibilité et d'Avant Projets Détaillés de Périmètres d'Irrigation sur la Rive Gauche du Fleuve Sénégal," prepared by GERSAR under Operation BIRD 775/SE, 1981.

11/ "Schema Directeur des Aménagements Hydro-Agricoles de la Vallée du Sénéfal Rive Droite en Mauritanie", prepared by GERSAR, June 1980.

12/ "Etude de Faisabilité d'un Programme d'Aménagement de Périmètres Villageois sur la Rive Droite du Fleuve Sénégal," prepared by SATEC under Convention and Financement du FAC No. 268/C/DDE/79/MAU, 1980.

13/ "Projet de Périmètres Irrigués Villageois, Rapport de Préparation," FAO/World Bank Coorperative Programme, Report No. 41/81/MAU. 5, April 12, 1981.

14/ "Project Paper," OMVS Integrated Development Project, No. 685-0621, USAID/Sénégal River Basin Development Office, December 1982.

15/ "Mauritania Small-Scale Irrigation Project, Staff Appraisal Report," Internal Working Document, WAN-19, World Bank, October 1982.

16/ "Etudes de Réhabilitation, de Factibilité et d'Avant Projets Détaillés de Périmètres d'Irrigation sur la Rive Gauche du Fleuve Sénégal, Périmètre de Podor," prepared by GERSAR under Operation BIRD 775/SE, 1982.

3. Site Design Plans

The IDP sites for irrigation development were appraised at the feasibility level to determine costs, socio-economic and technical feasibility, and institutional capabilities for implementation. Before the construction program can be executed, however, a final design is required for most sites. These final design plans will be prepared by the RDAs in each sector with the technical assistance of AID contractors. These site plans will be submitted to the respective USAIDs for review and approval prior to the release of funding for construction. The construction site plans will use the checklist provided in Appendix E to assure that all areas of concern are addressed, and will use the engineering criteria and administrative procedures provided below.

(A) Engineering Criteria for Small Perimeter Final Design

(1) Limiting Irrigation Velocities

The minimum velocity is determined by considerations of irrigation timing and canal silting. In the small perimeters, canals are not continuously filled with water. The pump is started in the morning and run for a maximum of about 10 hours per day. Thus, minimum velocity is calculated so that the water does not take more than one hour to reach the far end of the plot, and, secondly, so that there is not a build up of loam deposits in the canals. The minimum velocity for these two considerations is 1 ft/second.

The maximum velocity is determined by the erodibility of the soils comprising and surrounding the canals. For small canals the velocity should not be more than 2 ft/second on lighter loam soils and not more than 3 ft/second on the heavier clayish soils. Depending on the soil, the maximum velocity and side slope limits of the canals are as follows:

Material	Max. Permissible Velocity ft/sec.	Side slope Horizontal/Verticle	
Fine Sand	1.5	3:1	
Silty Loam	2.0	2:1	
Firm Loam	2.5	1.5:1	Limit
Stiff Loam	3.5	1:1	

With these considerations the IDP has established the following summary norms for irrigation velocities:

Dirt Canals	Lights soils	1 - 2 ft/sec.
	Heavy soils	1 - 3 ft/sec.
Lined Canals		1 - 2.5 ft/sec.

Based on the above velocity norms, the canals will be laid out on the natural soil surface following contour lines so as to be as straight as possible and to limit the need for raised canals. The ideal canal slope is 1 percent. The canal sectional design will be choosen to obtain the permissible velocities. In cases where the slope of the land is high, drop structures will be used, or in some cases alternatives to open canals considered (i.e. use of pipe).

(2) Soil Crop Relationships

For the Senegal River Basin several general soils studies have been prepared in French. These are:

a. "Etude Pédologique SEDAGRI-FAO, 1973.

b. "Etude Agropédologique de la Vallée et du Delta du Fleuve Sénégal, T.G. Boyadgien, FAO, 1978.

c. "Etudes Socio-Economique de l'OMVS, Sols et Végétation de la Moyenne Vallée et des Bordures," 1980.

d. "Etude sur les Unités Naturelles d'Equipement," par Chaumeny, 1973.

For the specific sites which have been selected for inclusion in the IDP, the following additional pedological data is also available:

a) Podor Perimeter (Senegal). A map has been prepared at a scale of 1:5,000 with soils classification and crop capability. SAED is currently refining this map with more detailed soils surveys.

b) Bakel Perimeters (Senegal). A pedological study by PEREIRA-BARETO (ORSTOM) at a scale of 1:2,000. A detailed study at a scale of 1:2,000 is underway by the FAO for the USAID project sites.

c) Gouraye Perimeters (Mauritania). The "SONADER Report" prepared by the FAO/World Bank Cooperative Programme contains a soils and crop capability study.

d) Kaedi Perimeters (Mauritania). The "Irrigated/Village Perimeters Project, Preparatory Report," prepared by the FAO/World Bank Cooperative Programme in December 1981 provides soils and crop capability information.

d) For the left bank up to Matam and the right bank in Mauritania up to Kaedi by the "Master Plans for Irrigation Development" prepared by GERSAR in 1980 and 1981 under World Bank financing provide:

- Norms for irrigated perimeters and basic data, Vol. 11, title 1.
- Agronomic norms and data, Vol. 12, title 1.
- Norms for design of irrigated perimeters, Vol. 13, title 1.

For the IDP, detailed topographical maps and soils data will be developed for each perimeter site. The scale of the topographical maps and the extent of the soils sampling and fertility analysis will depend on the site and number of hectares to be developed. In general, the IDP has established the following norms according to perimeter size.

For perimeters of less than 20 hectares the topographical maps will be of a scale of 1:1,000 with contours at 25 cm and elevation points taken for each 10 m^2. The soils data for these perimeters will be developed by the RDA zone office. The RDA sector agent will take soil samples in the field to determine the soil pH, salinity, and moisture content. The number of samples taken per hectare will depend on the number of soils in the area, with several samples taken for each soil type.

For perimeters between 20 and 200 hectares the topographical maps will be of a scale of 1:2,000 with contours at 50 cm and elevation points taken for each 20 m^2. More detailed soils analyses will be done for these perimeters, first of all, by the RDA zone office for areas of up to about 60 hectares. The RDA zone-level analyses will use a soils kit at the zone office to backup and verify the field analysis done by the sector agent. Secondly, for areas of greater than 60 hectares, samples will be sent for a laboratory analysis by the agricultural research station or another national or private soils laboratory. This type of analysis will provide complete expanded data on physical soil structure and chemical components --pH, cation exchange capacity, electrical conductivity, sodium absorption ratio, and amount of organic matter.

(3) Water Crop Relationships

IDP technical analysis for agriculture examined the water crop relationships for the major ecological zones and crops in the SRB. These are summarized in Figure F 1. This information will be supplemented by additional water and crop data at each perimeter site, by project water and crop monitoring, and by field research under the OMVS Agricultural Research II Project (625-0957).

(4) Field Level Tolerance

The established norm for difference of level between the upper and the lower point of a field in the SRB has been less than 10 cm. 17/ This is a realistic tolerance level given the fact that most leveling has been done by farmers, by hand. However, this level of tolerance has not always been met so that there has been uneven water distribution, waste of water, and reduced yields. For the IDP, the same field level tolerance level will be set for plot irrigation. Where greater slope causes tolerances exceeding this, contour furrow irrigation will be used instead of basin irrigation. To meet this tolerance level and hopefully to improve toward a 5 cm tolerance level, greater machine assistance with leveling will likely be needed--especially if plot size is to be expanded to facilitate use of animal traction.

17/ Schéma Directeur d'Aménagement," GERSAR, 1981.

(5) Embankment Compaction

For the larger canals, construction will be of selected materials brought from outside the perimeter and tested for permeability, erosion resistance, and plasticity. On the other hand, small perimeters will be build primarily with materials found within the perimeter, with material selection based on the soils surveys conducted for the final design. For choice of materials the plasticity index should be between 8 and 30 (Atterberg Limit) and the granulometry of between 8 and 45 % for elements less than 5μ and between 40 and 85 % for elements less than 50μ.

For the small perimeters, compaction will be done by farmers with hand tampers using a 10 cm lift. With these methods a compaction density of 75 % is possible, Water for aiding the compaction will be brought to the perimeter from the nearby river. In general, suitable soils are found in the vicinity of small perimeters, since they are usually located on loam and heavy loam soils bordering the river, and hand compaction is adequate for the size of canals and water velocities being used.

(6) Canal Lining

Canals are generally not lined and lining is not recommended if suitable soils and compation techniques are used. However, lining may be recommended in the rare cases when there is a continuous water flow in main canals or suitable soils and compaction is not possible. In these cases, the first choice for lining is local materials, or secondly, concrete blocks. Canals lined with plastic sheets or with cement have not proven to be effective nor economical in the project zones.

(7) Canal/Drain Relationships

In general, drainage canals in the Senegal River Basin are used to drain off excess rainwater, to permit the draining of rice paddies, to control the level of the watertable, and to evacuate excess irrigation water. Drainage considerations are a must in the larger perimeters like Podor which includes primary and secondary drainage canals with a drainage capacity of 2-3 liters/second/hectare. For the small perimeters, the need for drainage will be studied in the final construction design based on the terrain and soil conditions of the site. Since most of the small perimeters are on permeable soils and do not have drainage problems, drainage structures are not needed.

A primary drainage concern of IDP is the rainfall runoff of several watershed areas in the upper basin and how to protect perimeters from this runoff and as well as how to effectively channel and use the runoff for irrigation. An Italian firm is presently studying the Collenga watershed basin in Bakel and this study will provide important planning data for the IDP construction of the Collenga perimeter. Likewise, the Development Plan for the Upper Valley will provide similar information on several basins in the upper valley, particularly those in Mali where rainfall and runoff is substantial.

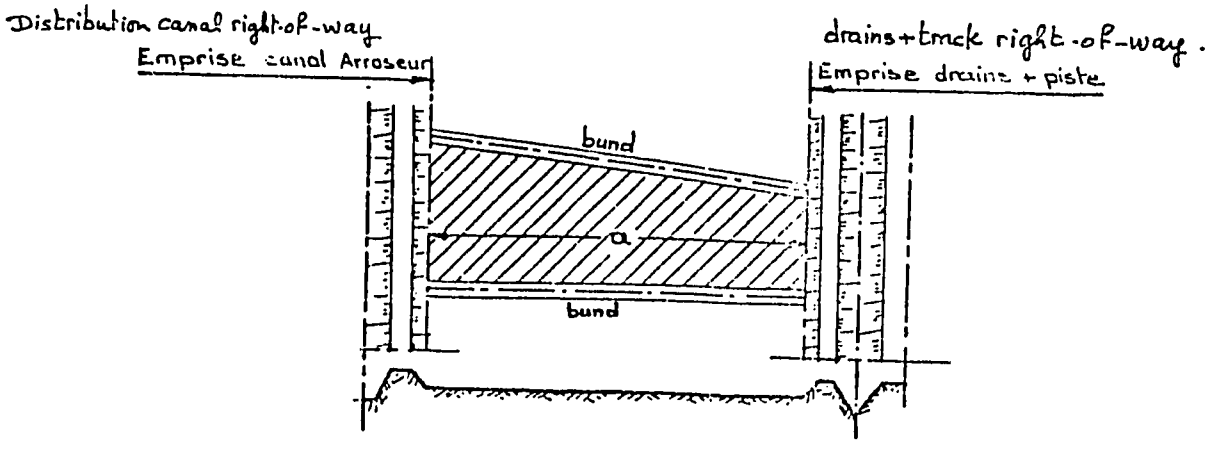
(8) Plot Configuration and Expandibility

The perimeter sites for the IDP have been selected according to: (1) land criteria: slope of land, micro-relief, vegetation, soils, flooding, ravines, and site shape; (2) socio-economic criteria: population within 3 kms of site, local interest, land tenure or allocation problems, and site accessibility for inputs and marketing; and (3) irrigable potential: water availability, seasonal changes in water availability, flooding, height of bank, water conveyance systems required, existing irrigation in area, and soil characteristics.

Final perimeter design will be completed with a concern for the eventual development of the entire site for irrigation and for ancilliary activities like fish culture, village forestry, local food processing, food and supply, storage, etc. Although perimeter design is site specific, certain general guidelines for a typical structure can be presented. The irrigation network structure has a layout of tertiary canals in horizontal rows along contour lines so that each parcel has direct access to all irrigation infrastructure such as canals, drains and pathways. A typical pattern is presented in Figure F 2 with a strip of parcels along a principal line. Several variations are possible within this design. For example, Figure F 2 presents several configurations for a 15 ha plot:

T1: 2 strips of 7.5 ha each
T2: 4 strips of 3.75 ha each
T3: 6 strips of 2.5 ha each.

Such a perimeter may be expanded either along the principal line with a secondary canal dimensioned for extension, or along contour lines if the primary canal is dimensioned for extension along the river. Perimeters under IDP will be build with dimensions calculated for possible extension according to site characteristics. Each site will have certain topographical advantages as well as constraints. Some general levelling of the site will normally be necessary before the irrigation network is laid out, but there will normally still be some general slope within the site. Each irrigated strip will be divided into parcels of trapezoidal shape with the parcel sides being the irrigation canals, and internal bunds along the perpendicular to contour lines of the parcel. The strip size will be determined by the slope and levelling required for the less than 10 cm tolerance.



(B) Administrative Procedures for Small Perimeter Final Design

In each of the five project zones, the RDA zone-level office will have primary responsibility for the preparation of the final perimeter design, for supervising field work by contractors, farmers, and other government agencies, and for supporting perimeter operations with technical assistance and training. The process of perimeter development and farmer decision making is shown in the network plan, Figure F 3. The zone-level RDA offices will receive technical, contracting, and procurement support from the national level and from the respective USAID. The RDA zone-level staff in each of the five project zones will include a zone-level project manager, and irrigation engineer, an extension/training specialist, and an agronomist. This management and technical staff will be supplemented by junior technicians and field agents. The present and planned staffing in each project zone and the administrative responsibilities of the RDA at the zone level are presented in the "Administrative Analysis," Volume III, Section 4.0.

The technical and administrative capabilities at the zone level will be reinforced through technical assistance in project management, irrigation engineering, agricultural extension and training, and social science research. The qualifications, functions and scope of work for each technical assistant is provided in the "Scopes of Work for Technical Assistants", Volume III, Section 6.0. In general, these technical assistants will be responsible for assuring the technical content of the field work and for training of RDA field staff.

The construction site plan which will be prepared for each perimeter will serve several purpose. First, it will provide the construction and irrigation operation plans for the perimeter. Second, it will provide an agricultural plan to guide extension and agricultural demonstration on the perimeter. Third, it will provide social and economic information to assure farmer agreement and participation in the perimeter development activities and to guide the farmer and farmer association training programs planned under the project. Fourth, it will include the public health data developed by the health surveillance component and serve as a guide for planning primary health care improvements. Fifth, the site plan will serve as a basis for the installation of the project management and impact monitoring systems. A discussion of how the site plan will be used for each of these functions is presented in the respective technical analyses of Volume III. This appendix concentrates on the first purpose, the engineering design and plans for irrigation operation.

(1) Land Information

The first step in the preparation of the construction site plan will be to gather detailed land information for the perimeter site. As presented above, general site identification studies exist and aerial photos as well as large scale topographic and soils maps are available for project sites. These will need to be supplemented by more detailed topographical and soils data. A topographic map will be prepared for each site under contract by a government agency specializing in this work or by a private engineering firm

resident in the region. The soils surveys will be done by the RDAs as discussed above. For Senegal, it is planned that the topographical study will be prepared by one of several engineering firms in Dakar. USAID/Senegal has used these firms for similar work and has received very satisfactory results. For Mauritania, it is planned that the topographic studies will be executed by the topographic office in SONADER headquarters or by a private engineering firm.. For Mali, it is planned that the Rural Engineering Service of Ministry of Agriculture, in Bamako will perform the topographical studies with possible contract assistance by a local engineering firm. Host country contracting with review and prior approval by USAID will be used for this work in Senegal. In Mauritania and Mali the USAIDs will contract directly for these services or have the technical services contractor subcontract for the serivces.

(2) Engineering Design

Using the expanded land information from the topographic and soils studies above, plus the additional information gathered on climate, water, agriculture, and socio-economic conditions of each site, the zone-level engineering staff of the RDA will develop an engineering design plan for each site to be rehabilitated or constructed. The engineering design will address all the problems encountered to date with pumping plants, penstocks, water distribution, and irrigation application as discussed above, and include final design and implementation plans. During the first few years of implementation this engineering design will mainly concern Bakel, since the World Bank will be funding the final irrigation design and perimeter development during the first phase of execution in Mauritania and since there will only be perimeter upgrading during the first phase of implementation in Mali. While preparation of the design plans will be the responsibility of the zone-level staff and project technical assistants, each zone will receive technical support from the national level (RDA headquarters, in Senegal and Mauritania and Ministry of Agricultural Rural Engineering Service in Mali). In addition, the national USAID engineering offices and the Irrigation Engineer in RBDO will provide overall technical guidance and monitoring. The RBDO irrigation engineer will refine the format and technical specification of the site plans before the fieldwork begins, so that overall consistency and high technical competence can be obtained.

(3) Construction execution

The zone-level RDA will be responsible for supervising construction contracting and execution, irrigation system procurement and installation, irrigation operations training, and other technical support and monitoring activities for irrigation. For Senegal, SAED has stationed a grader and bulldozer in Bakel to assist the construction of small perimeters. When the construction site plans are completed and the requirements for earth-moving equipment clearly defined USAID will assess the possibility of using a private contractor for the heavy equipment work in addition to SAED.

Up until now, the limited earthwork and phased timing of perimeter construction in Bakel have inhibited the use of a private contractor since equipment would have to be mobilized from Dakar or another region. It is anticipated, however, that with the IDP the volume of the earthwork involved and the pace of construction will be such that a private contractor can be found to do the work with increased efficiency and lower costs than that performed directly by SAED.

For Mauritania, it is planned that a construction brigade will be organized in each sector to supervise the construction work by farmers and by a contractor who will provide heavy equipment for major earthworks. Small perimeter construction in Mauritania will be financed in the first phase of IDP under the World Bank Small Perimeter Project. The World Bank has determined that adequate private construction capability exists locally in Kaedi and Nouakchott to permit contracting for construction services, if the work is properly organized to permit continuous work by the heavy equipment in the project zone during one dry season.

In Mali, it is planned that the construction will be undertaken by the rural equipment service (OTER) of the Ministry of Agriculture. This service has previously performed similar work in Kayes and has adequate staff and heavy equipment to perform the construction planned under IDP.

(4) Construction Supervision

For the small perimeter construction planned under IDP, the RDA engineering staff in each zone will provide construction supervision. For the Podor medium perimeter a private engineering firm will be hired to supervise the construction. Construction monitoring will be the responsibility of the respective USAID and its engineering staff.

Figure F1

WATER CROP RELATIONSHIP in Senegal River Basin

	PODOR				BAKEL				KAEDI			
	Rice		Corn		Rice		Corn		Rice		Corn	
	R.S	D.S	R.S	D.S	R.S	D.S	R.S	D.S	R.S	D.S	R.S	D.S
Crop duration	June20 Sept20	Feb 20/ May 20	July 1/ Oct 1	Oct 15/ Feb 15	Aug 5/ Nov 5	Mar 20/ June 20	Aug 1/ Nov 1	Nov 15/ Mar 15	June 20 Sept 20	Feb 20/ May 20	July 1/ Oct 1	Oct 15/ Feb 15
Evaporation (mm)	921	1171	869	1014	740	1526	728	1235	922	1338	834	1114
ETP (mm)	737	937	487	568	593	1221	408	692	738	1071	467	624
Effective rainfall(mm	187	0	208	12	307	95	307	0	315	0	269	6
Net Water requirement	1067	1267	279	568	922	1551	408	692	1068	1401	198	618
Net Water application	880	1267	279	556	615	1456	101		753	1401	198	618
Gross Water application	1257	1810	495	927	880	2080	166	1153	1075	2001	330	1030
Water volume (m3/ha)	12,570	18,100	4,950	9,270	8,800	20,800	1,660	11,530	10,750	20,000	3,300	10,300

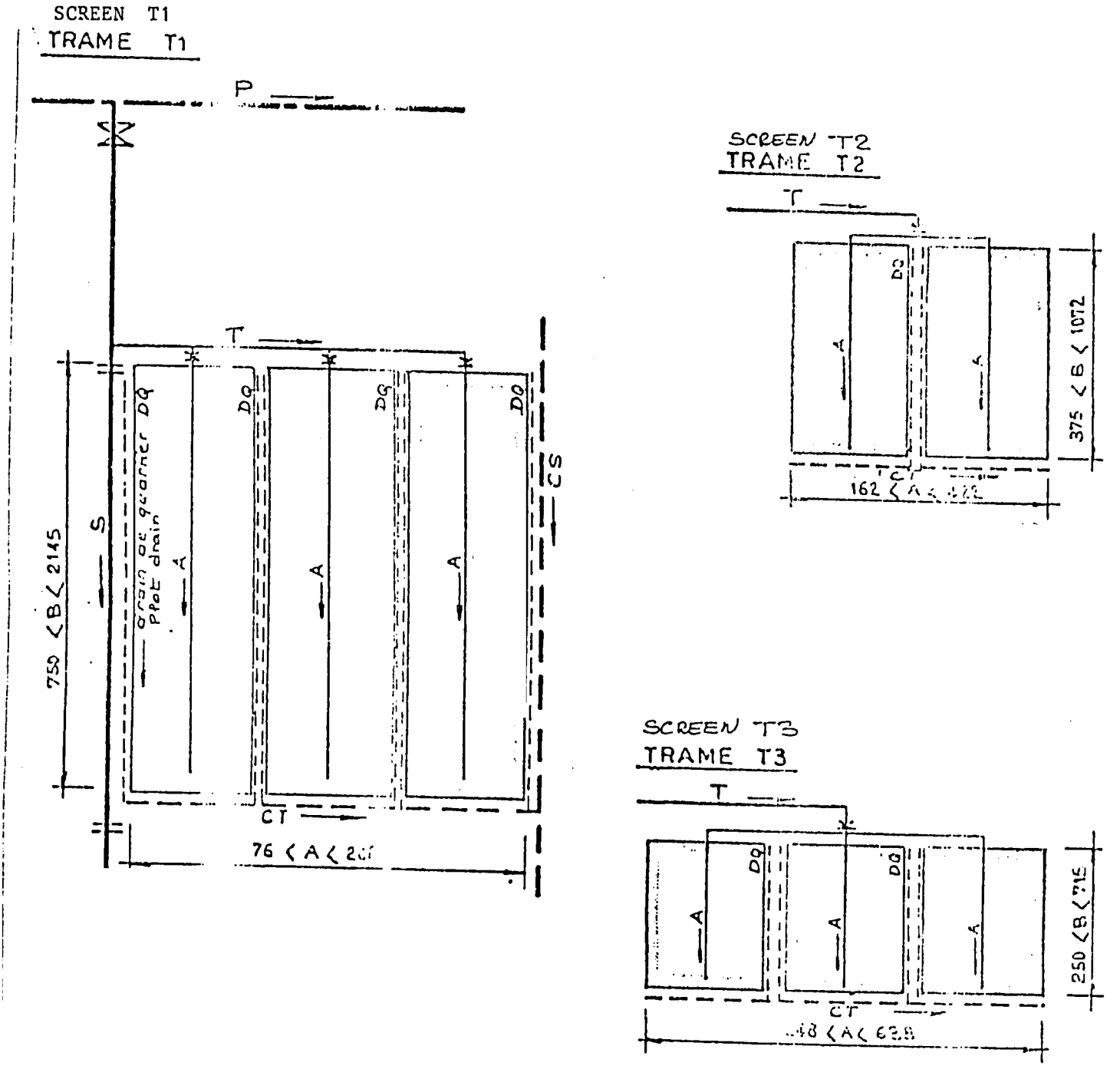
Note: See GERSAR/World Bank study "Master Plan for left Bank of Senegal River Volume 13 - 1981

R.S.: Rainy Season
D.S.: Dry Season

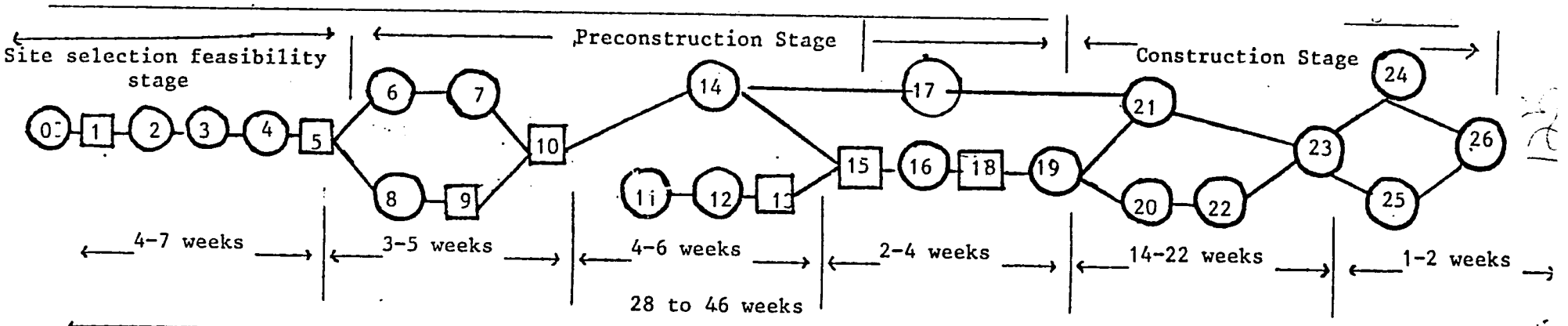
Figure F2
PLANCHE F2

SCHEMATIC STRUCTURE OF NETWORK

STRUCTURE SCHEMATIQUE DU RESEAU



IRRIGATION	DRAINAGE
P — Primary canal for irrigation with downstream regulation Canal Primaire d'irrigation en régulation par l'aval	CS — Secondary drain Collecteur secondaire
S — Secondary irrigation canal Canal secondaire d'irrigation	CT — Tertiary drain Collecteur tertiaire
T — Tertiary canal with horizontal banks Canal tertiaire d'irrigation à berges horizontales	DQ — Plot drain Drain de quartier
A — Plot distribution canals Canaux arroseurs de quartiers	
Flow regulation system, upper point of 2° network	



0. Village petitions for perimeter or perimeter expansion.
1. Orientation meetings of village groups with government services.
2. Site background and field surveys prepared by RDA -- socio economic and technical.
3. Perimeter planning visits by RDA technicians.
4. Identification of construction sites by RDA.
5. Site selection by RDA and village.
6. Preparation of detailed technical studies --RDA or contract topographic and soils studies.
7. Draft of construction design plan prepared by RDA.
8. Labor, land tenure and other socio-economic studies prepared by RDA for proposed construction design.
9. Resolution of land tenure and participation issues.
10. Village group review and approval of construction plan.
11. Participation/planning meetings of RDA and villagers on perimeter responsibilities.
12. List of village participants prepared and verified by RDA.
13. Resolution of participation/equity issues, if necessary.
14. RDA completes perimeter site plan and submits to USAID for approval.
15. Organizational meetings for establishing farmer association.
16. Association formed, government recognition requested, and trainees proposed.
17. Perimeter development contract signed between association and FDA.
18. RDA contracts for construction work specified in site plans.
19. Perimeter construction begins; agricultural inputs ordered.
20. Village technicians and managers given training by RDA.
21. Major canal network and dikes completed and pumps installed by RDA or contractor.
22. Farmer construction of irrigation network.
23. Construction completed.
24. Canal maintenance system established, farmers trained in irrigation techniques.
25. Agricultural inputs arrive.
26. Perimeter ready for planning.

□ Critical decision events

○ Other events

OMVS INTEGRATED DEVELOPMENT PROJECT (IDP) (625-0621)

PERIMETER DEVELOPMENT RESPONSIBILITIES

Zone - Perimeter Type and Area	Master Plan	Cost and Imple. Feasibility	Construction Site Plan			Construction	Construction Supervision
			Topo. Maps	Soils Survey	Const. Design		
/SENEGAL							
Bakel							
a. 281 ha. upgrading	Site studies by SAED adequate for identified perimeters - wider plan to be prepared under IDP.	Bakel Small Irrigated Perimeters Project (685-0208) and studies for Project Paper IDP, 1982.	Contracted locally by SAED	SAED	SAED	ED with contracted equipment rks	SAED and U.S. Technical Assistants
b. 470 ha. village perimeters				"	"		
c. 244 ha. Collenga perimeter	Italian financed study of Collenga Basin is underway		"	Contracted by SAED	"	"	"
Podor							
a. 332 ha. village perimeters	GERSAR Master Plan - 1981	GERSAR Feasibility Study - 1982	GERSAR	GERSAR, SAED now refining	Contracted locally by SAED	ntract by SAED ch U.S. and al advertising	A-E firm contracted by SAED.
b. 681 ha. Podor - 3 sectors		IDP technical analyses, 1982	"				
D/MAURITANIA							
Kaedi							
a. 780 ha. village perimeters - phase 1	GERSAR Master Plan - 1980	Phase 1: World Bank Staff Appraisal Report, Dec. 1982	SONADER	SONADER	SONADER	NADER with contracted equipment k	SONADER and technical assistants financed by World Bank (Phase 1) and AID (Phase 2).
b. 600 ha medium perimeters - phase 2	SATEC Identification Study - 1930.	Phase 2: IDP technical analysis, 1982.	Contracted by USAID	Contracted by USAID	SONADER	"	
Gourave							
a. 790 ha. village perimeters - phase 1	FAO/World Bank Village Identification, 1981	Phase 1: World Bank Staff Appraisal Report Dec. 1982	SONADER	SONADER	SONADER	ADER with tracted equipt work.	SONADER and technical assistants financed by World Bank (Phase 1) and (Phase 2).
b. 0 ha. village perimeters - phase 2							
c. 190 ha. upgrading - phase 2	Wider Master Plan to be prepared under IDP.	Phase 2: IDP technical analyses 1982.	Contracted by USAID	Contracted by USAID	SONADER	"	"
AID/MALI							
Kayes							
a. 232 ha. upgrading - phase 1	Study of 2,000 ha in Kayes Region, Kuwait financing 1977-79.	Studies by Direction du Genie Rural, Ministry of Agriculture, 1979-80.	Rural Engineering Service (Bamako)	National Research Service (Bamako)	OVSTM and Rural Engineering Service	ER, Kayes	OVSTM and U.S. Technical Assistants
b. 933 ha. basins - phase 2	Wider Master Plan to be prepared under IDP.						