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SENEGAL RIVER BASIN IRRIGATION REVIEW

DRAFT

OCTOBER, 1984

TAMS

TIPPETTS-ABBETT-McCARTHY-STRATTON

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EXECUTIVE SUMMARY

The Government of Senegal (GOS) wishes to increase the national level of food self-sufficiency. In view of climatic constraints one of the ways to ensure and to increase crop production is through irrigation. The GOS targeted the Senegal Valley for development of irrigated agriculture at the rate of 3,500 new hectares per year.

USAID wishes to support the GOS in its endeavours to accelerate the development of irrigated farming along the Senegal River. The completion of the Manantali Dam in 1989 in the headwaters of the Senegal River system will provide a guaranteed flow and allow for year round irrigation.

This report gives recommendations on how irrigated farming along the Senegal River can best be supported by USAID over the next five years. It is based on a review of the Project Paper of the Integrated Development Project. The recommendations are condensed into a comprehensive program which is described in Part 2 of this report.

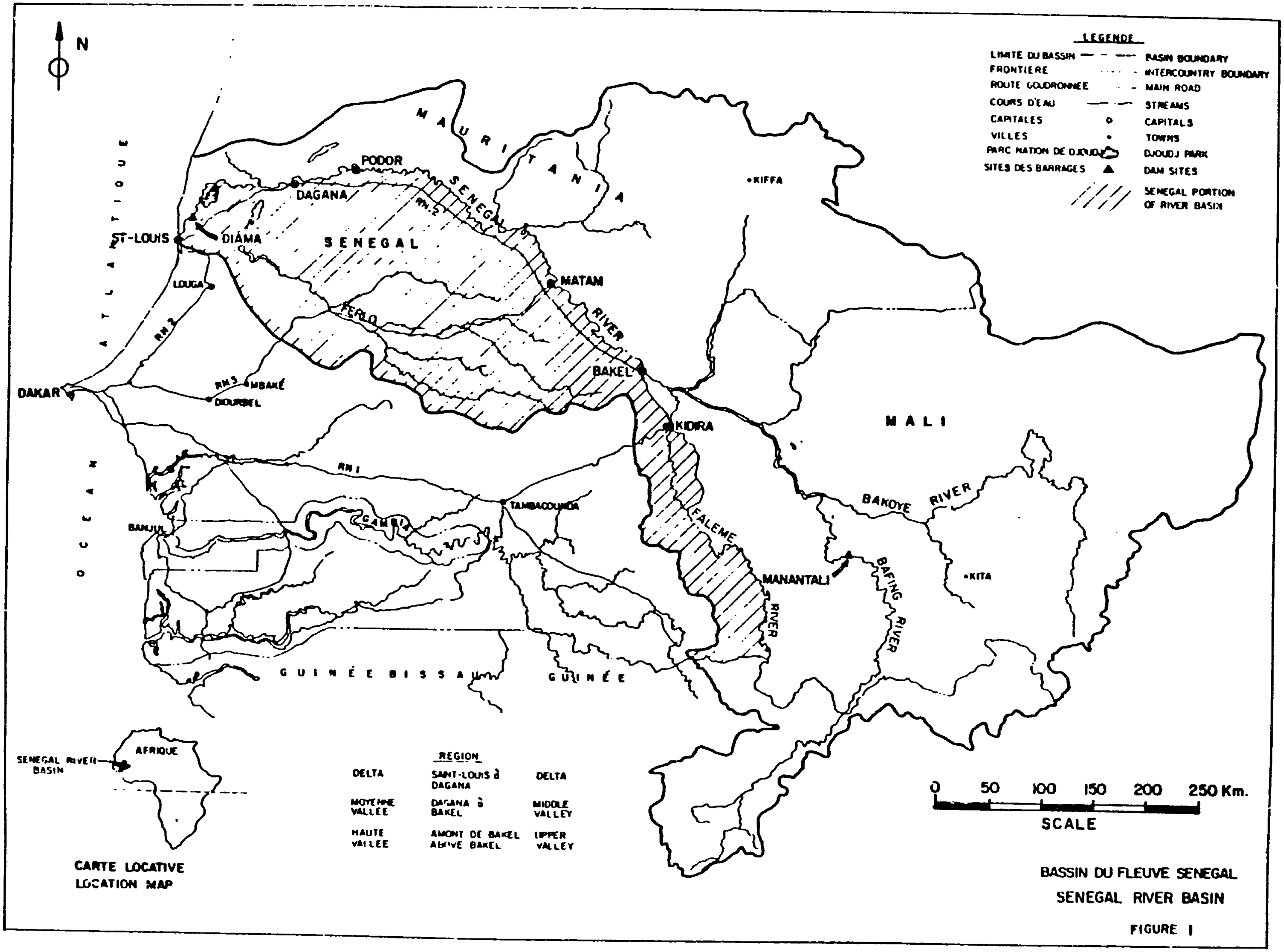
The possibilities of and constraints to irrigation are different in the three different parts of the Senegal Valley - the Delta, the Middle Valley and the Upper Valley. The comprehensive program presented here proposes different solutions therefore for the three parts of the Valley. The program consists of eight interrelated components each addressing different key issues but all geared to the main objective of increasing food production under irrigation in the Senegal Valley.

In the Delta we recommend limiting intervention to an assessment of drainage and leaching requirements that will become necessary upon completion of the Diama Dam (Component 1) and to determining the feasibility of rehabilitation of one Delta perimeter - the N'Thiagar perimeter - which could serve as an example elsewhere in the Delta (Component 2). In the Middle Valley we recommend proceeding, for technical and economic reasons, with an in-depth feasibility review of the Podor perimeter which is currently entirely designed for rice production (Component 3). Simultaneously work should begin on a Land Development Plan for a 10,000 ha area outside the floodplain (Component 4) and the establishment of a Demonstration/Investment Promotion Center capable of testing a range of suitable crops and several irrigation systems (Component 5). In the Upper Valley/Faleme River area, where the lowest irrigation infrastructure investments are required but basic physical data are missing, a resource inventory and subsequent master plan for development of irrigated agriculture is needed (Component 6). An initial 1,000 ha area irrigation sector can then be developed on the basis of the master plan and provided with agriculture support facilities and access roads (Component 7). The GOS agency responsible for irrigation development along the Senegal Valley is SAED. Program Component 8 focusses entirely on strengthening SAED's Planning and Development branch to manage the implementation of the previous seven components.

Figure 7 of this report gives a time schedule for the complete program; in Figure 8 a tentative cost estimate is presented which, including construction, amounts to $54 million.

PART I

INTRODUCTION



BASSIN DU FLEUVE SENEGAL
SENEGAL RIVER BASIN
FIGURE 1

1. INTRODUCTION

The Senegal River Basin in West Africa is the focus of a comprehensive regional development project designed by USAID, known as the OMVS - IDP (Organisation pour la Mise en Valeur du Fleuve Senegal-Integrated Development Project). The Senegal River Basin (SRB) is located in Guinea (9% of the river basin area), Mali (47%), Mauritania (22%) and Senegal (22%). The General Map of the SRB is shown on Figure 1.

The OMVS Integrated Development Project is concerned with Mali, Mauritania and Senegal only - the member states of OMVS. The project does not include Guinea where 50% of the inflow of the Senegal River originates.

1.1 Objective of Review

This review deals with one component of the IDP: the Senegal national program. The objective of this review is to verify the technical, economic and managerial adequacy of the Senegal portion of the original OMVS Integrated Development Project and make recommendations for its improvement, if needed.

At the request of USAID/Senegal, the review team not only assessed the IDP project, but also made a general evaluation of irrigation development potential and problems in the Senegal valley and formulated its recommendations in the format of a comprehensive 5-year program. This program is based on the assumption that it

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will be implemented by SAED through a leading U.S. firm of consulting engineers. Part 2 of this report contains this program. It is developed to provide effective USAID support to irrigation development in the Senegal/Faleme valley. Part 3 gives a general overview of the Senegal River Valley in Senegal. Part 4 deals strictly with a review of the Senegal national program of the IDP project paper.

The IDP (Project No. 625-0621) was defined in a draft Project Paper dated December 1982. Based upon a Technical Review of the Project Paper by James Stephenson in August 1983, a revised version of the main volume of the Project Paper was issued in December 1983. A table of contents of the Project Paper and its Annexes, as well as a listing of related documents, is presented in Annex 2.

The IDP project as a whole has three purposes:

1. to increase food production in the Senegal River Basin to keep pace with population growth;
2. to promote policy reforms that remove constraints to agricultural production; and
3. to improve the capability of private and public institutions in the Senegal River Basin to manage the transition from traditional to irrigated agriculture.

The IDP consists of four subprojects:

1. A regional program with OMVS
2. A Senegal national program
3. A Mali national program
4. A Mauritania national program.

For each of the four subprojects a number of subproject outputs are identified but no specific purpose is set. In order to verify the adequacy of any project or subproject one needs to know the purpose of the project, only then can it be determined if the project is adequately designed.

The Senegal subproject or project, no matter in what form it develops, needs a clearly defined objective and a definition of the "end of project" status in order to:

1. Permit effective project implementation
2. Allow for precise project evaluation

1.2 Review Procedure

This review was carried out in Senegal in August/September 1984 by a bilingual team of planners and engineers provided by Tippetts-Abbett-McCarthy-Stratton (TAMS), New York/Washington, D.C., under contract IQC 1486-1-19-1131-08/19. Team members were:

Dr. John Buursink	Team Leader, Land Use Planner
Mr. Gustavo Sobrino	Irrigation Engineer
Dr. Samuel E. Kao	Hydrologist
Mr. Geoffrey J. King	Agronomist/Soil Scientist
Dr. Wifredo de Rafols	Agricultural Economist
Ms. Pia Chesnais	Rural Development Assistant

The team received technical directions from USAID project officers:

Mr. John Balis	Chief ADO, USAID/Senegal
Mr. David Smith	AFR/TR/ENG, USAID/Washington, D.C.

The team was briefed by staff of the River Basin Development, Agricultural Development, Project Development and Engineering offices of USAID/Senegal. The team then studied the IDP project paper and reviewed key data and documentation which had provided the basis for the project paper. Practically all relevant documentation was found to be available in the two USAID/Senegal libraries and in SAED/St. Louis. The list of documents consulted is found in Annex 1.

In the Senegal River Basin itself, team members carried out on-site inspections in the valleys of the Faleme and Senegal (Bakel and Podor areas), and in the delta of the Senegal (N'Thiagar and St. Louis area). During these visits the team received full support from SAED, in particular from:

Mr. Oumar K. Dia	President Directeur General SAED/St. Louis
Mr. Arouna Fall	Directeur - Division de Planification et Amenagement
Mr. Faidior	Ingenieur Delegue de Podor
Mr. Yaya Dia	Ingenieur Delegue de Bakel

and their respective staff.

During its stay in Senegal the TAMS team also consulted with staff of the following UN agencies: FAO, ILO and WHO, all with offices in Dakar.

1.3 Location of the Senegal Program Area

The Senegal portion of the SRB, its principal population centers and the main roads and streams are shown on Figure 1.

The main streams within the basin in Senegal are the Faleme and Senegal rivers.

The Senegal/Faleme river valley is made of three distinct regions. The upper Valley, upstream of Bakel; the Middle Valley, between Bakel and Dagana; and the Delta, downstream of Dagana.

The Route Nationale 2 is the main paved road linking the valley population centers, it runs roughly parallel to the Senegal River, along its left bank. In addition, the area is connected with Dakar through Routes Nationales 1, 2 and 3 whereas the Upper Valley is also connected to Dakar via the Dakar-Bamako railroad.

PART 2

RECOMMENDED FIVE-YEAR PROGRAM

2. RECOMMENDED FIVE-YEAR PROGRAM

2.1 Program Objectives

This part presents a program for irrigation development in the Senegal portion of the Senegal River Basin. It is the result of our analysis of the physical resources of the Senegal valley and current irrigated farming in the area (see Part 3) and our review of the Senegal component of the IDP (see Part 4).

The Government of Senegal wishes to increase food production under irrigation in the Senegal valley. The Government plans to develop irrigated perimeters in the Senegal valley at the rate of 3,500 ha/year. Such development, currently estimated at some 10,000 dollars/ha, requires an annual capital investment of 35 million dollars (1984 prices). The Government wishes to keep its investments to a minimum. This can be done in two ways:

1. Develop areas where the cost per hectare for perimeter development is minimal such as in the Upper Valley and on the higher grounds of the Middle Valley where less extensive diking is required.

2. Develop farming systems in which high value crops are grown in the most cost efficient way to ensure maximum profitability thus allowing the farmers to repay the Government a larger share of its investments.

Irrigation development in the Senegal valley is constrained by a number of factors. The limiting physical factor for irrigation development in the Senegal valley is water not land. The total annual quantity of water available for irrigation, in particular reliable minimum flows available before and after construction of the Diama and Manantali Dams, is only approximately known. Irrigation along the Senegal River should thus aim at optimizing the use of water. In addition, different parts of the valley have specific constraints. Key constraints are:

1. Delta Area

   Due to the construction of the Diama Dam (scheduled completion 1986) the water regime and soil salinity status of the delta will drastically change and will affect the operation of existing perimeters, their possible rehabilitation and the design of new perimeters. Since the effects of the dam are largely unknown the feasibility of irrigation cannot be determined at this time.

2. Middle Valley

   In particular in the Podor Delegation emphasis in the past has been on rice cultivation for a number of reasons, not the least of which being the need to feed the population of the area. Under the right circumstances (soil and water) production of crops other than rice can be very profitable and require much less water than rice. However, this has not been sufficiently demonstrated in the field.

3. Upper Valley

Irrigation development is proceeding in a slow and rather haphazard way. It is not effective and thus costly because no overall plan exists to allow systematic and prioritized development. At the same time rural infrastructure necessary to support efficient farming is inadequate.

Our program recommended for action by USAID addresses these constraints and is intended to solve or alleviate them. The objectives of the program are defined in line with GOS objectives for irrigation development.

Generally the program is conceived to contribute to the full-scale, rational development of irrigated crop production in the Senegal valley in Senegal.

The Senegalese Government agency with overall responsibility for irrigation development in the Senegal basin is SAED, based in St. Louis. Since 1981 SAED has been a state affiliated organization with financial and administrative management autonomy, linked to the Government by a 'contract plan'. Our program will therefore need to be undertaken and controlled by SAED.

The immediate objective of our program is to assist SAED in accelerating the rate of development of irrigated perimeters in the Senegal valley. This can best be done by:

1. Providing sound technical advice, based on compilations and evaluations of Senegal's natural resource base, for the planning and site selection of new perimeters.

2. Developing standardized low-cost engineering designs requiring less subsequent maintenance inputs for new irrigated perimeters or rehabilitation works.

3. Introducing and developing rational farming systems with improved water management practices for rice and other crops.

4. Training Senegalese staff in improved planning and development of irrigation projects to strengthen the Senegalese capacity for continuing work in this field.

2.2 Program Overview

An overview of the proposed program is presented in Figure 2. The program consists of eight components each one of which is briefly defined in Figure 2. At the same time a cost estimate is presented for the total program and for each separate component. The full program is scheduled to be implemented over a five-year period, the time required for implementation of each component is also indicated in Figure 2. It is strongly recommended that the whole program be implemented through one U.S. firm of consulting engineers.

FIGURE 2. SENEGAL IRRIGATION PROJECT PROGRAM OVERVIEW

REGION	PROGRAM COMPONENT	NAME	OBJECTIVE	ESTIMATED COST 1984 DOLLARS MILLION US$	TIME FRAME PROJECT YEAR:
Delta	1	N'Thiagar Perimeter Site Investigation/ Monitoring Program	Define drainage and leaching requirements for rehabilitation of the N'Thiagar perimeter and establish methodology to assess similar impacts of Diama Dam on other perimeters in Delta.	0.7	1,2,3
Delta	2	N'Thiagar Perimeter Rehabilitation Feasibility Study	Determine technical and economic feasibility of rehabilitation of N'Thiagar perimeter	0.5	3
Middle Valley	3	Podor Perimeter Implementation	Implement Podor cuvette irrigation perimeter and start perimeter operations.	14.3	1,2,3,4,
Middle Valley	4	Land Development Plan for 10,000 ha Irrigation	Establish land development plan for 10,000 ha irrigation and select plan and lay out representative site for 200 ha demonstration/ investment promotion center.	3.4	1,2,3
Middle Valley	5	Development of Demonstration/ Investment Promotion Center	Design, implement and begin operation of demonstration/investment promotion center.	8.5	2,3,4,5
Upper Valley	6	Bakel Master Plan	Prepare a resource inventory and master plan for development of irrigated agriculture in the Upper Senegal/Faleme valleys.	4.0	1,2,3
Upper Valley	7	Bakel Irrigated Perimeter Development	Implement an initial 1,000 ha irrigation sector on the basis of the master plan supported by a fully operational experimental farm and provided with water and power supplies, and access roads.	15.0	3,4,5
Senegal Portion of Senegal River Basin	8	SAED/DPA Management and Training	Strenghten SAED's DPA office to allow for effective program coordination and management and subsequent independent continuation.	5.0	1-5
			SUBTOTAL	51.4	
			CONTINGENCY	2.6	
			TOTAL	54.0	

Note: The above estimates do not include GOS counter part costs, USAID management costs, nor escalation beyond 1984.

2.3 Program Components

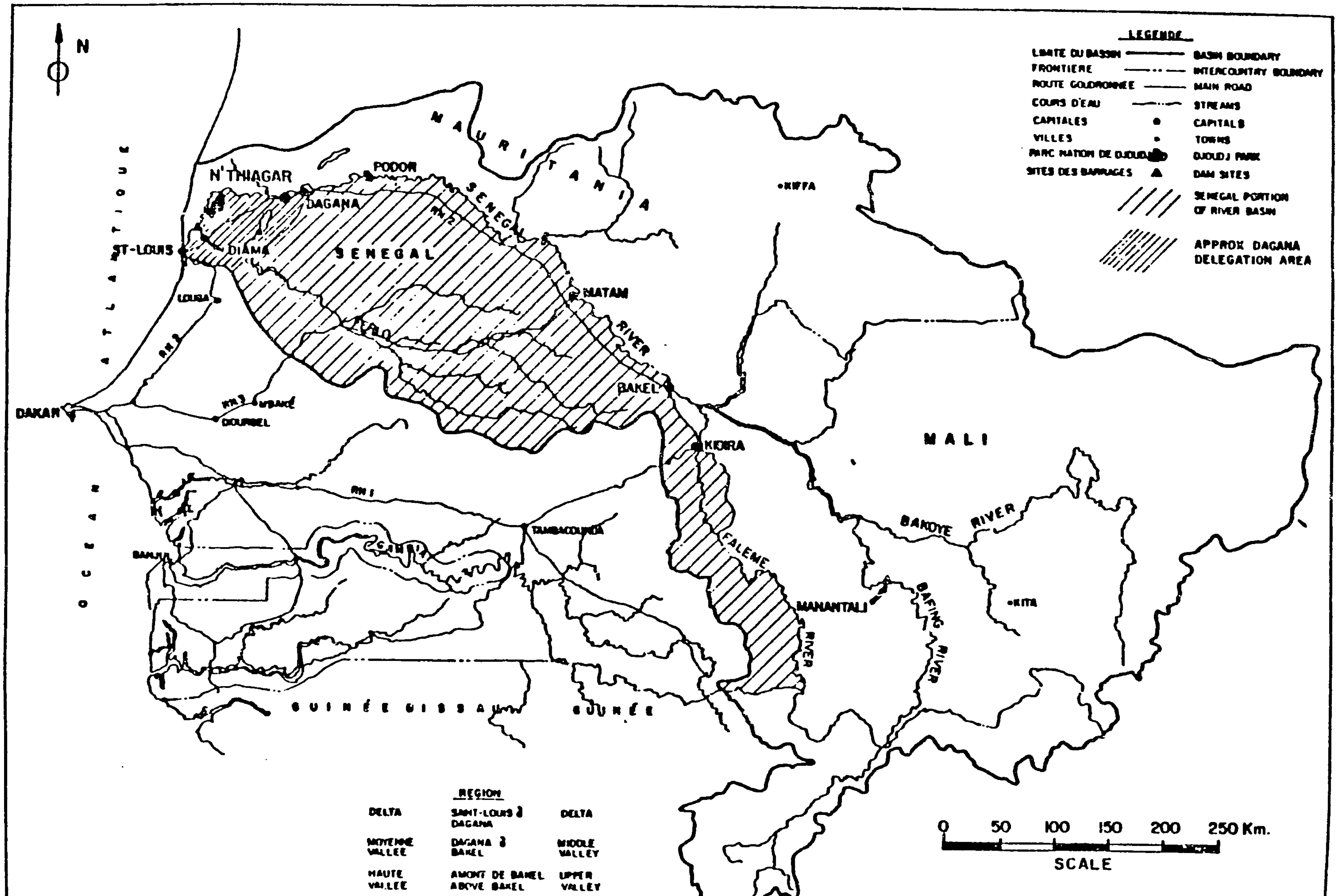
2.3.1 Delta Area - Components 1 and 2 (location shown on Figure 3)

The cost of irrigation development in the Delta of the Senegal River is substantially higher than in most of the middle and upper valleys. This is due to soil salinity problems and the associated leaching water requirements and to the necessity and difficulty of drainage.

N'Thiagar in the Delta needs extensive rehabilitation and considerable improvement. The IDP proposed to complete the existing feasibility and technical studies and to prepare a project dossier which SAED could submit to other donors for funding such rehabilitation and improvement.

However, in view of the unknown effects of the Diama Dam and prior to its completion, the impact of the Diama reservoir should be investigated; the review of the feasibility of rehabilitation and improvement of perimeters located in the Delta area should follow said investigation.

On the basis of the above, we recommend the execution of the following two program components for the N'Thiagar perimeter in the Delta area.



DELTA AREA
SAED DAGANA DELEGATION

FIGURE 3

Component 1 - N'Thiagar Perimeter Site Investigation/Monitoring Program

a. Objective

Define drainage and leaching requirements for rehabilitation of the N'Thiagar perimeter and establish methodology to assess similar impacts of the Diama Dam on other perimeters in the Delta.

b. Scope

1. Groundwater monitoring:
   - Select sites for installation of 12 piezometers in the perimeter and 5 or 6 around the perimeter
   - Design and supervise installation, development and testing of piezometers by qualified local contractor
   - Set up groundwater sampling and monitoring program
   - Conduct in situ permeability tests in selected test pits and piezometers according to the lay of the land
   - Develop math drainage model for N'Thiagar perimeter

   The above piezometers should be integrated with the network proposed under the USAID Groundwater Monitoring Project No. 625-0958.

2. Soil salinity monitoring:
   - Review and update existing soils map of perimeter to scale of 1:2,000
   - set up soil salinity sampling/monitoring program

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Items 1 and 2, above, need to be carried out over a 3-year period starting observations in the 1985 dry season to obtain pre-Diama data for one season. Installation of piezometers thus needs to start in early 1985.

3. Drainage and leaching requirements and report:
   In the third year the drainage and leaching requirements can be calculated and a report prepared outlining the procedure and approaches for application in other perimeters.

c. Estimated Requirements

The estimated requirements are as follows:

1. Expatriate Staffing

Drainage specialist	10 months over 3 years
Soil Scientist	8 months over 3 years
Agronomist	3 months over 3 years
Total	21 months

2. Subcontract for installation, development and testing piezometers with a qualified local firm.

3. Computer drainage modelling by consulting engineer.

4. Equipment and SAED support, engineer and soils scientist
   - lab, topo, drafting, secretarial, etc.

5. Vehicles

6. Per diems, international travel, communications, transportation, reproduction etc.

Component 2 - N'Thiagar Perimeter Rehabilitation Feasibility Study

a. Objective

Determine technical and economic feasibility of rehabilitation of the N'Thiagar Perimeter

b. Scope

1. A complimentary study of the physical resource base, particularly the project area land capability for irrigation, climate and water supply, in order to ensure that the cropping patterns proposed and the yields predicted can be maintained for a sustained period and in order to assess the scale of the project.

2. A thorough examination of the farmers and the land tenure structure involved in the project area in order to ensure that the proposed development is appropriate to their attitudes and capacities.

3. A thorough study of the engineering alternatives for rehabilitating the irrigation and road networks and draining the project lands, and their phasing, in order to ensure that the most appropriate economical but safe solution is achieved.

4. An adequate preliminary design of, and a construction schedule for both project and on-farm works, in order to demonstrate their suitability and to estimate their costs and the phasing of these costs.

5. The determination and scheduling of the agricultural pattern (size and type of farm enterprise, crops and their yields) on the basis of physical and human resources, present land use, market projections and prices.

6. The determination and phasing of the various measures and inputs necessary to achieve the agricultural plan.

7. The determination of the management and organization necessary to construct and implement the project to the time schedules predicted.

8. The determination of the economic benefit to the country, the financial returns to the farmers, the financial results of the operating authority and the repayment of project costs by beneficiaries.

c. Estimated Requirements

1. Expatriate staffing

Irrigation/ drainage engineer, P.M.	8 months

Soils scientist	1 month
Agronomist	1 month
Agroeconomist	2 months
Rural sociologist	2 months
Hydrologist	1 month
Soils/foundations engineer	2 months
Electrical engineer	1 month
Pump station specialist	2 months
Designer	2 months
Total	22 months

2. Sub-contract, drilling, testing of soils and foundations by qualified firm/soils lab.

3. Equipment and SAED support - engineer, miscellaneous topographic surveys, drafting, secretarial, etc.

4. Vehicles

5. Per diems, international travel, communications, transportation, reproduction, etc.

2.3.2 Middle Valley - Components 3, 4 and 5

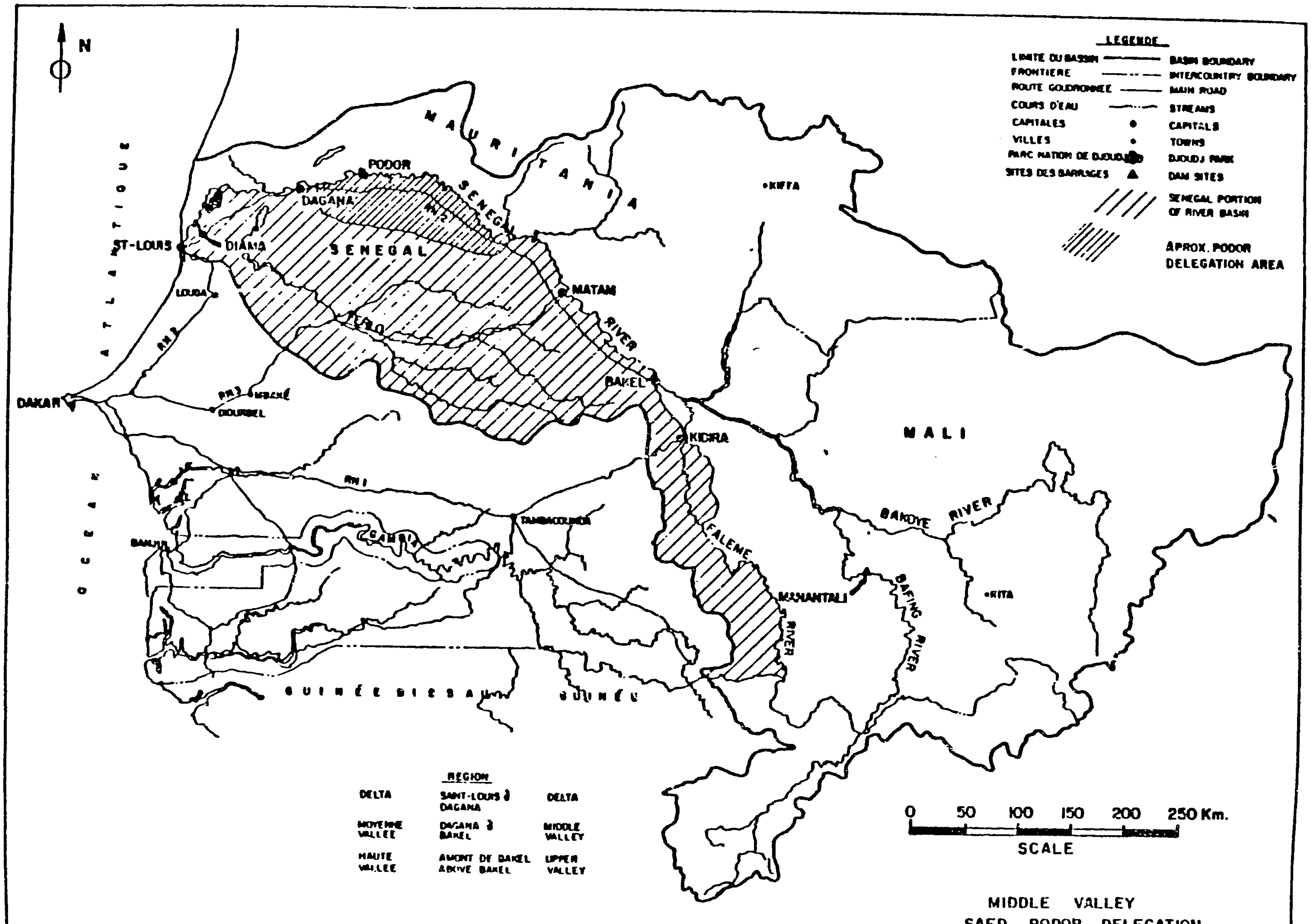
(Location shown on Figure 4).

The Podor cuvette perimeter was chosen due to socio-political reasons rather than for economic and technical considerations.

The area was set aside by the GOS several years ago for USAID contribution to the development of rice production in the heavy soils located in the flood plains of the Senegal River Valley and as a relief to the local population of the town of Podor and several nearby villages. Similarly, at that time, the GOS set aside several other areas in the flood plains of the Middle Valley for development by other donors.

The GERSAR master plan and subsequent engineering designs are based on the assumption that this perimeter will be developed primarily for rice and therefore the design flows correspond to the peak water demand for said crop although other crops such as corn might be produced more economically on the upper less heavy soils.

The project area is unique in the sense that it cannot be expanded and that it does not appear to be a prototype of future larger development. In effect, the proposed perimeter covering a gross area of 1400 ha is an island between the Senegal and Doue rivers and thus will require complete diking for flood protection. The lower part of the island outside the proposed irrigated perimeter has been set aside for flood recession agriculture. One or more farmer cooperative(s) will have to be organized for



MIDDLE VALLEY
SAED PODOR DELEGATION

FIGURE 4

management/operation of the irrigated perimeter and for agricultural production in both the irrigated perimeter and in the flood recession area. The irrigation water supply system is made of five independent sub-systems each fed by a separate pumping station. Distribution is by earth canal systems with very low velocities. The perimeter has an integrated drainage system and dewatering of drainage is provided by a pumping station.

In our opinion several issues need to be resolved before project implementation (see Part 4). These issues should be addressed by means of an in-depth project feasibility review. Possible use of buried pipe should be explored to facilitate operation and maintenance. Necessary buildings, equipment and power supply should be included.

At present some 170 hectares have been developed by SAED with funding from the Fond Europeen de Developpement (FED) and organized in several village irrigated perimeters. These small areas are farmed by village groupements.

The Middle Valley undoubtedly has a considerable potential for better areas than the Podor cuvette. In particular in some of the higher terraces not constrained by heavy soils or high development costs due to flood protection requirements and large flows required for rice production. It also appears that these areas lend themselves to diversified cropping patterns and more economical agricultural production. Also possibilities for future expansion appear to be excellent in these higher areas.

However, the available data base on physical resources, crops and marketing is scarce or nonexistent in the areas outside the flood plains and will have to be investigated. These investigations should be followed by planning the facilities required for irrigated agricultural development and by feasibility level design of said facilities. Trials of different crops other than rice, including high yielding varieties and of different irrigation systems combined with a suitable promotional effort to attract potential private investors, can best be carried out by way of a Demonstration/Investment Promotion Center.

In order to show investors interested in participating in the development of the Middle Valley the different possibilities regarding suitable crops and effective irrigation systems, the size of such a Center should be in the order of 200 hectares.

On the basis of available information and our visits to the area we recommend that the initial effort be focussed on the Podor Delegation areas where abundant land resources outside the flood plains appear to be available and because of its closer location to sources of potential services and available regional infrastructure.

Based on these considerations we recommend the carrying out of the following three program components for the Middle Valley.

Component 3 - Implementation of Podor Perimeter

a. Objective

Implement Podor cuvette irrigated perimeter and start perimeter operations.

b. Scope

1. Project Feasibility Review:
   - Physical resources
   - Crops/cropping pattern/ag practices
   - Human resources/farmers organization
   - Land tenure
   - Farm size/pattern/land development
   - Layout/design of perimeter
   - Access
   - Power supply
   - Operation and maintenance of perimeter facilities (irrigation, drainage, dikes, roads, power, buildings, etc.)
   - Project benefits/financial analyses

2. Bid documents
   - Design modifications and drawings as may be required/Design report
   - Supplementary field/lab investigations as may be required
   - Technical specs/pay items

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- Quantity take offs/Cost estimate
- Administrative/financial tender documents

3. Bid process (call for tenders subject to USAID regulation)
   - Contractors prequalification
   - Contractors bids
   - Bid analysis
   - Contract award
   - Order to commence work

4. Construction management
   - Review/approval of construction drawings prepared bu contractor
   - Supervision of construction, quality control including sampling/testing by independent qualified lab
   - Payment quantities/documents
   - Preparation of "as built" drawings
   - Procurement of mechanical/electrical equipment, including spare parts
   - Review/approval of shop drawings.O&M manuals of equipment by suppliers
   - Testing of facilities/equipment
   - Start-up
   - Preliminary acceptance

5. O&M
   - Transfer to organized farmers association/cooperative
   - Training of operators for minimum of one full year

6. Ag Program

As per IDP. However, assure that the training and extension program is based on work done at the Fenaye Research Station which, in turn, will need the timely support under the OMVS Agricultural Research Project II (625-0957).

7. Training program for farmers

As per IDP. However, the animal traction trainers should be replaced by farm machinery trainers.

c. Estimated requirements

1. Project Feasibility Review

- Expatriate staffing

Irrigation/drainage engineer, PM	6 months
Civil engineer	3 months
Soils/foundation engineer	1 month
Hydrologist	1 month
Soils scientist	1 month
Agronomist	1 month
Ag economist	2 months
Power supply specialist	1 month
Pump station specialist	2 months
Rural sociologist	2 months
Designer	2 months
TOTAL	22 months

/p

- SAED input - Engineers, soils scientist, soils lab, draftspeople, bilingual secretary, survey party, agro-socio-economic surveyors, drivers, etc.
- Vehicles
- Per diems, international travel, transportation, insurance, reproductions, communications, misc.

2. Bid Documents

At this stage of the project and pending execution of the Project Feasibility Review, it is not possible to make a precise estimate of requirements. Therefore a preliminary estimate is suggested as follows:

Expatriate Staffing

Civil engineer, P.M.	6 months
Irrigation/drainage engineer	6 months
Structural engineer	4 months
Foundations/soils engineer	4 months
Pump station specialist	3 months
Electrical engineer	2 months
Mechanical engineer	2 months
Civil engineer/roads/misc.	2 months
Spec writer	3 months
Misc. specialists	4 months
Designers	4 months
TOTAL	40 months

- Subcontract foundations exploration, soils analyses by qualified firm/lab
- SAED input - engineers, draftspeople, bilingual secretary, survey party, drivers, etc.
- Vehicles
- Per diems, international travel, out of pocket, transportation, reproductions, communications, insurance, misc.

3. Bid process (based on 6 month period)

Expatriate staffing

Senior construction engineer, PM	6 months
Design P.M.	2 months
Pump station specialist	1 month
Electrical engineer	1 month
Total	10 months

- SAED input, cost engineer, assistant, bilingual secretary, drivers

- Vehicles
- Per diem, international travel, transportation, communications, reproduction, insurance, misc.

4. Construction Management

At this stage of the project and pending preparation of Bid Documents it is not possible to make a precise estimate of requirements. Therefore a preliminary estimate based on a 30 month construction period is suggested as follows.

Expatriate Staffing

Senior Construction Engineer, P.M.	30 months
Civil engineer	12 months
Mechanical/electrical engineer	12 months
Misc. experts	4 months
Designers	26 months
Total	84 months

- Subcontract, independent qualified soils/concrete test lab for quality control.
- Subcontract quality control of buildings/structures as may be required by GOS under 10-year guarantee insurance provision (payment might be by contractor or owner as per current Senegalese law)
- SAED inputs: engineer(s), field inspectors, drafting, bilingual secretary
- Vehicles
- Per diem, international travel, transportation, communications, reproductions, insurance, misc.

5. O & M

Tentative requirements, subject to review as better knowledge of project design, construction and organization are known.

Expatriate Staffing

Senior Irrigation engineer, specialized in O&M of similar projects	12 months
Trainers (pending arrangement with suppliers) assumes 1 trainer for pump stations, one for irrigation, drainage and road systems.	24 months
Total	36 months

- SAED input, technical, office, secretarial support, drivers, as required
- Vehicles 36 months
- Per diem, international travel, transportation, communications, reproductions, insurance, misc.

6. Ag Program

As per IDP with previously suggested modifications.

7. Training Program for Farmers

As per IDP with previously suggested modifications.

Component 4 - Land Development Plan

a. Objective

Establish a Land Development Plan for 10,000 ha irrigation and select, plan and layout representative site for 200 ha Demonstration/Investment Promotion Center.

b. Scope

1. Carry out soils and topo surveys over a gross area estimated at 50,000 ha at 1:20,000 scale.

2. Determine land tenure and human resources within the above area.

3. Select 15,000 ha of irrigable land to have approximately 10,000 ha net irrigable area.

4. Prepare detailed soils and topo maps of selected 15,000 ha at scale of 1:2,000.

5. Carry out hydrologic and hydrogeologic feasibility investigations.

6. Study alternative development schemes.

7. Conduct feasibility agronomic and agro-economic studies

8. Prepare preliminary designs of main infrastructure of selected alternative, at feasibility level of detail.

9. Prepare preliminary development plan for selected alternative.

10. Prepare preliminary costing and economic/financial evaluation of proposed development plan.

11. Select, plan and layout 200 ha Demonstration/Investment Promotion Center. Determine preliminary investment cost and annual O&M costs.

c. <u>Estimated requirements</u>

1. Expatriate Staffing

Team leader, P.M.	36 months
Soil scientists	18 months
Hydrologist	4 months
Hydrogeologist	12 months
Rural sociologist	12 months
Irrigation engineer	24 months
Agronomist	18 months
Agroeconomist	12 months
Marketing specialist	8 months
Civil engineer	12 months
Design engineer	12 months
Misc. experts (forestry, environmental engineering, geologist, etc.)	6 months
Designers	6 months
TOTAL	180 months

42'

2. Subcontract aerial photo restitution for 50,000 ha, 1/20,000 scale including field controls, restitution and mapping with appropriate contours.

3. Subcontract low altitude aerial surveys, aerial photo restitution 15,000 ha, 1/2,000 scale including flight, aerial photos, field controls, restitution and mapping with appropriate contours.

4. Subcontract, groundwater exploration, drilling development and testing; estimated 6 main wells, 18-24 inches in diameter, variable depth; 10 observation piezometers variable depth, 4-6 inches in diameter, step-up pump testing of main wells, water sampling and laboratory analyses, well/piezometer geologic logging and development by qualified firm. Test pumps should be capable of lifting 80-100 lps from all aquifers tested. The piezometers could be coordinated/integrated with the network proposed under USAID Groundwater Monitoring Project No. 625-0958.

5. Misc. soils exploration/lab for materials and foundatons by qualified lab.

6. SAED input - assistant team leader, counterpart engineers and scientists, topographic survey crews, drafting, soils lab, bilingual secretary, administrative assistants, drivers, etc.

7. Vehicles 144 months

8. Per diems, communications, international travel, transportation, reproductions, etc. irrigation, drainage and road systems

Component 5 - Demonstration/Investment Promotion Center

a. Objective

Design, implement and begin operations of Demonstration/ Investment Promotion Center.

b. Scope

After site selection, planning and layout under Component 4, the establishment of this demonstration/investment promotion center needs design, implementation (construction and procurement) for such inputs as offices, housing, workshops, farm buildings, access and internal roads, water supply systems, various irrigation systems, drainage system, power supply, on-farm development and several other facilities. Given the special nature of this facility, implementation should be by a negociated contract with a reputable contractor and by procurement of equipment required following the design and specs established by the consulting engineer and following a prequalification/ short-list procedure according to USAID regulations.

Construction management should be by the U.S. consulting engineering firm with scope similar to that indicated for the implementation of the Podor perimeter. Upon construction, the consulting engineer in agreement with USAID and SAED should set up a farm management/demonstration team in charge of running all farming operations and an investment promotion unit. The latter unit would develop and later implement the investment promotion program geared to attracting potential investors and to follow the legal/financial process until contractual agreements are finalized.

c. Estimated requirements

At this stage of the project it is not possible to make an accurate estimate of required inputs; however, a tentative cost estimate is given in Section 2.5 of the present report.

The expatriate staffing for the operation of the demonstration/investment center may be as follows:

1 Agronomist/Farm Manager
1 Agribusiness specialist
1 Irrigation engineer
1 Electrical engineer
1 Mechanic
1 Veterinarian

Short-term advisors (legal, financial, technical)

The above expatriate staffing will have to be supplemented by a number of Senegalese professional, technical and administrative staff and by Senegalese skilled and common labor. All necessary farm inputs and equipment should also be provided.

This center should work in close coordination with the Ministries of Finance and Rural Development, SAED, experimental station and other related GOS agencies and with USAID and other financial and invesetment institutions, as well as with potential corporate and individual private investors.

2.3.3 Upper Valley - Components 6 and 7

(Location shown on Figure 5)

The Bakel Delegation (upper part of the Senegal River and the Faleme) is the area in the Senegal valley where the lowest infrastructure investments are required for irrigated perimeter development. Thirty perimeters exist in the area totalling some 900 ha; their development has been substantially aided by the Bakel Small Irrigated Perimeters Project.

The basic physical data on the Bakel Delegation are even more limited than in the downstream parts of the valley. No evaluation has been made of potentially irrigable areas in this Delegation. Site selection of new perimeters has been based on local (village) demand rather than on any appraisal of the technical qualities of the sites.

For most effective development of the area we propose a two-phased approach. The first phase (Program Component 6) consists of a complete resource inventory of the area of the Bakel Delegation (some 200 x 50 km, see Figure 5) including the Senegal and Faleme valleys as well as the adjacent dieri land. Then, a master plan for development of the region should be made; such a plan would include all aspects of rural development but would focus on irrigated perimeters. The master plan should address such issues as watershed management of the dieri lands, including soil conservation measures and control of runoff, which currently inundates irrigated perimeters and destroys dikes; rural roads, village

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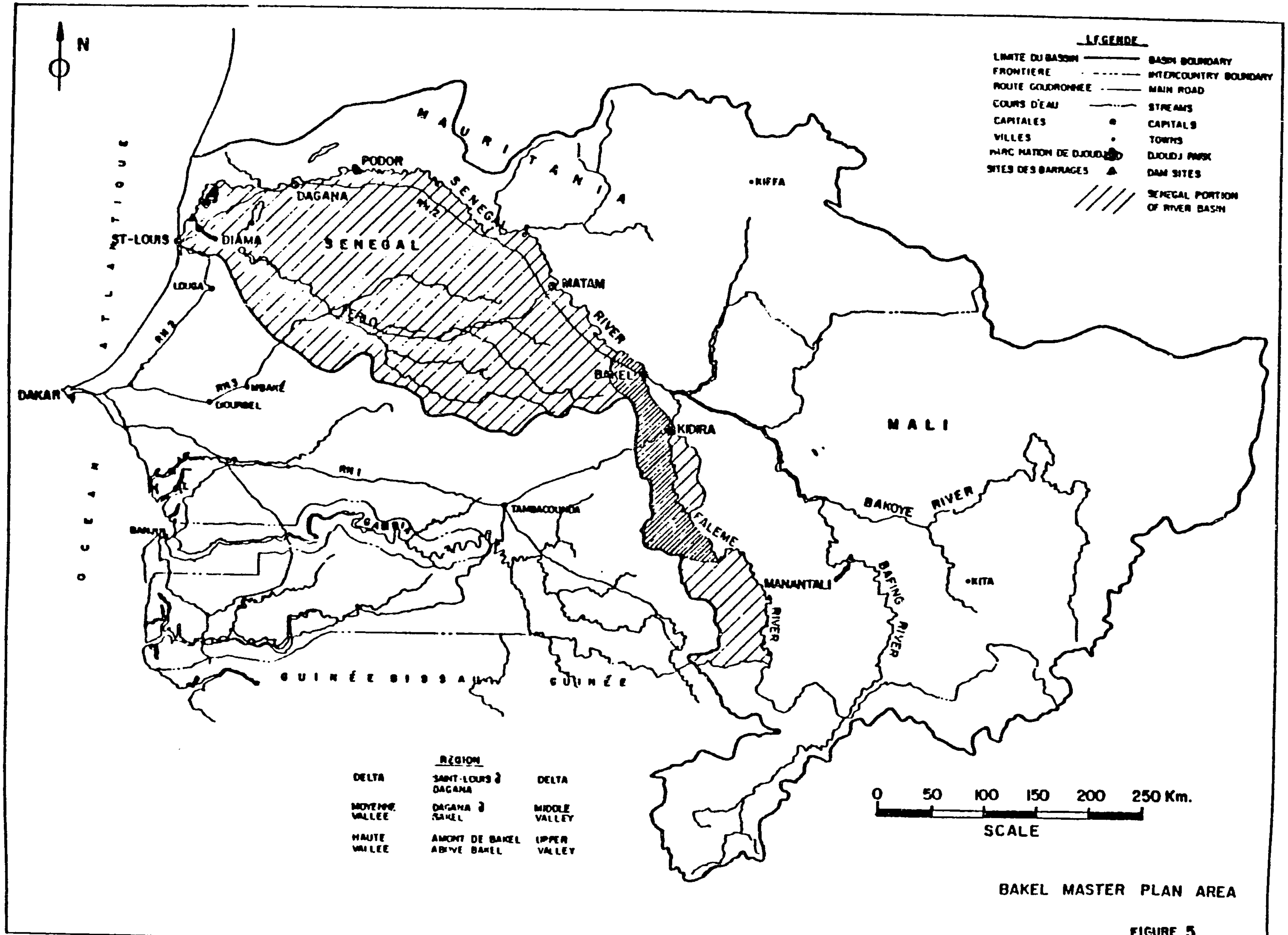

BAKEL MASTER PLAN AREA

FIGURE 5

water supply, power requirements of municipal and agricultural users, and health facilities. The master plan would set priorities for development in an organized and efficient manner and would guide future investments in the Bakel Delegation.

The second phase (Program Component 7) consists of the execution of perimeter development of an initial 1000 ha area on the basis of the master plan findings. The outputs would include irrigation as well as the necessary infrastructure of feeder roads.

The future systems and main structures will be of a more permanent nature than present and design/specifications will be upgraded. This will include, but not be limited, to the following concepts as deemed appropriate:

1. Combining pumping stations and/or construction of larger fixed structures where warranted. Use of electric pumps for areas close to existing power stations or where addition of a generating facility and power transmission can be justified. Power features are to be coordinated with power authority.

2. Penstocks will be buried and will lie on properly designed foundations, anchoring/slope stability will be provided where needed.

3. Larger siphons, entrance/outlet structures will be of improved design/construction. Alternative designs will be considered, cast-in-place concrete siphon vs. pipe, water

stops/joints, grills, fencing to keep people/animals away from siphons.

4. Head basins will be designed to insure required flow distribution, energy dissipation and flow measurement functions. Larger basins will be of reinforced concrete and will be protected for stability (compacted fill/drainage, as required). Fencing will be provided for human/animal safety.

5. For larger canal systems, flow measurement weirs, hand operated gates, sills will be provided to insure proper water control.

6. Main earthwork will be compacted by mechanical means, degree of compaction/humidity will be tested at site lab to check conformity with specifications.

7. Concrete/mortar mixes will be designed, aggregates will also conform to specifications, inspection/tests will be conducted during construction.

8. Farm roads and drains will be introduced as needed.

9. Need for diking will be evaluated as part of alternative configuration analysis and will take into consideration the watershed management concept. This feature will be added when economically justified.

10. Size of farm blocks land development for new areas will be determined based upon proposed cultural pattern/desired degree of mechanization.

11. Buried pipe and possible canal linings will be considered as alternatives to earth canal systems to improve water control, minimize losses and need for maintenance.

12. Call for tenders might be a viable option for large systems in the future, especially if qualified contractors are involved in other construction activities in the area.

Component 6. Bakel Master Plan

a. Objective

Prepare a resource inventory and master plan for development of irrigated agriculture in the Upper Senegal/Faleme valleys (SAED Bakel Delegation).

b. Scope

The resource inventory for an area of 200 x 50 km includes the following elements:

- topography
- soils/land capability
- crop suitability
- natural vegetation/range resource
- land use/land tenure

- inventory of existing agricultural conditions
- surface/groundwater and climate
- human resources
- animal number/type (seasonal)
- marketing survey
- processing

The results of the natural resource inventory will be presented at 1:50,000. Aerial photography at 1:10,000 with mapping, for final presentation at 1:20.000, presents the detailed results of the potentially irrigable lands. This data base constitutes a basic needed planning tool for most effective development of the area. The master plan is prepared to set priority areas for irrigation development in an organized and efficient manner and to guide future investments in the Bakel Delegation. Based on the proposed development, an area of 1000 ha will be selected for implementation, on the basis of criteria established in the Master Plan. A feasibility study will be prepared for this 1000 ha project, including:

- physical resources
- crops/cropping patterns/ag pattern/ag practice/ag economics
- human resources/farmer organization
- land tenure
- farm size/pattern/land development
- layout/design of perimeter

- power supply
- access
- project benefits

c. Requirements

The inputs required for production of a master plan for a gross area now estimated at 1,000,000 ha (10,000 sq. km) along the upper Senegal and Faleme valleys over a three-year period are estimated at approximately US $4 million. This cost essentially covers expatriate technicians, aerial photography and final map and report production.

Component 7. Bakel Irrigated Perimeter Development

a. Objective

Implement an initial 1,000 ha irrigation sector on the basis of the master plan, supported by a fully operational experimental farm and provided with water and power supplies, and access roads.

b. Scope

1. Bid documents
   - Design and drawings as required/design report
   - Supplementary field/lab investigations as may be required
   - Technical specs/pay items
   - Quantity take off/cost estimate

- Administrative/financial tender documents

2. Bid Process (call for tenders subject to USAID regulation)
   - Contractors prequalification
   - Contractors bids
   - Bid analysis
   - Contract award
   - Order to commence work

3. Construction Management
   - Review/approval of construction drawings proposed by contractor
   - Supervision of construction, quality control including sampling/testing by independent qualified lab
   - Payment quantities/documents
   - Preparation of as-built drawings
   - Procurement of mechanical/electrical equipment, including spare parts
   - Review/approval of shop drawings. O&M manuals of equipment by suppliers
   - Testing of facilities/equipment
   - Start-up
   - Preliminary acceptance

4. O & M
   - Transfer to organized farmers association/private investors
   - Training of operators for minimum of one full year

5. Ag Program

- As per feasibility study

6. Training Program

- As per feasibility study

c. Requirements

The level of funding required for the implementation (items 1, 2 and 3 above) of 1,000 ha of irrigation project is estimated at US $10 million. Other development costs (items 4, 5 and 6) are estimated at an additional US $5 million.

The timing, phasing and costs of other support facilities necessary for full development of the Bakel Delegation agricultural potential can be determined upon completion of a the master plan for the area (see Component 6). Such facilities include, but are not limited to, village drinking water supplies and power, health care, educational facilities, improved credit, agro-industries, etc.

2.3.4 SAED/DPA Management and Training - Component 8

SAED was created in 1965 and through the years developed into a large regional development agency with responsibility for the entire left bank of the Senegal and Faleme rivers. Since 1981 SAED has been undergoing reorganization, its major objectives are now:

- to limit the cost of irrigated agricultural production and the cost of state intervention
- to increase agricultural production by placing 240,000 hectares of land under irrigation during the next 50 years
- to have the rural population manage local development activities
- to secure and increase local incomes
- to safeguard the environment and improve social conditions.

More and more SAED is taking the role of coordinator, advisor and manager of irrigation development and becoming a technical support organization to local farmer groups. Figure 6 shows how SAED intends to change its functions in the near future.

One of the key departments of SAED is the 'Direction de la Planification et des Amenagements' (DPA). The main task of DPA is to 'plan and supervise, within the general policy set by the Direction Generale', all regional rural development undertakings, to

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assist the operational services in perimeter development and water management and to assure the monitoring of agricultural production. Further details on SAED and the functions of DPA are presented in Annex 3.

It is essential that close collaboration be established by the consultant carrying out the seven main components of the Program and SAED, in particular SAED's DPA office. For effective implementation of the Program the technical and operational capability of DPA in St. Louis needs therefore to be strengthened. This requires Component 8, which includes:

- transfer of U.S. managerial, administrative and technical know-how by direct on-the-job training and by formal training in the U.S. of administrators, engineers, planners, agronomists, etc.
- introduction of modern U.S. office equipment and supplies, including vehicles and emergency power supply and drafting equipment.

Component 8 - SAED/DPA Management and Training

a. Objective

Strengthen SAED's DPA office to allow for effective program coordination and management and subsequent independent continuation.

b. Scope

The management and training functions necessary to execute the Program in a timely manner by the consulting engineer with SAED involves:

- mobilization of staff
- procurement of equipment
- organization and scheduling of work
- supervision of work progress
- liaison with AID and GOS
- coordination of operations
- administration and accounting
- demobilization

c. Requirements

1. Expatriate staffing

Project Director	5 Years
Deputy Technical Manager	5 years
Administrator	5 Years
Accountant	5 Years

2. Local Support Staff (Managerial, administrative, clerical, secretarial) — 30-40 years

3. U.S. Back-UP and Support — 5 Years

4. Equipment and Supplies

Office equipment, including computer

Drafting equipment

Power supply

Vehicles (5)

5. Overseas Training DPA Staff 5 x 2-3 Years each

6. DPA Existing Office Space and Facilities

2.4 Time Schedule

The period of time scheduled for the Program is arbitrarily set at five years. In this period of time substantial tangible progress can be made in the development of irrigation in the Senegal valley. In Figure 7 a tentative time schedule is presented which shows when the major program components will be carried out.

2.5 Cost Estimate

A preliminary estimate of the costs of the program was made. These costs should be considered as indicative only. At this time some of the program components cannot be exactly costed in view of the substantial variations that are possible in construction costs. In Figure 8 a tentative cost estimate is presented which shows the level of funding (1984 dollars) required for each program component on an annual basis. This cost does not include GOS and USAID costs.

FIGURE 6. PROPOSED DISENGAGEMENT OF SAED DURING THE THREE YEARS OF THE NEW "CONTRACT PLAN" JULY 1984 - JULY 1987

FUNCTIONS	NOW	AT THE END OF THE "CONTRACT PLAN" JUNE 1987
Regional Planning	SAED	SAED
Fund Raising	SAED/Ministry of Plan	SAED/Ministry of Plan/Private Sector
Preparation of Perimeters		
- Location analysis	SAED	SAED
- Technical engineering analysis	SAED	SAED or others
- Construction of perimeters		
. Major ground work	SAED or Private Sector	SAEDorPrivate Sector
. Subsidiary work		
Large perimeters	SAED	SAED/Private Sector
Small perimeters	SAED/Farmers	Farmers
- Irrigation equipment (purchase and installation)		
Large perimeters	SAED	SAED and others
Small perimeters	SAED	SAED and others
- Irrigation equipment, management upkeep, water management		
Large perimeters	SAED	SAED and Farmers
Small perimeters	SAED	Farmers/Private Sector
- Land Preparation		
Large Perimeters	SAED	SAED and Farmers
Small Perimetesr	SAED+GUMA*/Private Sector	GUMA*/Private Sector
Inputs Distribution		
. Seeds	SAED	Farmers (to be studied)
. Fertilizer	SAED	Private Sector/Farmers
. Pesticides	SAED/Farmers	Private Sector/Farmers
. Fuel and electricity		
Large perimeters	SAED	Farmers
Small perimeters	Farmers/SAED	Farmers
Harvest	Farmers	Farmers/GUMA
Threshing	Farmers	Farmers/GUMA/Private Sector
Marketing of Paddy	SAED/Village Sections	Village Sections
Milling:		
Traditional	Farmers/Private Sector	Farmers/Private Sector
Factory	SAED	Private Sector
Marketing of Rice		
Whole Grain	SAED/CPSP	Private Sector
Broken Rice	SAED/CPSP	Private Sector/CPSP
Maintenance		
Provision of spare parts	SAED/Private Sector	Private Sector/SAED
Mechanical Work	SAED/Private Sector	SAED/Private Sector
Extension Services		
Traditional	SAED	0
Revised	SAED	SAED
Farmers Training (literacy, numeracy)	SAED	SAED

*GUMA = Groupement d'Utilisation en commun du Materiel Agricole (Association for the use of agricultural equipment)

FIGURE 7. SENEGAL IRRIGATION PROJECT - TIME SCHEDULE

REGION	PROGRAM COMPONENT	NAME	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Delta	1	N'Thiagar Perimeter Site Investigation/ Monitoring Program					
Delta	2	N'Thiagar Perimeter Rehabilitation Feasibility Study					
Middle Valley	3	Podor Perimeter Implementation					
Middle Valley	4	Land Development Plan for 10,000 ha Irrigation					
Middle Valley	5	Development of Demonstration/ Investment Promotion Center					
Upper Valley	6	Bakel Master Plan					
Upper Valley	7	Bakel Irrigated Perimeter Development					
Senegal Portion of Senegal River Basin	8	SAED/DPA Management and Training					

FIGURE 8. SENEGAL IRRIGATION PROJECT COST ESTIMATE IN MILLION DOLLARS

REGION	PROGRAM COMPONENT	NAME	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
Delta	1	N'Thiagar Perimeter Site Investigation/ Monitoring Program	0.4	0.1	0.2	-	-	0.7
Delta	2	N'Thiagar Perimeter Rehabilitation Feasibility Study	-	-	0.5	-	-	0.5
Middle Valley	3	Podor Perimeter Implementation	1.0	3.6	4.6	4.3	0.8	14.3
Middle Valley	4	Land Development Plan for 10,000 ha Irrigation	1.0	1.2	1.2	-	-	3.4
Middle Valley	5	Development of Demonstration/ Investment Promotion Center	-	2.4	2.8	1.7	1.6	8.5
Upper Valley	6	Bakel Master Plan	1.0	1.5	1.5	-	-	4.0
Upper Valley	7	Bakel Irrigated Perimeter Development	-	-	4.0	6.0	5.0	15.0
Senegal Portion of Senegal River Basin	8	SAED/DPA Management and Training	1.0	1.0	1.0	1.0	1.0	5.0
		SUBTOTAL	4.4	9.8	15.8	13.0	8.4	51.4
		CONTINGENCIES	0.2	0.5	0.8	0.7	0.4	2.6
		TOTAL	4.6	10.3	16.6	13.7	8.8	54.0

Note: The above estimates do not include GOS counterpart costs, USAID management costs, nor escalation beyond 1984.

PART 3

SENEGAL RIVER VALLEY IN SENEGAL

3. SENEGAL RIVER VALLEY IN SENEGAL

3.1 Land

3.1.1 Data Requirements for Irrigation

The land characteristics most significant to irrigation studies are of soil, topography and drainage.

FAO (1979) lists the following principal uses and reasons for soil studies in irrigation investigations:

- i. to ensure selection of soils for irrigation that are productive;
- ii. to aid in the location of canals and other irrigation works;
- iii. to determine irrigation needs of specific soil types;
- iv. to determine drainage needs of specific soil types;
- v. to determine alkali reclamation needs;
- vi. to determine overall land levelling needs;
- vii. to determine erosion control needs;
- viii. to help in determining the size of farms;
- ix. to aid in appraising land value in order to allocate the costs of development on the basis of ability to pay;
- x. to aid in determining crops suitable for particular soils;
- xi. as an aid in devising individual farm management needs, such as use of fertilizers, use of soil amendments, subsoiling, safe land levelling, type of irrigation and/or drainage, etc.

In terms of topography, FAO states that information "is extremely important in irrigated agriculture for it influences choice of irrigation method, the labor requirements, irrigation efficiency, drainage, erosion, range of possible crops, costs of land development and size and shape of fields." Drainage, defined as "the removal of excess surface and subsurface water" (FAO) is important in controlling water table levels, and thereby aeration of the rooting zone and control of salinization and alkalinization of the soils.

3.1.2 Existing Data Base

Information on the land characteristics of the Senegal valley - especially information at a scale pertinent to irrigation planning - is limited. In general, most of the valley (downstream from Bakel) is mapped, as to soil and geomorphology, at 1/50,000. This is supplemented by several reports for individual small areas. Only that information pertinent to our specific study area is included here, other reports are listed by ORSTOM.

Equally limited is the apparent consideration given to the physical characteristics of the land in much of the existing irrigation planning and development. This is not only true of SAED but also of projects implemented by "experienced" donor agencies. The Bakel Small Irrigated Perimeters Project was designed and implemented on a totally inadequate data base. Data collection forms part of the IDP, but only for preselected areas. A thorough analysis of the physical situation is almost nonexistent.

Perimeter locations are chosen on the basis of socioeconomic demand rather than physical suitability. At the present stage of development - area and technology - this may not be important, however, as water management and productivity become of greater concern, the failure to consider physical suitability may prove to be very limiting. SAED now has a policy of soil mapping of new or rehabilitated perimeters, but there is little evidence that this information is considered in executing perimeter development.

Existing data pertinent to the program areas in the Senegal valley are as follows:

Etudes Hydro-Agricole du Bassin du Fleuve Senegal. SEDAGRI, 1973. This report is one of a series of studies of the Senegal River Basin executed under FAO auspices. The area covered is of the valley, only upstream to Bakel. Two sets of maps, at 1/50,000 scale, are presented, the first covering soil and geomorphic units, and the second soil capability for irrigated agriculture. The procedures and mapping units are fully described in the accompanying report.

The soil-geomorphic mapping relied heavily on air photo interpretation of geomorphic units, the geomorphology being considered central to soil differentiation. Soils are classified by the French/ORSTOM system. Soil capability was determined using a modification of the US Bureau of Reclamation guidelines. The classification is essentially based on physical characteristics - soil, topography and drainage; socio-economic considerations are not discussed. In terms of the soil, the principal characteristics considered are texture and salinity, other factors being considered as non-differentiating in the valley or being intimately associated with these two characteristics. In this way six irrigability classes were recognized (see Figure 9). Classes 1 and 2 are irrigable for a variety of crops, and classes 1R and 2R are suitable primarily for irrigated rice production.

Classes 6 and 6R are considered essentially non-irrigable. According to this classification, 74% of the valley, or some 828,000 hectares, are irrigable, of which only 23.6% (17.5% of valley lands) are suitable for rice (see Figure 10). If this is accepted at face value, then it provides an interesting contrast to the emphasis being placed on rice in the existing perimeters. No breakdown is given of the division of these lands between the three countries of Senegal, Mali and Mauritania.

This land classification system was criticized in a review carried out for USAID by the Bureau of Land Reclamation. In particular they criticize the lack of economic analyses which, when considered, would considerably reduce the land considered suitable for irrigation. Their full comments are reproduced in Appendix 5.

This study is the only complete study for most of the valley. however, it is a reconnaissance study and its scale and detail are insufficient even for a preliminary choice of irrigated perimeters; as noted, 74% of the valley is considered irrigable, given the characteristics studied, which does little to help delimit

FIGURE 9. CRITERIA EMPLOYED FOR LAND CLASSIFICATION

Caractères du terrain	Classe 1	Classe 2	Classe 1 R	Classe 2 R	Classe 6	Classe 6 R
SOL						
Texture (voir triangle fig. n° 13)	Moyenne : 15 à 35 % d'argile moins de 85 % de sable	Fine à très fine 35 à 60 % d'argile et grossière 0 à 15 % d'argile, 70 à 85 % de sable.	Plus de 60 % d'argile.	Plus de 60 % d'argile.	Sable : moins de 10 % d'argile, plus de 85 % de sable.	Plus de 60 % d'argile.
pH	de 4,5 à 9	de 4,5 à 9	de 4,5 à 9	de 4,5 à 9	4,5 ou 9	4,5 à 9
Salinité (extrait 1/10 en µmhos)	< 800	800 à 1 000 ou > 1 000 + drainage facile	< 800	800 à 1 000 ou > 1 000 + drainage	> 1 000 + drainage difficile	> 1 000 + drainage difficile
TOPOGRAPHIE						
Pente	0,25 à 2 %	2 à 5 % + mesures antiérosives.	< 0,5 %	< 0,5 %	> 5 %	< 0,5 %
Relief	Peu de nivellement [illegible]	Nivellement [illegible]	Très peu de nivellement < 300 m3	Très peu de nivellement < 300 m3	Nivellement important + [illegible]	Très peu de nivellement < 300 m3
Couvert végétal		[illegible]				
DRAINAGE						
[illegible]	moins de 50 m/ha	50 à 300 m/ha	assurée par gravité	assurée par gravité	difficile par gravité.	assurée par gravité.
Drainage	non nécessaire	nécessaire et possible, [illegible], avec drainage facile	non nécessaire	nécessaire et possible (nappe filtrante à moins de 50 cm).	nécessaire et difficile	nécessaire et difficile (pompage)

(To be finalized for inclusion in Final Report)

FIGURE 10. HECTARAGE ACCORDING TO LAND CLASSIFICATION

Famille de carte		Classes d'aptitudes 1	2	1 R	2 R	6	6 R	TOTAL
Bakel 4 c	(ha)	2,796	656	—	—	305	—	3,757
Bakel	(%)	74.4	17.5	—	—	8.1	—	
Sélibabi 1 a	(ha)	4,879	6,078	2,737	—	4,791	—	18,485
1 b	(ha)	12,810	1,650	4,058	—	3,144	—	21,662
1 c	(ha)	15,051	8,631	7,675	—	7,312	—	38,869
3 a	(ha)	1,780	2,155	2,375	—	78	—	6,388
Selibabi	(%)	40.4	21.9	19.7	—	17.9	—	
Matam 2 d	(ha)	7,083	2,779	5,282	—	1,838	—	16,982
3 d	(ha)	2,017	4,758	406	—	341	—	7,522
4 a	(ha)	7,388	6,792	3,954	—	1,246	—	19,380
4 b	(ha)	9,867	3,283	10,122	—	8,051	—	31,323
4 c	(ha)	20,762	18,772	942	—	7,148	—	47,624
Matam	(%)	38.0	29.3	16.7	—	15.0	—	
Kaédi 1 a	(ha)	15,539	8,261	4,391	—	5,283	—	33,474
1 b	(ha)	12,114	11,794	17,068	—	6,290	—	47,266
1 c	(ha)	4,272	1,136	3,905	76	1,288	—	10,677
2 a	(ha)	4,271	10,548	13,238	—	4,678	—	32,735
2 b	(ha)	1,740	4,434	6,300	—	152	—	12,626
Kaédi	(%)	27.7	26.4	32.8	0.05	12.9	—	
Podor 2 b	(ha)	1,025	[illegible],028	—	—	514	—	3,570
2 c	(ha)	2,622	7,390	3,896	—	680	—	14,583
2 d	(ha)	13,252	21,231	9,750	—	3,384	—	47,617
3 a	(ha)	18,790	21,504	13,518	3,420	3,257	—	60,459
3 b	(ha)	26,292	20,394	8,699	—	4,780	—	60,165
4 a	(ha)	18,240	15,160	11,262	114	5,046	—	49,824
4 b	(ha)	2,0[illegible]0	1,516	614	—	1,136	—	5,306
Podor	(%)	34.0	36.9	19.7	1.4	7.7	—	
Dagana 1 c	(ha)	1,495	33,652	2,374	154	10,814	74	48,556
1 d	(ha)	512	7,992	1,570	—	440	—	10,514
3 a	(ha)	421	10,566	1,373	2,185	3,885	—	18,430
3 b	(ha)	3,782	18,674	5,756	—	12,340	—	40,552
4 a	(ha)	4,025	24,039	5,467	296	12,022	—	45,552
4 b	(ha)	14,295	26,114	12,107	156	2,932	—	55,514
4 c	(ha)	—	—	—	—	6,120	—	6,120
Dagana	(%)	10.9	54.2	12.8	1.2	21.7	0.03	-
Saint-Louis 2 a	(ha)	—	6,180	—	320	55,280	6,110	67,89[illegible]
2 b	(ha)	—	2,238	120	214	26,166	—	25,736
2 c	(ha)	470	24,144	136	4,776	25,271	9,031	63,826
2 d	(ha)	7[illegible]6	41,538	240	13,446	10,381	5,095	71,407
4 a	(ha)	[illegible]	10,792	—	2,840	8,804	3,216	25,706
4 b	(ha)	376	10,976	2,594	5,944	4,290	3,744	27,924
Saint-Louis	(%)	0.5	33.5	1.0	9.6	45.6	9.5	
Louga 4 c	(ha)	—	3,433	—	—	8,850	—	12,183
Louga	(%)	—	28.1	—	—	72.6	—	
Surfaces totales		230,675	401,488	161,929	33,941	258,339	27,273	1,113,645
% du total		20.7	36	14.5	3.0	23.2	2.4	

SOURCE: ETUDES HYDROAGRICOLES DU BASSIN DU FLEUVE SENEGAL. SEDAGRI (1973) priority areas. Similarly, many of the mapping units are so large that proposed perimeters fall completely inside one unit. The concept of a mapping unit should be fully understood. On average, land within a mapping unit has characteristics which are closer to the central concept of that unit than to the central concept of adjacent units. At 1/50,000, this can hide a lot of variation.

Etude Hydro-Pedologique des Perimetres de Bakel - FAO, 1983. This study, executed by the SAED soils unit under the guidance of an FAO expert, provides soils information for seven existing (in 1982) perimeters in the Bakel Delegation. The work consists of a series of 7 maps (the office resonsible at USAID for the Bakel project eventually located 5 of these 7 maps. This is instructive in light of the comments previously made about the lack of attention being given to the existing data base) and an accompanying report.

The perimeters of Gallade, Kounghani, Yafera and Collengal were mapped using existing topographic maps at scales of 1/1,000 and 1/20,000. Such maps did not exist for Gande, Sebou, and Ballou, for which sketch maps were produced in the field. Mapping was executed by systematic observations, as normal for this scale of work. A maximum depth of 1.5 m was studied, which is perhaps shallow for irrigation studies. The maps present, for each mapping unit, slope, microrelief, soil texture and depth, and soil drainage (hydraulic conductivity). Further details on the physical and chemical properties of the soils are contained in the accompanying report. An interpretation of soil capability for irrigation was made, loosely based on the U.S. Bureau of Reclamation system. Again, the interpretation was entirely based on physical characteristics, economic aspects were not considered. Finally, consideration was given to crop suitability.

While the quality of the work is not questioned, two observations are made. Firstly, this work covers but a very small portion of the Bakel Delegation and many of the perimeters studied have already been expanded beyond the limits of the study area. Secondly, the maps contain no location control, making it difficult to relocate the study areas in the field.

Bassin Versant du Collengal de Bakel: Rapport Interimaire - Land System, Rome. This report is a study of the watershed of the Collengal stream, which enters the Senegal River just upstream of Bakel. The study consists of a series of maps and an accompanying report. Among the maps are found soil and soil capability maps at a scale of 1/20,000, and topographic maps at 1/2000. The report provides some elaboration on the cartographic units and the soil characteristics, but provides no explanation as to how the mapping was carried out. While an integrated watershed approach is desirable, this study is very limited in its aerial coverage and does not add significantly to our knowledge of the potential for irrigation in the valley.

Etudes de Rehabilitation, de Factibilite et d'Avant Projets Detailles de Perimetres d'Irrigation sur la Rive Gauche du Fleuve Senegal: Perimetre de Podor - GERSAR, 1983.

As part of the GERSAR master plan for the left bank of the Senegal River, the soils unit of SAED carried out a soils study of the Podor basin. Soil observations were systematically made on the basis of a grid, with observations being made to the depth of 2.5 meters. A number of samples were taken and details appear in the report. Classification was by the French system. Two maps are presented. The first shows soil type, surface texture, and geomorphology. The second presents, for each mapping unit, information on texture, salinity, acidity, alkalinization, and permeability for each 30 cm of soil depth, down to 150 cm. While the maps are at 1/5,000 scale, the work was apparently carried out at 1/10,000. This is the inverse of the normal process and it should be noted that increasing scale does not increase detail; thus the detail is that appropriate to a map at 1/10,000. However, the network of observations was fine and the soils do not appear to be very variable, such that the information is probably acceptable for irrigation planning.

Agro Pedologie de la Vallee et du Delta du Fleuve Senegal - FAO, 1978. The existence of this report is noted, but we were unable to obtain a copy during our visit.

Soils of the Senegal River Basin - M.K. Radwan, 1982. This report was commissioned as part of a Louis Berger study for USAID. It consists essentially of a reworking of existing information, especially the 1975 FAO report, supplemented by limited field observations. It does contain some specific comments on some of the Bakel perimeters and of the Podor basin and on soil capability for different crops.

Aerial Photographic Coverage (see Figures 11, 12 and 13). In 1980, the whole Senegal River Basin was flown for photo coverage at a scale of 1/50,000 and, for subareas, at 1/10,000. Photography exists in panchromatic and in color infrared. This is a valuable data source which, to our knowledge, has never been used. An incomplete set exists at USAID. SAED, who is responsible for development in the valley, does not have a copy of the photos. Indeed, SAED/Bakel was unaware of their existence. One of the noticeable aspects wherever we went was the lack of maps. At the very least these photos could be used to generate maps of existing and intended areas of intervention. Considering the cost of obtaining aerial photography, the lack of usage is inexcusable.

3.1.3 Nature of the Valley Lands

The Senegal-Faleme valley in Senegal is here considered in three sections - the Upper Valley, upstream from Bakel and including the Faleme, the Middle Valley from Dagana to Bakel, and the Delta, from St. Louis to Dagana. These three areas each have quite distinct characteristics.

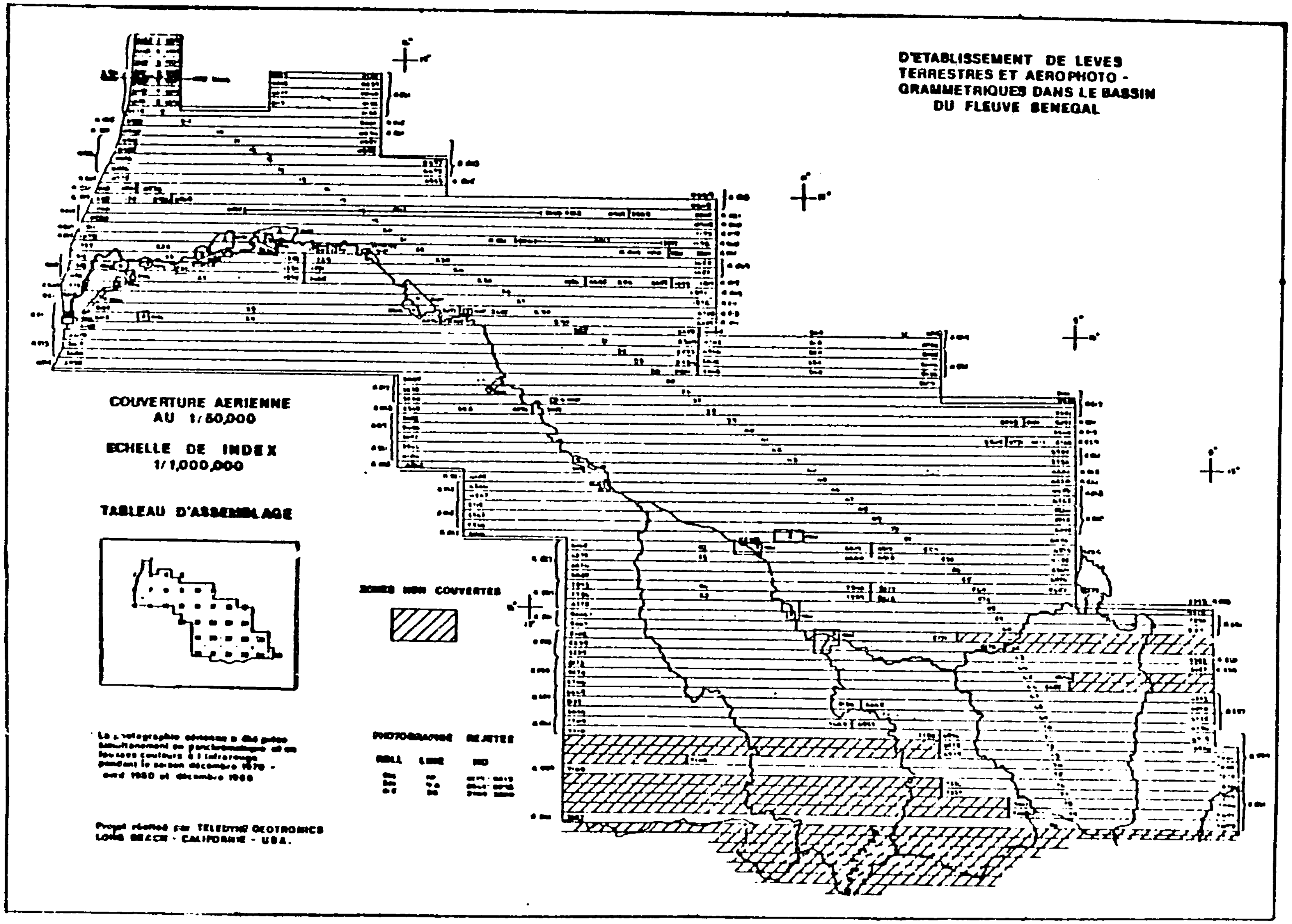


FIGURE 11. AERIAL PHOTOGRAPHIC COVERAGE OF THE SENEGAL RIVER BASIN PROJECT OMVS/USAID NO. 625-0620

FIGURE 12. ORTHO PHOTO MAPS - SCALE 1/50,000

MAURITANIA AND SENEGAL

E. Dagana
- 3b
- 1d
- 4c
- 4a
- 4d
- 4b

F. Guiers Sud

G. Kaedi
- 1c
- 1a
- 1b
- 2a
- 2b

H. Keur Momar Sar

I. Matam
- 3b
- 4c
- 4d
- 4a
- 4b
- 2b

J. Naudi

K. Podor
- 3a
- 3b
- 4a
- 4b
- 2c
- 2d
- 2b

L. Selibabi
- 3a
- 1c
- 1a
- 1b

SOURCE: TELEDYNE GEOTRONICS (1980)

FIGURE 13. ORTHO PHOTO MAPS - SCALE 1/10,000

SENEGAL

1. Bakel
   - Bakel (Badiara) = 38
   - Bakel (Bakel Ville) = 39
   - Bakel (Lotiande) = 40
2. Diawara & Mouediri
   - Diawara (Diawara) = 41
   - Diawara (Doundou Khore) = 42
   - Diawara (Ouloum Baba) = 43
   - Mouediri-Diawara (Mouediri) = 44
   - Mouediri (Galadi) = 45
   - Mouediri (NDiorol) = 46
   - Mouediri (Dembankane) = 47
3. Kassak & Boundoum
   - Kassak-Boundoum (Kassak Nord) = 127
   - Boundoum Nord (Zone Moyenne) = 128
   - Boundoum Nord (Boundoum Nord) = 129
   - Boundoum Nord (Gorom-Aval) = 133
   - Boundoum Nord (Gaela) = 134
   - Boundoum Nord (Rhad) = 135
4. Lac de Guiers
   - Lac de Guiers (Seier) = 121
   - Lac de Guiers (Kougue) = 122
   - Lac de Guiers (Tounde Maram NDoumbe) = 123
   - Lac de Guiers (Marinaguene) = 124
5. Matam
   - Matam (Ourossogui) = 50
   - Matam (Matam-Sud) = 51
   - Matam (Matam-Ville) = 52
6. St. Louis
   - St. Louis = 144-145
7. N'Thiagar
   - N'Thiagar (Natche) = 115
   - N'Thiagar (N'Thiagar Village) = 116
   - N'Thiagar (Naw) = 119
   - N'Thiagar (Djeuleuss) = 120
8. Vallee du Lampsar
   - Vallee du Lampsar (Ross Bethio) = 130
   - Vallee du Lampsar (Diagambal) = 136
   - Vallee du Lampsar (Thilene) = 137
   - Vallee du Lampsar (Ndiaouta) = 138
   - Vallee du Lampsar (NDiol) = 139
   - Vallee du Lampsar (NDelle) = 140
   - Vallee du Lampsar (NDioungue) = 141
   - Vallee du Lampsar (Lampsar) = 142
   - Vallee du Lampsar (Lampsar Nord) = 143

SOURCE: TELEDYNE GEOTRONICS (MARCH 1980)

The Upper Valley. This part of the Senegal valley is unique in a number of respects - firstly, it is in a climatically more favorable zone than the lower valley, with average annual rainfall above 500 mm. It is the only part of the valley where rainfed cultivation has a traditional base. Recession agriculture, however, is limited by the configuration of the valley. The rivers' (Senegal-Faleme) course is clearly defined in this region, with the flood plain being about 1/2 to 1 km wide (visual estimates) and edged by high (10-15 m) banks. Inland, on the Senegal side of the river, there is a high terrace, approximately 1 to 3 km wide (visual estimates). This terrace is rarely flooded; people addressed in this region said that it has never been flooded "in their lifetime". Typically the terrace slopes gently inland from the levee bordering the river, to a depression or 'marigot', and then rises again to a series of low hills formed by a rock outcrop (see Figure 14). The river side of the terrace is where most of the existing perimeters are located, fed by pumps floated in the river, or, occasionally, from the marigot. Towns and roads are located on the highest land, on the levee. While the terrace is rarely flooded by river water, runoff from the hills frequently causes extensive flooding. The hills contain little ground cover and but the barest cover of soil, providing no impedence to runoff (eaux de ruissellement). Thus it has been found necessary to protect some perimeters with a dike. However, last year the force of runoff water was such that the dike at Collengal was breached, causing considerable damage to the perimeter. At other times, the

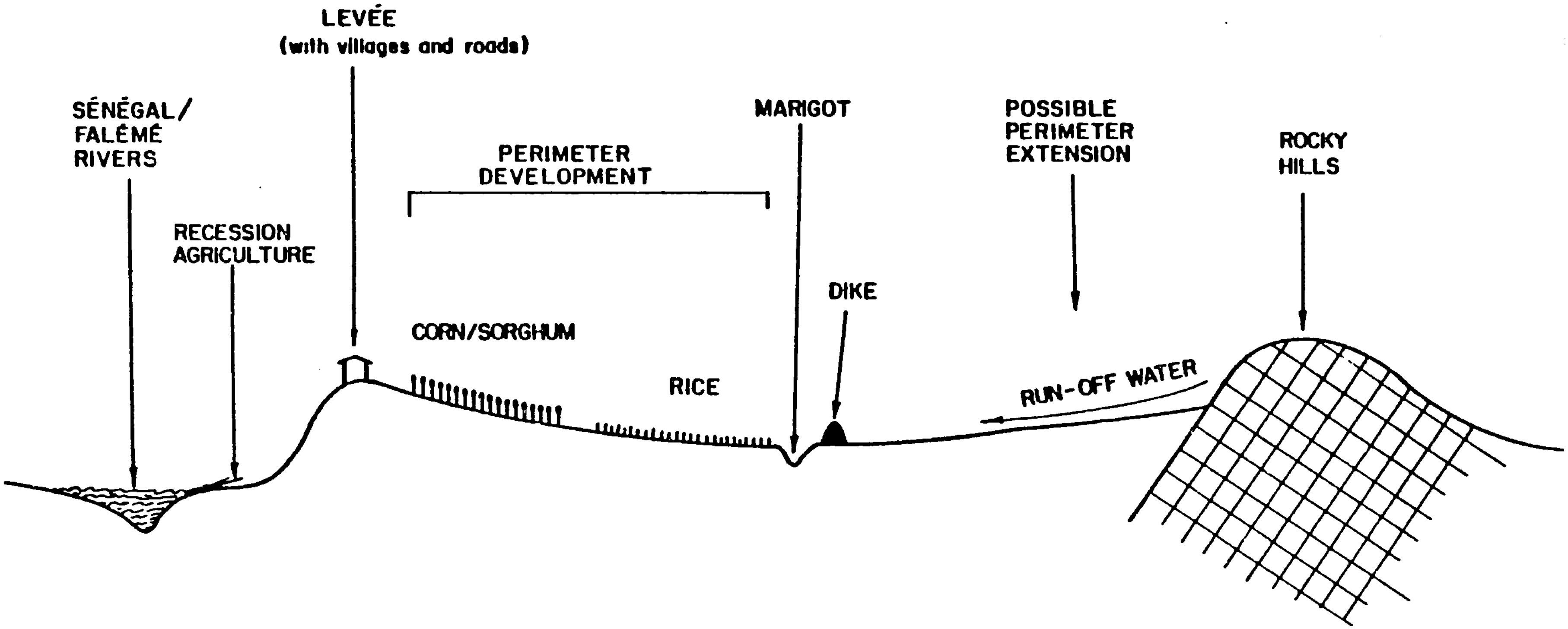


Figure 14 . HYPOTHETICAL CROSS SECTION OF SENEGAL UPPER VALLEY (SENEGAL PORTION)

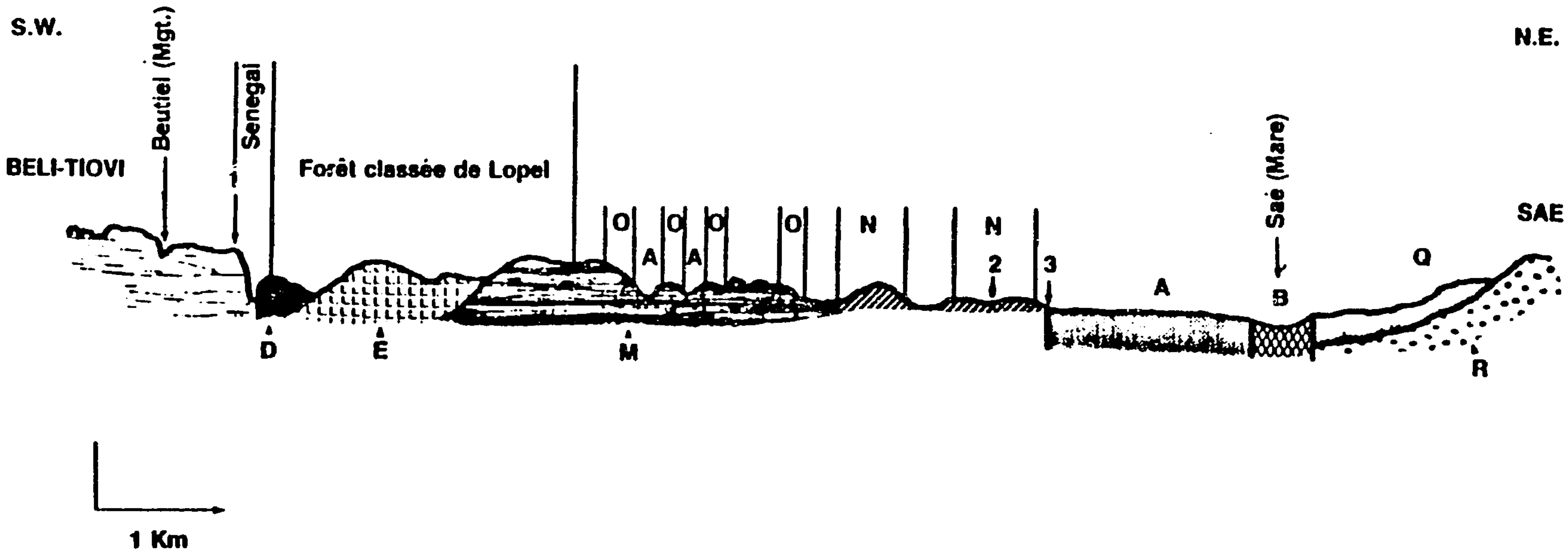
water builds up behind the dike, and this creates a requirement for drainage. This runoff problem may also limit perimeter extension across the rest of the terrace. In the long term, control of the runoff in place would be the preferred solution.

From the point of view of soils, this area is also quite different from the lower parts of the valley with a greater representation (proportionally) of the lighter 'fonde' soils. These are generally cultivated to corn and sorghum, with rice reserved for the heavier soils in the depressional area around the marigot. The rare inundation, moister climate, and greater biological activity would also lead to the expectation of greater soil development in terms of horizonization, structural development, etc., than occurs elsewhere in the valley. The elevation, slope and soil texture of the terrace generally allow for adequate surface and internal drainage except, as noted, when inundated by rainfed floods. The slope of the land, however, demands that greater attention be given to levelling.

Casual observation suggests that the terrace is quite extensive and that there is considerable potential for further irrigation development. However, many of the perimeters are located along the Faleme River, which will not be influenced by the Manantali Dam, thus there will remain a problem of water supply. Also, accessibility is a problem. The terrace is cut in several places by marigots and the general state of the roads is poor. Should the region ever attain significant surplus production, it remains a long way from, and poorly connected to, markets in Senegal. Unless production was directed to some processing facility at Bakel, the likelihood is that surplus production will cross the river.

<u>The Middle Valley</u>. Downstream from Bakel, the river valley opens up, with the flood plain varying between 10 and 25 km in width. The river itself begins to meander and divides into a number of tributary channels, the principal of which is the Doue. The flood plain is relatively level and is composed of an intricate series of levees, terraces and internally drained depressions. A partial cross section is given in Figure 15.

All but the highest areas are subject to regular, but not necessarily annual, flooding. Soils show a direct relationship with the geomorphology, as described in Annex 4. The depresssional basins are dominantly fine textured (Hollande - clays), while the levees are more coarse textured (Fonde - sands and silts), with intermediate and complex areas falling into the 'faux Hollande'. The literature does not adequately discuss the complexity of soil occurrence, but it may be assumed, with the progressive shifting of river channels and the annual variation in flood levels, that many areas are indeed very complex, both in terms of variation with depth and in the areal distribution. The soils are all 'young' soils, with little soil development. Drainage of the levees is good, but the depressional basins are poorly drained and salinity problems occur in these basins as far upstream as Podor.



A Cuvette de décantation
B Cuvette basse
D Levée actuelle
E Levée subactuelle
1.2.3. Routes

M Haute levée
N Delta de rupture de levee
O Petite levée
Q Terrasse marine
R Dune éolienne

Figure 15 Partial Cross Section of the Middle Valley Bogué Plain in Mauritania, from Beli-Tiovi in Senegal to Saé in Mauritania
Source: SEDAGRI

The climate in the Middle Valley is much drier than at Bakel (about 300 mm at Podor) and cultivation of the adjacent dieri land is not widely practiced and is extremely marginal. Traditionally the economy has relied on recession farming of the depressional basins. The recent reduction in flooding of these basins has destabilized, economically and socially, the whole of this region, and provided the motivation for irrigation development.

It is difficult to discuss this section of the valley without mentioning the dieri lands which edge it. These consist of stabilized dunes with a cover of grasses and scattered *Acacia* and *Balanites* trees. A fragile equilibrium exists in this environment and this has been seriously interrupted by the recent drought combined with the impact of man (deforestation and overgrazing) such that there is now little grass cover and the dunes are beginning to become "active." In the short term the effects may be minor - for example the main road (Route Nationale 2) is already covered by sand in places. In the long term, however, the viability of agriculture in the valley may be at risk. Irrigation structures may fill with sand and, ultimately, the dunes may encroach on the valley itself. Stabilization of the dieri should be considered as an integral part of managing the valley lands.

In terms of irrigated perimeter development, this has taken place almost exclusively in the depressional basins. These areas are relatively flat which minimizes the need for levelling. Soils are generally fine textured and the most suited to rice production -

which production has priority with the government. However, these are also the areas most prone to flooding and least well drained, necessitating extensive diking and drainage works. It also removes those lands most amenable to recession farming. The higher land is more economic to develop for irrigated agriculture, but this requires a shift in concept away from rice.

The Delta. Downstream from Dagana the valley gives way to a large delta. Here the river has a very low slope and the area shows very little relative relief. Any development in the Delta, therefore, requires considerable attention to both protection (diking) and drainage. The principal characteristic of the delta, however, is the annual intrusion of salt water. The high soil salinity creates special and expensive problems of development, which may or may not be ameliorated by the Diama Dam.

While large areas of land remain to be developed in the Middle Valley, and before the effect of the Diama Dam is known, immediate perimeter development can best be done in areas outside of the Delta.

3.2 Water

3.2.1 Senegal River

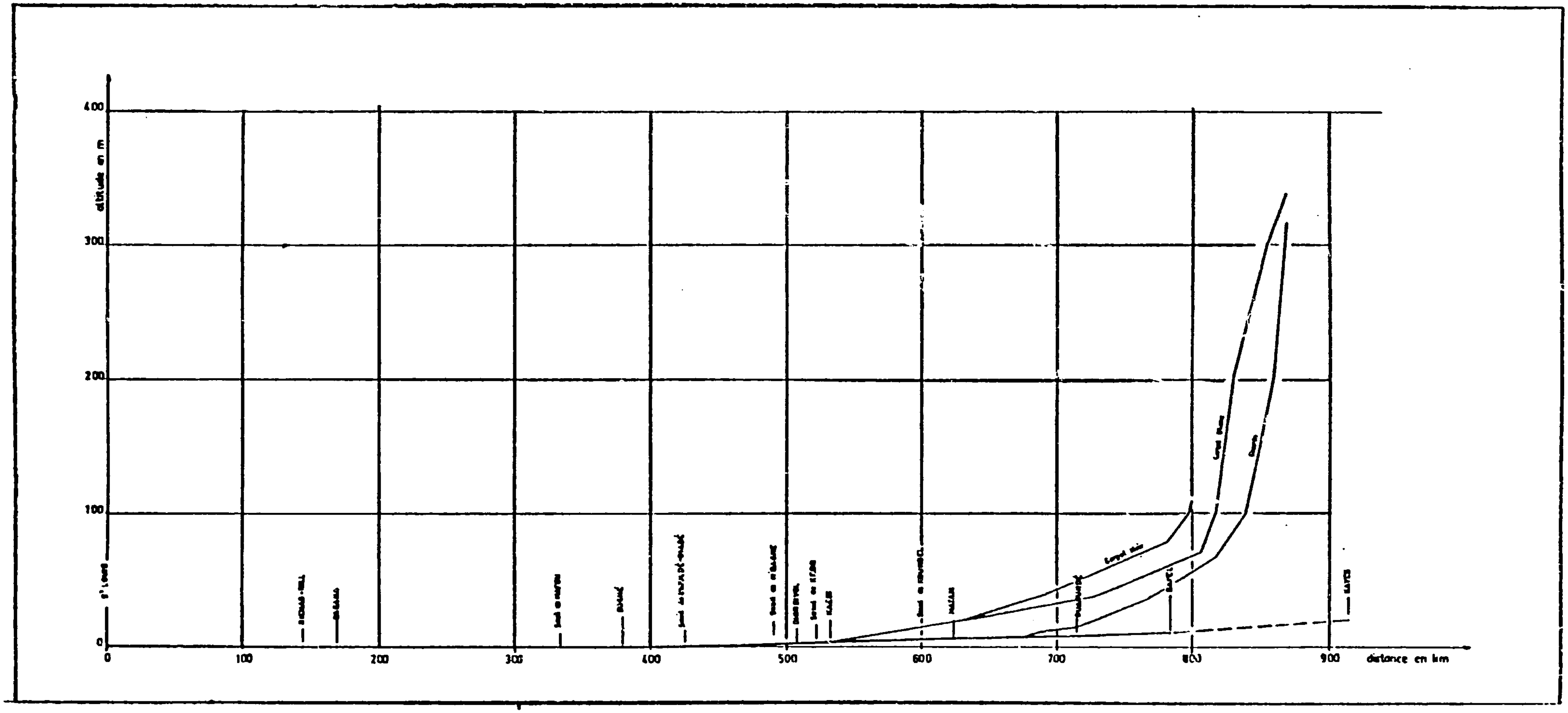
The Senegal River provides the water for irrigation in the valley. It is about 1800 kilometers long with an approximate drainage area of 290,000 square kilometers. As shown in Figure 1, the river originates in the northern highland of Guinea, runs northerly through Mali and then along the border between Senegal and Mauritania, and finally discharges to the Atlantic Ocean near Saint-Louis.

The main course of the Senegal River is formed at Bafoulabe by the junction of the Bafing and the Bakoye rivers in Mali. A major left tributary, the Faleme River, joins the main river near Bakel. These three tributaries supply practically all the flow of the Senegal River. The profiles of the Senegal and Faleme rivers are shown in Figures 16 through 18.

The drainage area upstream of Bakel comprises almost the whole source of flows of the Senegal River. The mean annual rainfall in this area ranges between 700 mm and 2000 mm. The water courses are characterized by deeply entrenched valleys and steep valley slopes. The average slope of the river between Bafoulabe and Kayes is approximately 0.03%, while between Kayes and Bakel, it is approximately 0.005%.

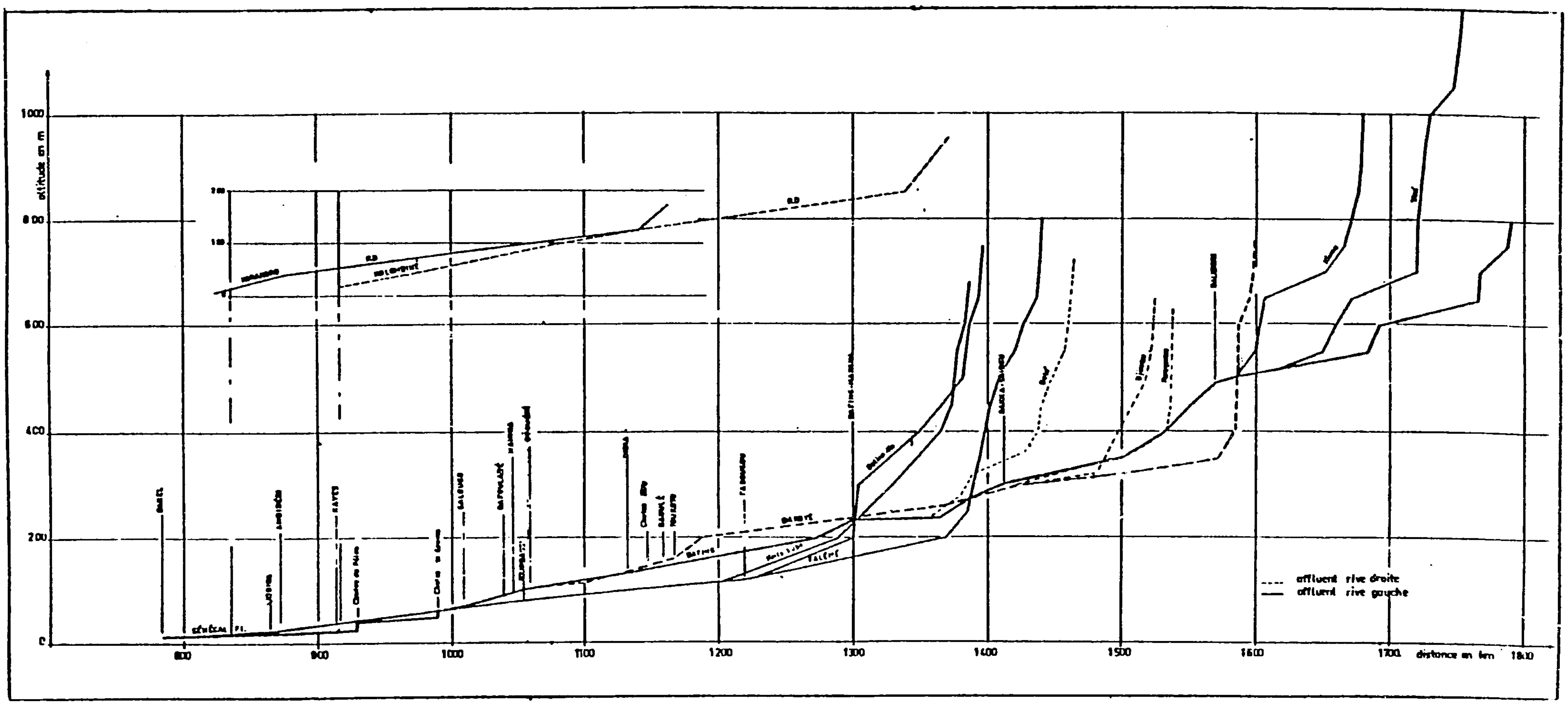
The Middle Valley, from Bakel to Dagana, is essentially a wide alluvial plain surrounded by semi-desert. In this region, the

FIGURE 16. PROFILE OF THE SENEGAL RIVER DOWNSTREAM OF BAKEL



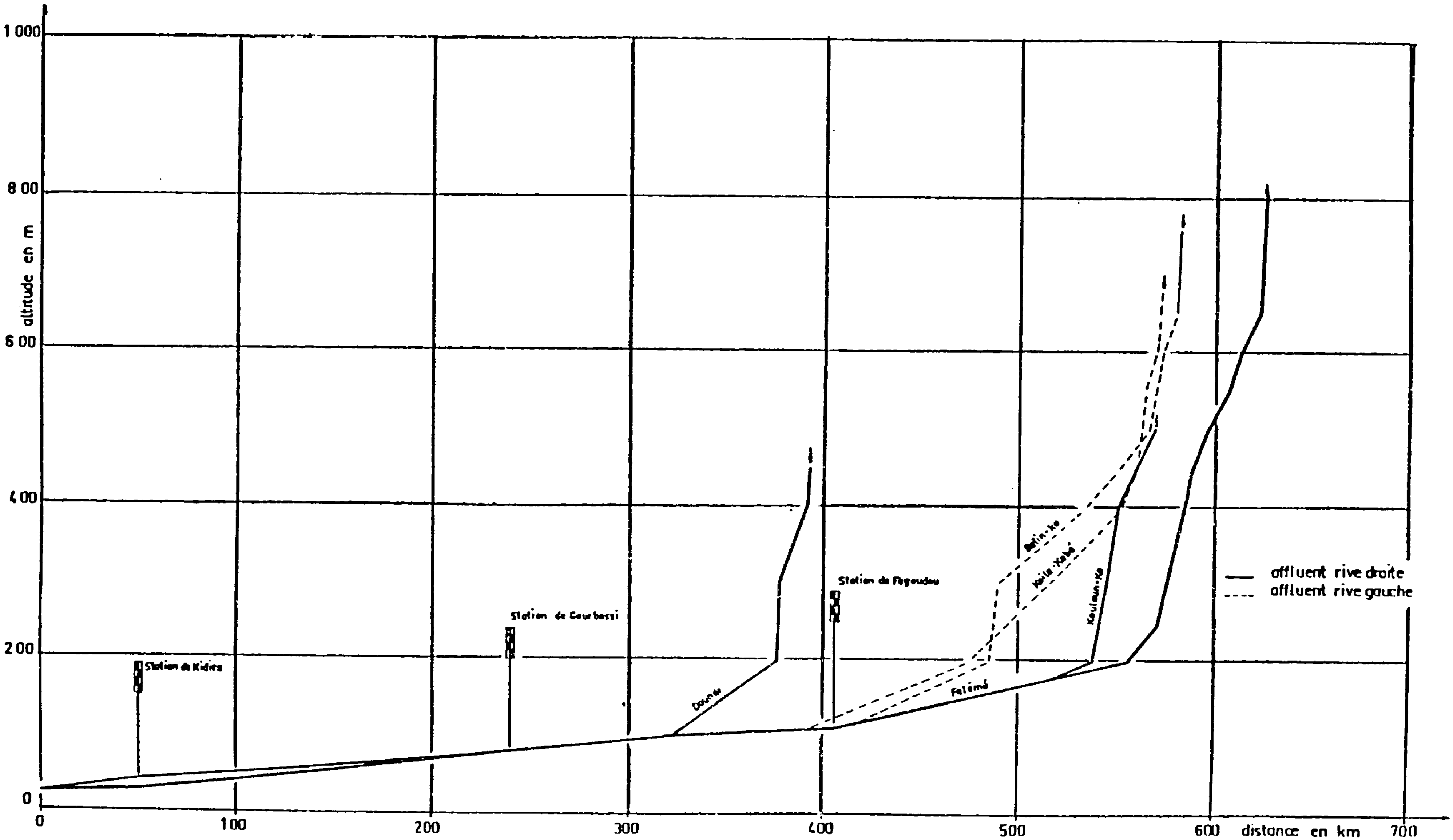
SOURCE: C. ROCHETTE (1974)

FIGURE 17. PROFILE OF THE SENEGAL RIVER AND ITS PRINCIPAL TRIBUTARIES UPSTREAM OF BAKEL



SOURCE: C. ROCHETTE (1974)

FIGURE 18. PROFILE OF THE FALEME RIVER AND ITS PRINCIPAL TRIBUTARIES



SOURCE: C. ROCHETTE (1974)

river bed widens and the slope of the river channel decreases. The average slope between Bakel and Matam is only 0.003%, while between Matam and Dagana, it is even less than 0.001%.

Between Leboudon Doue (km 244) and Vending (km 481), the Senegal River consists of two channels: the Senegal and the Doue. Numerous sills and bars are found in the Middle Valley portion of the Senegal River. The mean annual rainfall in this region ranges from 300 mm to 700 mm.

The Delta, the area downstream of Dagana, consists of a well-defined main channel and numerous sidearms. The river bed in this region is well below sea level and the slope is practically zero. The outlet to the sea is located about 18 kilometers south of Saint-Louis.

3.2.2 Existing Streamflow Conditions

The streamflow in the Senegal River has been measured at various locations since 1903. Detailed information on streamflow records is in the publications of Rochette (1974) and Groupement Manantali (1977).

Streamflow in the Senegal River is closely associated with the rainfall in the drainage area upstream of Bakel. Variations in annual streamflows are significant from year to year. Annual average, maximum and minimum flows for eight representative stations are summarized in Figure 19.Streamflow in the Senegal River

FIGURE 19. ANNUAL AVERAGE AND EXTREME FLOWS FOR SELECTED STATIONS IN THE SENEGAL RIVER BASIN (Natural Condition)

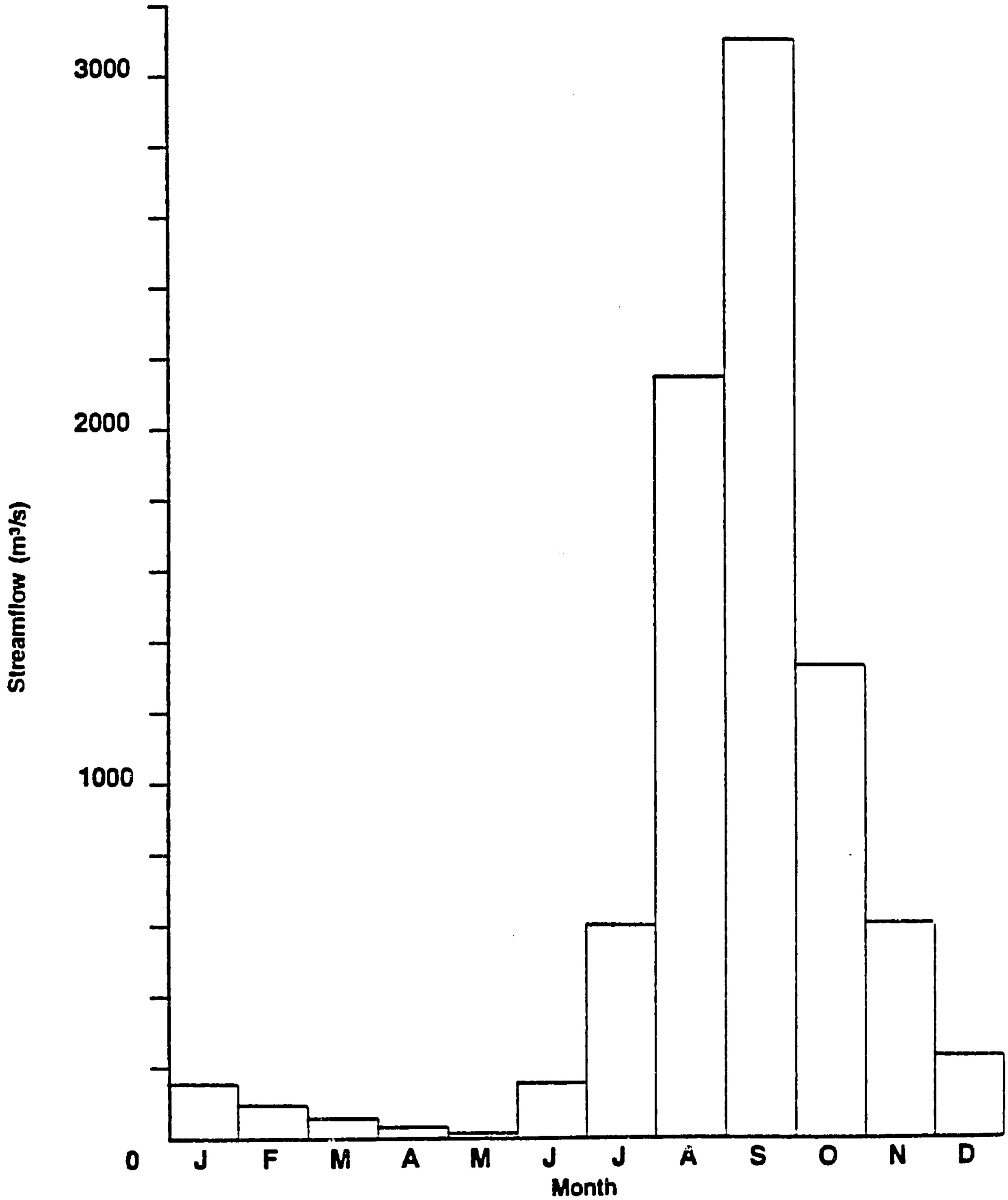
Station	River	Drainage Area Sq. Km.	Annual Flows (cubic meters/s)			Period of Record
			Average	Min.	Max.	
Soukoutali	Bafing	27,800	380	227	584	1903-1975
Oualia	Bakoye	84,700	168	29	302	1903-1975
Salongo	Senegal	128,400	606	246	974	1903-1975
Kayes	Senegal	157,400	612	210	982	1903-1975
Kidira	Faleme	28,900	187	21	340	1903-1975
Bakel	Senegal	218,000	751	266	1247	1903-1975
Matam	Senegal	253,000	776	283	1394	1903-1965
Dagana	Senegal	268,000	691	292	969	1903-1965

SOURCE: GANNETT FLEMING CORDDRY AND CARPENTER (1980)

is highly seasonal. The annual flow is basically concentrated in the months from July through November. Flows in the rest of the months are practically zero. The monthly distribution of flows at Bakel, based on 75 year of observation, is exhibited in Figure 20.

Annual flood (the highest flood each year) is essential to recession farming in the Senegal River Valley. The frequency distribution of annual floods at six representative stations are presented in Figure 21. Because of the significant channel and floodplain storage in the Middle Valley, a flood peak at Bakel is generally reduced when it reaches Saint-Louis.

Figure 20
Mean Monthly Flows of the Senegal River at Bakel



Date Base: 1903–1978
Source: GERSAR (1983)

FIGURE 21. ANNUAL PEAK FLOWS AT SELECTED STATIONS FOR SELECTED RETURN PERIODS (Natural Condition)

Station/River	Annual Peak Flows, cubic meters/s		
	10-Year	100-Year	1000-Year
Soukoutali/Bafing	3200	4000	4600
Oualia/Bakoye	2300	3000	3400
Kayes/Senegal	5400	6500	7400
Kidira/Faleme	2600	3300	3800
Bakel/Senegal	6900	8800	10100
Dagana/Senegal	3200	3800	4200

SOURCE: GANNETT FLEMING CORDDRY AND CARPENTER (1980)

3.2.3 Future Flow Regulations

OMVS has started the construction of two dams in the Senegal River to regulate the flows for irrigation, municipal/industrial water supply, navigation and hydroelectric power. The first dam is the Diama Dam which is located 27 kilometers upstream of Saint-Louis. The second dam is the Manantali Dam which is situated 1200 kilometers upstream of the outlet, in Mali (see map Figure 1).

The dates of completion of the Diama and Manantali Dams are scheduled, respectively, for 1986 and 1989.

Diama Dam. This dam is designed as a fresh water barrier to prevent salt water intrusion from the ocean to areas upstream of the dam site during the dry season. The dam, together with the dike system, will provide the following functions:

1. Diversion of river water to Lac de Guiers for a more extended annual period, for municipal water supply to Dakar and for irrigation at Richard Toll;

2. A year-round source of fresh surface water for irrigation and municipal/industrial purposes in the Delta;

3. Availability of surface water for the annual recharge of Lac R'Kiz and the Aftout es Sahel.

The normal operating level of the dam impoundment will be at 1.5 meters IGN. As an option, the dam is capable of providing additional water for irrigation by increasing the storage capacity through elevation of the water level to 2.5 meters IGN. The elevation at the top of the dam will be 4.0 meters IGN. A flood with a recurrence frequency of once in 1,000 years is predicted to produce a maxium water level of 3.2 meters IGN in the impoundment upstream of the dam. The dike system is designed to retain a maximum water level projected for a flood with a recurrence frequency of once in 100 years plus a 0.75 meter freeboard which is able to retain a 1,000 year flood (SOGREAH, 1977). The characteristics of impoundment at Diama are listed in Figure 22.

FIGURE 22. DIAMA IMPOUNDMENT CHARACTERISTICS

	At 1.5 m IGN	At 2.5 m IGN
Reservoir Length	360 km extending Guede-Boghe area	to 380 km extending to Boghe-Cascas area
Reservoir Width	0.3 to 5.0 km	0.3 to 5.0 km
Enclosed Surface Area	235 sq. km	440 sq. km
Water Volume	0.25 billion cubic meters	0.58 billion cubic meters

Manantali Dam. This dam is situated on the Bafing River. The controlled releases from the reservoir created by this dam will serve the following objectives:

1. A year-round supply for irrigation of 255,000 hectares of land between Manantali and Saint-Louis (for three countries).

2. A year-round flow of 100 cubic meters per second in excess of irrigation and other requirements to provide water depths needed for navigation.

3. The production of 800 gigawatt-hours per year of electric power at the dam.

The elevation of the spillway at the reservoir will be 208.0 meters IGN. The dam is designed for controlled releases of a flood with a recurrence frequency of once in 10,000 years. During such a flood, the water in the reservoir would rise to an elev-

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ation of 211.1 meters IGN. The elevation at the top of the dam will be 212.0 meters IGN.

The characteristics of the Manantali Reservoir are listed in Figure 23. The minimum water level to be allowed during reservoir operation is based on the study made by the Groupement Manantali (1977) with the assumption that water requirements downstream of the reservoir are not entirely satisfied during one of every ten years. The bases for reservoir operation, as prepared by Groupement Manantali, have been incorporated into the OMVS development plan.

FIGURE 23. MANANTALI IMPOUNDMENT CHARACTERISTICS

	At Spillway Elevation	At Minimum Water Level to be Allowed During Reservoir Operation
Water Level (meter IGN)	208.0	187.0
Corresponding Surface Area of Reservoir (sq. km)	477	275
Reservoir Water Volume (cubic meters)	11.3 billion	3.4 billion

Maximum Useful Water Storage Volume = (11.3 - 3.4) billion cubic meters = 7.9 billion cubic meters.

The Manantali Reservoir is not designed for the purpose of flood control in the Senegal River, even though the reservoir might be able to reduce the peak flow for small or medium size flood in the Bafing River. Once the reservoir is filled, the reservoir's capability of flood peak reduction will be relatively small.

Regulated releases from the dam will take place throughout the dry season and during each annual flood until the reservoir is full. After the reservoir has filled, unregulated discharge will take place until the reservoir inflows are less than the releases required for downstream water uses.

3.2.4 Irrigation Return Flow

The rate of irrigation return flow is difficult to quantify before soil information is available and crop patterns are set. The major concern of the irrigation return flow is its impact on water quality in the Senegal River and downstream irrigated areas and in the adjacent groundwater aquifer. According to personal communication with Mr. Gac on August 20, 1984, ORSTOM started a water quality monitoring program, both in the Senegal River and in the aquifer adjacent to the river, in 1980. The water sampling stations along the river are:

Kidira (Faleme)
Bakel (Senegal)
Salde (Senegal)
N'Goui (Doue)
Podor (Senegal)
Guede (Doue)
Dagana (Senegal)
Saint-Louis (Senegal)

Water samples have been collected and analyzed on a weekly basis. Daily water samples have been collected and analyzed at Bakel during the wet seasons. However, this ORSTOM water quality program is still in the preliminary stage and water quality data have not been published yet.

AID is starting up a groundwater monitoring program (625-0958) in conjunction with OMVS. This project will cover an area from Kayes to Saint-Louis. The U.S. Geological Survey will provide the technical assistance on borehole drilling as well as water sampling and analysis. AID should work closely with ORSTOM to exchange the water quality information in the future.

After the proposed development projects at Podor and Bakel are completed, the water in the drainage ditches (irrigation return flow) should be periodically sampled and analyzed for salinity concentration. If the quality of the irrigation return flow should become a source of pollution in the Senegal River, the irrigation return flow may be diverted to an evaporation pond instead of discharging to the river.

3.2.5 Water Rights

Ultimately, the limiting physical factor for irrigation development in the Senegal valley is water, not land. The total annual quantity of water available for irrigation, in particular reliable minimum flows before and after Manantali, is only approximately known. Irrigation along the Senegal River should

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thus aim at optimizing the use of water. The issue of water rights in the Senegal River Basin concerns the regional water allocation among the OMVS member states and the priority of water use in each of the countries involved.

Regional Water Allocation. According to the Draft Environmental Report on Senegal (Man and the Biosphere Program, 1980), the OMVS member states made the following resolution on the Status of the Senegal River:

Article 4 No project which would alter the agricultural, industrial or navigational use of the river may be implemented without the unanimous approval of OMVS member states.

Article 6 Navigation on the Senegal River is free and open for OMVS member states.

Article 7 Member states will cooperate to maintain the river in navigable condition.

Water Use in Senegal. The priority of water use in the country of Senegal is still in the ad hoc stage. A committee of surveillance and management of water use priority has been formed. So far, the committee has not made any recommendations.

Although an order of priority for water use is not legally specified, in practice the order is generally:

1. Drinking water supply (with first preference given to the most populous zones);
2. Livestock and agricultural needs; and
3. Industrial and recreational requirements.

AB

3.3 Population

No in-depth study of the population was made for this report. However, it is instructive to consider the number of inhabitants now living in and near the Senegal Valley on the Senegal side of the river.

SAED (1983) gives the following break-down for each of its Delegations:

Delta area	Delegation de Dagana	250,000
Middle Valley	Delegation de Podor	165,000
	Delegation de Matam	175,000
Upper Valley	Delegation de Bakel	80,000
	Total	670,000

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3.4 Irrigated Agriculture

The traditional form of irrigated agriculture in the Senegal River Valley is the farming of cereal crops in the lower portions of the flood plain using flood recession.

Irrigation by more modern methods with increased control of flows has been limited by the availability of a dependable water supply. Irrigation was developed with the introduction of large scale operations for production of sugar cane, and other industrial crops, in the vicinity of Richard Toll, with more dependable water supplies from the Lac de Guiers.

At present, irrigated agriculture is practiced from the Delta to Bakel in the Upper Valley. Figure 24A presents data concerning the net surface areas under irrigation along the Senegal portion of the Senegal River valley, in the four delegations of SAED.

Irrigated perimeters are exploited by large agro-industrial privately owned corporations, by cooperatives, by small village groupements, and by individuals. Areas irrigated by the latter are shown in Figure 24B. The main crops grown are rice, sugar cane and tomatoes. The available data on rice production is presented in Figure 25.

FIGURE 24A. IRRIGATION AREAS (IN HECTARES) DEVELOPED IN THE SENEGAL RIVER VALLEY IN SENEGAL AS OF JULY 1983

	Total Zone	Total Perimeter	Total Delegation
DELEGATION DE BAKEL			
Perimetre de Bakel			
Zone du Goye Inferieur	278		
Zone du Goye Superieur	404		
Zone de Faleme	117		
Total Perimetre de Bakel		799	
Total Delegation de Bakel			799
DELEGATION DE MATAM			
Perimetre de Matam			
Zone de Boki-Diave	545.7		
Zone de Dial	369.5		
Zone de Nguidjilone	661		
Zone de Matam	164.6		
Zone de Bow	320.4		
Zone de Diela	493.5		
Total Perimetre de Matam		2,555	
Total Delegation de Matam			2,555
DELEGATION DE PODOR			
Fanaye (ISRA)		12.7	
Prive Ousmane Ly		5	
Ngalenka		208.5	
Perimetre de Nianga+Cuma		645	
Perimetre de Guede-Chantier+Cuma		399	
Petits Perimetres Podor-Guede		1,026.5	
Samba Baba Ly		2.5	
Centre de Recherche de Guede		20	
Perimetre de Aere Lao			
Zone de Ndioum	425		
Zone Madina Ndiaytebe	276		
Zone de Pete	574		
Zone de Demet	359		
Zone de Thioubalel	290		
Total Aere Lao		1,924	
Total Delegation de Podor			4,238
DELEGATION DE DAGANA			
Delta, (Agro-industries, Grands, Perimetres intermediaires et villageois, Foyers prives)		19,245	
Perimetre de Dagana + Cuma		1,925	
Total Delegation de Dagana			21,170
TOTAL SENEGAL			28,762

SOURCE: OMVS

FIGURE 24B. PRIVATE IRRIGATION PERIMETERS EXISTING IN THE SENEGAL VALLEY IN SENEGAL - 1984

SAED Delegation	Name of Owner	Area Developed (Ha)	
		Farm	Delegation
Dagana	Yerim Coly Diop	20	
	Albert Assane	40	
	Alioune Diaw	20	
	Air	20	
	Matar Niang	40	
	Abdoulaye Djire	1.4	
	Lamire Niang	1	
	Aziz Diack	2.2	
	Maguette Dial	3	
	Moustap Ndiaye	2	
	Ass.Ferm.de la Tahoney	8.2	
	Ablaye Sar	2	
			159.8
Podor	Ousmane Ly	5	
	Samba Baba Ly	2.5	
	Sow infirmier	2	
	Thiam	5	
	Amadou Niang	6	
			20.5
Matam	?	0	
			0
Bakel	Tuabou	2	
			2
TOTAL			182.2 ha

Note: The marabouts are not considered as private ownership.

SOURCE: USAID/RBDO

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FIGURE 25. PADDY RICE PRODUCTION IN THE SENEGAL RIVER VALLEY IN SENEGAL

YEAR	AREA IN HA OF PADDY RICE	PRODUCTION IN TONS OF PADDY RICE	YIELD TONS/HA
1970/71	15,766	23,000	1.46
1971/72	11,748	27,940	2.38
1972/73	11,534	6,541	1.44
1973/74	8,049	9,809	1.22
1974/75	9,391	17,220	1.83
1975/76	10,522	12,955	1.26
1976/77	10,725	23,215	2.17
1977/78	7,777	17,300	2.22
1978/79	9,490	27,380	2.88
1979/80	9,798	30,775	3.14
1980/81	9,692	31,584	3.25
1981/82	10,312	36,850	3.57
1982/83	13,699	35,930	2.62
1983/84	14,826	35,780	2.41

Source: Ministry of Rural Development, 1984

3.5 Economics of Irrigation

The high capital infrastructural cost of irrigation, and the potential benefits to farmers and society make the economics of irrigation a complex social as well as economic issue. Confronted with a high demand for scarce development resources, economic analysis is a tool for planners to prioritize investment opportunities. Volume III "Economic and Financial Analysis" of the IDP Project Paper proposed irrigation projects in the Bakel and Podor areas in the Senegal Valley.

A careful review of the project documents reveals an extensive analysis of the costs and benefits of both the Bakel and Podor proposed perimeters. The critical assumptions have been tested, independently verified, and in our judgment fall well within the quality standard required for the analysis. The only issue which was not fully addressed in the IDP Project Paper is the cost of water to pay for construction of the dams ensuring the year round water supply. Our preliminary analysis of dam and perimeters costs gives the following total infrastructure costs in CFA/ha for crop of rice (1984 values). (See Annex 6)

	Dam CFA/ha	Perimeter CFA/ha	Total CFA/ha
Bakel Perimeters	52,283	101,273	= 153,556
Podor Perimeters	52,283	245,798	= 298,081

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Economic Development Costs. Very large differences in IDP irrigation development costs exist between the Middle Valley (Podor at $6,800/ha) and the Upper Valley (Bakel at $2,150/ha). Bakel land is located on the confluence of the Senegal and Faleme Rivers and enjoys relative security from the floods from each river particularly after completion of the Manantali Dam. Down river, Podor land lies on a low flood plain where annual flooding occurs.

In Podor, extensive diking and drainage infrastructure is required to control flooding. These capital intensive water works, typical of large perimeters in this area, require organization, intensive water management and large scale cultivation.

In the Bakel area, irrigation development requires only limited diking and leveling and a pump. This type of development is known as small perimeter, denoting the size and quality of the current irrigation works and its simpler organization.

Internal Rate of Return. The IDP study calculates the internal rate of return for Podor at 7.49 and Bakel at 11.46. These figures are not considered high by world standards but do fall within the low side of the acceptable limits. The capital intensive nature of the Podor project accounts for its lower return.

Summary. The geographical site differences between Bakel and Podor provide examples of land to be developed along the river. The IDP analysis presents an accounting of the capital investment required to develop each site. There is little advantage in comparing the two projects on economic return basis or on a capital investment basis except for raising the issue of how best to use constrained resources to maximize return to the area. Accelerating the development of perimeters in the Bakel area in the short term would maximize the economic returns as compared to perimeters downstream in the flood plain.

The Podor project has benefits extending beyond those considered in the IDP economic analysis. They are of a social and political nature and are beyond the scope of this analysis.

3.6 GOS Agricultural Policy

It is important in considering irrigation development in the Senegal valley to understand the objectives of the Government of Senegal. Recently, the Ministry of Rural Development formulated a new agricultural policy (Ministere du Developpement, 1984). Below are some excerpts related to irrigation development objectives.

First, the general objective of agriculture is stated:

p. 62 "Produire plus et mieux en vue de repondre aux necessites de developpement economique et social de notre pays et partant relever le niveau de vie de chaque citoyen senegalais, plus particulierement celui des masses rurales laborieuses, reste la finalite de notre agriculture."

Then, in particular as far as cereal production is concerned:

p. 63 "L'importance de la filiere cerealiere est evidente, en raison de la trop grande pression alimentaire et financiere qu'elle exerce sur l'economie nationale. Les besoins en cereales sont importantes face a une production de plus en plus faible, ce qui se traduit par un niveau d'importations tres eleve."

In considering food requirements versus food production it is mentioned that in 1983/84 only 31.5% of cereal needs were covered by national production.

In view of climatic constraints one of the ways to ensure sustained crop production is through irrigation:

p. 64 "La production cerealiere en culture irriguees sera priviligiee dans les zones qui permettent une maitrise totale ou partielle de l'eau; il s'agit principalement des zones ou l'irrigation est possible (vallee du fleuve Senegal, Casamance, Senegal-Oriental, et Bas-Saloum)."

With the objective of reaching 75% food self-sufficiency in the year 2000 the following targets are set:

Average ha to be brought under irrigation in Senegal:

5,000 ha/year

Average yield:

8 tons/ha of paddy equivalent

Average ha to be developed for irrigation in the Senegal River valley:

3,500 ha/year

The GOS further wishes to reduce its own role in the development of agriculture and has redefined its financial participation as follows:

p. 88 "L'Etat peut donc se desengager progressivement, en tant que financier mais dans des limites bien precises car il va sans dire que l'Etat ne peut se desengager totalement du financement du developpement, puisqu'il en est le moteur. Si donc nous parlons de desengagement, nous devons attendre allegement de l'Etat pour les charges qui normalement doivent incombrer au producteur.

C'est pourquoi, dans le cadre du nouveau role de catalyseur et d'impulsion que l'Etat devra jouer, il lui faudra envisager, chaque fois qu'une action est prise en charge par le producteur, d'intervenir sur le niveau des prix par des subventions tant que l'optimum n'est pas realise, quant a l'objectif que l'action concernee vise a atteindre. C'est le cas, dans le domaine des intrants de l'engrais, du materiel agricole et des produits phytosanitaires."

p. 89 "La relance de la production agricole, plus particulierement la production cerealiere, dans un systeme de maitrise de l'eau exige d'importants fonds d'investissement, auxquels l'Etat doit faire face pour parvenir a notre objectif d'autosuffisance alimentaire. Du reste, tout l'y oblige, car c'est de la survie de notre population qu'il s'agit.

L'analyse du financement du developpement montre par exemple que notre pays a investi et continue d'investir, sur emprunts exterieurs et sur fonds publics, d'importantes sommes d'argent dans le domaine de la construction de barrages et d'amenagements hydro-agricoles. Meme, dans ce domaine, les charges de l'Etat peuvent etre allegees."

A brief statement on the present situation reads:

p. 89 and 90

> "Les perimetres irrigues realises sur fonds d'investissements publics, sont repartis aux fins de mise en exploitation entre les populations des zones concernees.
>
> Les consequences sont que:
>
> - le beneficiare disposant d'un tel outil de production, ne rembourse rien a l'Etat, malgre qu'il en tire un revenu important, a cette echelle;
>
> - l'Etat se trouve dans la situation de rembourser le credit, ce qui revient, en definitive, a faire supporter par l'ensemble des citoyens, des fonds offerts a ces producteurs.
>
> On comprend, des lors que la dette publique, gagee exclusivement sur les ressources publiques, elles-memes limitees, soit alourdie par des investissements couteux non remboursables par les beneficiaires directs."

A reform of the present system is then proposed based on the following principles:

p. 90 and 91

> "- l'Etat emprunte, realise ou fait realiser par les populations techniquement encadrees, les amenagements necessaires;

- l'Etat procede au morcellement equitable des parcelles et evalue le cout ramene a l'hectare ou a la parcelle, chaque parcelle devant etre remise contre contrat pour un credit a long terme, a chaque beneficiaire qui s'engagerait par le biais de son groupement, de sa section ou de sa cooperative, a rembourser les annuites dudit credit sur le produit des recoltes, sous forme de redevances.

L'Etat qui aurait emprunte le financement a des conditions douces rembourserait a son preteur par les ressources provenant des producteurs eux-memes, donc a qui il retrocederait le credit, par l'intermediaire de leur structure cooperative, dans les memes conditions de duree, de differe d'amortissement et selon le meme taux d'interet."

Government policy further specifies:

p. 92 "Il reste evident que ce desengagement de l'Etat ne concerne, pour les amenagements hydro-agricoles, que les investissements ou amenagement tertiare ainsi que les charges d'exploitation des perimetres irrigues. Les grandes infrastructures (barrages, digues) ainsi que les amenagements primaire et secondaire devront continuer a etre a la charge de l'Etat, parce que relevant de ses missions de service public, notamment celles d'assurer le maintien et l'amelioration de l'outil de production qui est un bien public."

In order to reduce the cost to the Government of irrigation development it is then proposed to use the services of the Army Corps of Engineers and a number of other Government organizations:

p. 93 "- la participation du corps du Genie de l'Armee nationale dans les grands travaux d'amenagement; une telle intervention, dans la mesure ou elle permettrait de faire l'economie du personnel et des engins de genie civil, postes les plus couteux dans le prix de revient de l'amenagement, permettra d'amenager des superficies importantes a des couts reduits;

- la participation, a differentes stades des operations d'amenagements, des services techniques particuliers de l'Etat (Travaux publics, Service topographique, Faculte des Sciences de l'Universite), pour les etudes et meme la realisation d'ouvrages, pour ce qui concerne les travaux publics."

The financing of the investment necessary for irrigated farming without further burdening Senegal's financial resources would thus be greatly facilitated by:

- l'abaissement des couts de travail
- le gage de remboursement par la production

- le relevement du niveau des finances publiques par l'allegement du poids de l'endettement de l'Etat
- l'augmentation de la capacite nationale d'absorption des credits.

PART 4

REVIEW OF IRRIGATED PERIMETER DEVELOPMENT PROPOSED BY USAID (IDP)

4. REVIEW OF IRRIGATED PERIMETER DEVELOPMENT PROPOSED BY USAID (IDP)

4.1 IDP Senegal Subproject

4.1.1 Objectives

As stated in our Introduction (Part 1), no specific objectives have been defined for the Senegal subproject. The activities of the subproject are described in the IDP Project Paper, Volume 2, Section 3.3.3. It appears from this that the Senegal subproject is primarily concerned with the development of irrigated agriculture in three areas in the valley of the Senegal River. These areas are:

1. Bakel area (995 ha), in the Upper Valley, some 800 km upstream of Saint-Louis
2. Podor area (1,063 ha), in the Middle Valley, some 250 km upstream of Saint-Louis
3. N'Thiagar area (870 ha), in the Delta, some 100 km upstream of Saint-Louis.

The Project Paper does not give a clear rationale for the selection of these areas. Some indications are given:

On p. 35: "The strategy for working in the two selected zones (Bakel and Podor) is to develop areas that have previously been isolated from the rest of the economy but

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which show great potential for food production."

On p. 46: "...SAED proposed three sites to be considered for financing under the IDP. Two sites were studied in detail, Bakel and Podor, and have been included in the project. The third site, N'Thiagar, was examined but not included because of funding constraints and because issues of technical and socioeconomic feasibility arose which the (design) team was unable to study in depth."

On p. 47: "The rehabilitation of the N'Thiagar perimeter is an important priority for SAED... Because of this, and because N'Thiagar is representative of the types of problems requiring resolution if agricultural development is to succeed in the Delta region, USAID agreed to finance further studies of this perimeter."

A more logical procedure would have been to define the objective(s) of USAID technical assistance in the development of irrigation in the Senegal valley and then select the sites most appropriate to such objectives in collaboration with SAED.

As described in the IDP Project Paper (Volume II, page 35), the development of irrigated agriculture by USAID in the Bakel and Podor areas involves:

In Bakel: Continue and expand the successful prototype agricultural development program that was started under the Bakel Small Irrigated Perimeters Project (No. 685-0208).

In Podor: Development of the Podor irrigated perimeter, which will ultimately include a gross area of approximately 1,428 ha.

A summary of IDP proposals for the three areas concerned (described in detail in the IDP Project Paper) follows below.

4.1.2 Bakel Area

The IDP agricultural program in Bakel will upgrade existing perimeters, expand existing perimeters or create new irrigated perimeters, while continuing extension activities in the 25 villages that participate in the Bakel Small Irrigated Perimeters project. An overview of perimeters to be upgraded or extended is given in Figure 26.

As stated, the IDP proposal heavily depends on the results of the Bakel Small Irrigated Perimeters project. The latter project was reviewed in January 1982 by CID/Utah State University. The review team concluded:

"Overall, the Bakel Project has been extremely successful at exposing the problems which are encountered in perimeter irrigation development in the Senegal River Valley ... there is ample evidence that these problems are not unique to Bakel. It would seem eminently wise that solu-

FIGURE 26. PERIMETERS IN THE BAKEL AREA PROPOSED BY THE IDP

Bakel Perimeter	Existing Ha	Ha to be Upgraded	New Ha
Gande	8	8	0
Gallade	8	6	20
Moudieri	45	45	40
Diawara	45	30	0
Yellingara	7	-	-
Manael	8	-	-
Tuabou	12	-	-
Gassambilakhe	24	24	40
Kounghani-Marabout	6	6	-
Kounghani-Village	30	30	-
Golmy-Marabout	5	-	-
Golmy-Village	0	20	20
Yafera	62	62	40
Aroundou-Emigre	13	0	-
Aroundou-Village	49	20	40
Ballou	120	100	120
Sebou	30	30	-
Debekhoule	20	20	-
Djimbe	15	15	-
Dialiquel	12		-
Senthiou-Dialiquel	6	-	-
Ouro-Imadou	10	-	-
Seling	15	15	-
Kidira	33	33	-
Naye	8	-	-
Guitta	10	-	-
Senedebou	18	-	-
Collengal	92	92*	152
Total Bakel	711	556	472

* To be upgraded under Phase 2.

SOURCE: IDP PROJECT PAPER, VOLUME II, DECEMBER 1983 tions to the problems encountered in Bakel be determined before additional funds are spent in expanding perimeter irrigation on some new project in the Senegal River Valley."

In the period from June 1977 to June 1984 a total of 700 ha were developed for irrigation by the Bakel project at a total cost to USAID of $7,209,000.

4.1.3 Podor Area

The IDP agricultural program at Podor aims at the integral development of the Podor medium perimeter in a two-phased approach. The program calls for construction of the perimeters in accord with the Podor Pilot Scheme, November 1982, as developed by GERSAR. The total gross area considered for development is 1,428 ha resulting in 1,171 ha net irrigable land in 5 hydraulic sectors (Figure 27). The program further calls for providing organizational and agricultural support to participants (sic) in existing small perimeters in the southern portion of the site in Phase 1 and to participating farmers in the Podor perimeter in Phase 2.

FIGURE 27. AREAS PROPOSED FOR DEVELOPMENT IN THE PODOR PERIMETER

Podor Perimeter	Existing ha (1981)	Gross ha Proposed	Net ha Proposed
Podor-Sector C1 (1)	-	301	247
Podor-Sector M1 (2)	-	182	149
Podor-Sector C2 (2)	36 (Kodite)	329	270
Podor-Sector M2 (1)	-	304	249
Podor-Sector M3 (2)	63 (Fonde As Goumel)	312	256
Total Podor	99	1,428	1,171

(1) Phase 1 (2) Phase 2

4.1.4 Technical Support

In addition to the physical aspects of irrigated agricultural development described above for Bakel and Podor the project will provide:

- Support to the activities of SAED.
- Support to existing farmer associations in Bakel, and new associations in Bakel and Podor.
- Training for farmers and agricultural technicians.
- Improved agricultural extension.

- Improved rural credit and production input supply system.

- Continuous monitoring and evaluation systems.

4.1.5 N'Thiagar Area

N'Thiagar is a site proposed by SAED for rehabilitation under the IDP. The existing perimeter was developed in 1977-78 by SAED. It is a "problem" perimeter of some 870 ha which has fallen into disrepair with a record of low yields, high production costs and sociological problems. Under the IDP, funds were to be provided to complete the feasibility studies of N'Thiagar and prepare a project dossier that can be submitted to other donors for possible financing. Estimated cost of the study is $100,000.

4.1.6 Health and Roads

Two other components of the IDP are a health surveillance program for the whole Senegal Valley and a feeder road program for the Bakel area.

The Health Surveillance program is designed to assist the Government of Senegal prevent a deterioration in human health in the river basin due to an increase in the prevalence of malaria, schistosomiasis, or other health problems which might be exacerbated by the introduction and practice of irrigated agriculture. Activities will include:

- Improving Senegal's disease surveillance and control capacity by the long-term training of epidemiologists, nurses and laboratory technicians.

- Monitoring by use of periodic epidemiological surveys the prevalence of malaria, schistosomiasis, malnutrition and other diseases in the villages around the perimeters of Bakel and Podor.

- Evaluating the effectiveness of different approaches to the control of the above diseases.

<u>The Feeder Roads program</u> includes planning and construction of 51 kilometers of low-volume feeder roads to connect village perimeters in the Bakel area to National Highway No. 2 which runs roughly parallel to the river on high ground several kilometers back from the river bank. The construction program would connect perimeters having a total of 730 hectares to the national highway. Although planned as part of the IDP, funding for the feeder road component is being provided to Senegal under a separate bilateral project of USAID/Senegal.

4.2 Bakel Area

4.2.1 Land

Thirty perimeters exist in the area of the Bakel Delegation; their development has been substantially aided by the Bakel Small Irrigated Perimeters Project (USAID). Presently, they vary in size (amenage) from 5 to 120 ha and are scattered about 150 kms along the Senegal and Faleme Rivers, with eight perimeters downstream from Bakel and the others upstream. Thus they fall primarily in the area of the Upper Valley (see Part 3.1). Proposed IDP interventions in the region will, by the end of 1985, have been substantially completed by SAED (see Figure 28). Thus this section of the IDP will have to be substantially rewritten. However, in doing so, it is instructive to review the technical basis for the presently proposed interventions.

Basic physical data on this region are very limited (see Part 3.1). Regional soils information exists at a scale of 1/200,000. The Senegal River valley has been mapped at a scale of 1/50,000 for soils and soil capability, but only upstream as far as Bakel. Thus the perimeters of Gande, Gallade, Moudieri, Diawara, Yelingara, Manael, Tuabou and Gassambilakhe are covered by these maps. However, the largest of these perimeters is only 60 ha, represented at this scale by a square approximately 1.3 cm on a side, well within the size of the average mapping unit on these maps. Thus the scale of map is totally inadequate for even an initial evaluation of potential irrigated sites for perimeters of this areal

FIGURE 28. PRESENT STATUS OF IRRIGATED PERIMETERS IN THE BAKEL AREA

	IDP			
Bakel Perimeter	Existing Ha	Proposed New Ha	Total Ha	Actual Ha July 1984
Gande	8	-	8	8
Gallade	8	20	28	8
Moudieri	45	40	85	60
Diawara	45	-	45	45
Yellingara	7	-	7	10
Manael	8	-	8	27
Tuabou	12	-	12	12
Gassambilakhe	24	40	64	27
Kounghani-Marabout	6	-	6	6
Kounghani-Village	30	-	30	30
Yafera	62	40	102	102
Aroundou-Emigre	13	-	13	13
Aroundou-Village	49	40	89	59
Ballou	120	120	240	120
Sebou	30	-	30	43.16
Debekhoule	20	-	20	20
Djimbe	15	-	15	28.3
Dialiquel	12	-	12	24.8
Senthiou	6	-	6	6
Ouro-Imadou	10	-	10	10
Seling	15	-	15	15
Kidira	33	-	33	33
Naye	8	-	8	?
Guitta 1	10	-	10	10
Guitta 2	-	-	-	18.5
Senedebou	18	-	18	34.8
Collengal	92	152	244	116
Golmy-Marabout	·5	-	5	5
Golmy-Village	(20)	20	40	?
Dounde	-	-	-	10.5
TOTALS	711	472	1203	903+

(1) Expansion problems due to crossing marigot and land tenure
(2) To be developed over two years

SOURCE: SAED/BAKEL DELEGATION

magnitude. The Collengal area has recently been mapped (Land Systems) at 1/20,000, but even at this scale most of the existing Collengal perimeter falls within one mapping unit.

Maps at 1/1,000 or 1/2,000 exist of seven perimeters in this region but several of these perimeters have already expanded beyond the areas mapped. Topographic maps at 1/1,000 or 1/2,000 exist for most of these perimeters.

Site selection in the Bakel region has been based on local demand - a 'bottom-up' concept - rather than on any appraisal of the technical qualities of these sites. This reflects, at least in part, the lack of an adequate data base for this region, as previously discussed. This is partially recognized in the IDP, which includes an upgrading of the existing data base, but only for preselected areas. How these areas were selected, or how future selection might take place, is left open.

Specifically, the IDP for Bakel proposed:

1. Small Perimeter Upgrading: "a detailed plan for each perimeter to be upgraded will be prepared ... which will utilize relevant information available for the sites as USAID/Senegal and the SAED office in Bakel. The upgrading of a perimeter will include examination of all aspects of the existing installation (cropping pattern, soil characteristics, etc.)..." As previously noted, existing relevant information is very limited, and considerable primary data collection

should be envisaged.

2. Development of New Small Perimeters: "The locations for development of new small perimeters ... have been established by field investigation by the RBDO irrigation engineer in conjunction with the USAID irrigation engineer and SAED personnel... For development under the project it will be necessary first to confirm each site selection by a technical and socio-economic feasibility study...", including "topographic survey and large scale maps: soil survey, percolation tests and soils analysis, cropping plans", etc.

   Selection of these sites was clearly not based on technical (land) considerations and it is difficult to see how inventory of these sites will permit their "confirmation" unless that inventory is extended onto alternate lands. Further, by limiting the inventory to pre-selected sites, the IDP precludes planning of future extensions on a rational basis.

3. Completion of Bakel-Collengal Medium Perimeters. Again, a technical and socio-economic feasibility study is proposed, but involving the whole watershed. This has already been done (Land Systems) and the final report of this study should be carefully examined before the work is repeated.

This last aspect raises one other important consideration. The original Bakel Small Irrigated Perimeters Project was proposed as an integrated development project. All pretense of integration,

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apart from the name, has been dropped from the IDP. The problems of runoff at Collengal illustrate the value of the integrated approach, as the perimeters cannot be isolated from their environment. Further, dieri cultivation has a traditional base in the region and remains the preferred agricultural practice of many farmers. Finally, livestock management is important both in terms of watershed management and as an impetus to the introduction of forage into the crop rotation on the irrigated perimeters.

4.2.2 Water

Water Availability - The issue of water availability for the proposed project at Bakel is not addressed in the IDP Project Paper. The following two conditions are analyzed below:

1. Existing Streamflow Condition and After Completion of Diama Dam. The availability of water for the proposed irrigation development at Bakel under the existing streamflow condition and the condition after the completion of the Diama Dam will be similar to that at Podor (see Part 4.3.2), i.e., the irrigation water supply is sufficient during the wet season but not so dependable during the dry season.

   After a study of the natural depressions (mouilles) in the river bed, Louis Berger International (1980) concluded that the water in the natural depressions could provide water supply for 1880 hectares of irrigated land during the dry season. However, the validity of these conclusions was questioned by SAED (letter dated August 1, 1980).

2. After Completion of the Manantali Dam. As discussed earlier, the Manantali reservoir will provide a year-round supply for irrigation of 255,000 hectares of land between Manantali and Saint-Louis. However, approximately half of the perimeters in the Bakel area will be located along the Faleme River and cannot directly benefit from the year-round supply in the Senegal River. In other words, the problem of dependable water supply for irrigation perimeters along the Faleme River during the dry season will not be solved even after completion of the Manantali Dam.

Flood Protection - As part of the Bakel area is subject to flooding and the existing information is not entirely sufficient to design the flood protection system for all perimeters, the IDP Project Paper rightly called for hydrologic studies and design on the perimeters to be upgraded and the new perimeters to be developed. In view of the overall situation, we recommend:

1. AID should contract an engineering firm to provide a regional flood study for the Bakel area so that the design criteria for flood protection on each perimeter will be consistent. The regional flood study should include the impact of flood flows from the Faleme River.

2. If the objective of the diking system is to provide the protection of a 10-year flood with a 1.00 m freeboard for

each perimeter, the crest elevation of the dike should be determined on the basis of the flood level after the completion of the Diama Dam and prior to completion of the Manantali Dam because this flood level represents the worst condition in the river.

3. Sites outside the flood prone area in Bakel are suitable for agricultural development. The possibility of trade-off on perimeter sites should be evaluated in the study of cost-effectiveness of diking systems.

4. The existing perimeters to be upgraded and the proposed new perimeters in the Bakel area are scattered within a strip of 150 km. It is expensive to provide a diking system to protect each individual perimeter from flooding. The capital improvement costs for diking, roads, irrigation canals and pumping stations can be significantly reduced if the sites are lumped together.

4.2.3 Irrigation Systems

The Bakel perimeters were born as a joint effort of SAED/farmer groupement and have had the financial and technical support of USAID since 1976.

The evaluation mission of Utah State University in 1980 pointed out several deficiencies that called for improvement in the design, construction, operation, and maintenance of small perimeters and made specific recommendations thereof. Some of these recommendations, supported by USAID's irrigation engineer's field observations, notably those concerning improvements in the pump/raft systems and fuel storage, are being implemented.

During the 4-day visit to Bakel conducted by the TAMS team from August 28 to August 31, 1984, the team could observe the generally poor condition of the existing irrigation systems. This stems from the fact that both canals and structures are designed very quickly, built by hand and generally following a piecemeal approach with subsequent extensions.

There is a lack of appropriate water control, no flow measuring devices, incomplete structures, poor workmanship (rudimentary systems), poor fill compaction by hand, inadequate canal berms, no gates, fragile structures made of concrete blocks, no quality control during construction.

The latter plus the inadequate maintenance result in quick degradation of facilities and constant need for rehabilitation/repairs.

Furthermore, drainage is now done by use of irrigation canals, i.e., there is no separate drainage system. The lack of drainage will eventually result in salinity build-up in the lower, less permeable soils. The roads for operation/access/maintenance are very limited or nonexistent.

SAED does a general initial grading only and farmers divide the plots into tiny basins which are then levelled by hand.

The quality of design and construction and the lack of proper maintenance also results in unnecessary water losses and fuel consumption. However, since no measurement of water is done, there is no knowledge of how much water is applied nor the resulting irrigation efficiencies.

The suggested improvements to design/construction of present irrigation systems are included in Part 2 of this report.

The irrigation appendix of the IDP Project Paper discusses several technical requirements of the proposed expansion program for small perimeters and includes rough estimates of volume of work involved. However, this document is based on field inspections and not on actual designs. In any case, the review of the proposed program done during the field visit led to the finding that SAED has carried out a good part of the program as proposed in the Project Paper upon the survey conducted by USAID/RBDO irrigation engineers in July 1983 (see Figure 28).

Collengal - The existing Collengal perimeter presently covers a gross area of 116 ha. The perimeter shows poor levelling and inadequate maintenance of canal systems. The area is protected by a dike and reportedly was flooded by runoff from neighboring marigot in 1983.

The Italian firm of Land Systems has prepared a reconnaissance report and avant-projet detaille for extension, however, the SAED Ingenieur Delegue does not plan for immediate extension pending resolution of farmer organizational problems.

The reconnaissance report made by Land Systems appears to be quite comprehensive and follows an interesting integrated development approach.

A brief examination of the interim document (avant projet detaille - APD), calls for the following remarks:

- The APD document appears to be incomplete; in effect it includes only a general development plan, no design or calculation of proposed structures are presented. The cost estimate is not sufficient detailed.

- The report states that design flows (gravity canal system) are based on a peak demand of 1.2 liters per second per hectare. This appears insufficient as all other systems are conceived for 3 to 4 liters per second per hectare.

- The system has reportedly been designed for an ultimate gross area of 550 ha. However, only the immediate extension of existing perimeters to 220 ha is shown on the development plan. The future extension is not shown.

4.2.4 Farming

<u>Crops</u>. The traditional agricultural system of the Bakel region placed emphasis on dieri or rainfed farming for corn, sorghum, millet, and cowpeas, with some marginal rice production in flooded 'bas fonds'. Recession agriculture is limited to a narrow

strip along the valley, where millet, sorghum and vegetables are grown. The drought has imposed severe limitations on both of these cultural systems and led to the introduction of irrigated farming. During the team's visit to Bakel a number of perimeters were visited and, in general, crops appeared to be appropriately distributed in accordance with apparent soil type. Corn and sorghum were being grown on the lighter soils, and rice on the heavier depressional soils. While perimeters and individual parcels varied considerably, the team was generally impressed with the care and attention being given to the fields. Much of the rice was being transplanted (in comparison to the Middle Valley), spacing appeared appropriate, weeding was being undertaken, and ing eneral the crop apperaed to be in good condition. Parts of the perimeters are cultivated to a second crop (contre saison froide - October to January) with emphasis on corn and vegetables. Some experimentation with fruit trees is being undertaken on some of the perimeters, but only bananas so far have shown any success. One problem of this development seems to be to stimulate the interest of local farmers, in terms of providing adequate watering and weeding. Prior to the team's visit to Bakel, yield information was only available for rice (an expression of the emphasis being placed on that crop), but the accuracy of the recorded yields remains an open question. An average of 6 tons/ha ofpaddy, for the Bakel Delegation, was reported, with variation from 4 to 8 tons/ha. During the Bakel visit we obtained the information presented in Figure 29.

While there is clearly pressure to produce rice, SAED appears more open to other cultures here than in the Middle and Lower valley. This undoubtedly reflects the greater importance oflighter soils in this area, whch are unsuited to rice production. Other crops grown follow the traditional cultural pattern (corn, sorghum, millet) (see Figure 29). Introduction of other crops will be constrained for some time by the rice objective and traditional practices.

The agronomic picture for the Bakel region was extensively reviewed in the Keller (Utah State University) Report. Please refer to this report for specific recomendations. We have little to add to his observations; he emphasizes the development and testing of short season varieties of traditional crops, and suggests some rotations. Wheat would probably grow well in this area, but is apparently constrained by political cosiderations. The development of rotations, including forage, should be encouraged. Keller places considerable emphasis on the development of an experimental/demonstration farm, and this appears to be the only recommendation which has seen any action. This respects the need to test varieties under local conditions. It would also provide opportunities to do research leading to maximizing the efficiency of agricultural chemicals and water use. As Keller notes, water is the major limiting factor to crop production in the Bakel area, and its use should be optimized. In the long term, this means deemphasizing rice, which is very consumptive of water.

FIGURE 29. WINTER SEASON CULTIVATED AREAS, PRODUCTION AND YIELDS IN THE BAKEL IRRIGATED PERIMETERS

Year	Net Cultivated Area - Ha				Production MT		Yields MT/ha (1)	
	Rice	Corn	Sorghum	Total	Rice	Corn	Rice	Corn
1975/76	20	3	3	26	46	6	2.3 (2.0)	2
1976/77	60	15	4	79	130	30	2.2 (2.5)	2
1977/78	88	20	6	114	370	50	4.2	2.5
1978/79	125	100	10	235	650	250	5.2	2.5
1979/80	225	223	6	454	1069	558	4.75	2.5
1980/81	270	290	20	580	1283	580	4.75 (4.79)	2.0 (2.4)
1981/82	286	237	46	569	1770	568	6.19	2.4
1982/83	297	149	67	513	1200	443	4.04 (4.22)	2.97 (2.15)
1983/84	439	109	46	594	2398	N/A	5.46 (5.95)	N/A

SOURCE: SAED/BAKEL DELEGATION

(1) These are average values for net cultivated area - SAED/Bakel sometimes adjusts estimates based on actually harvested areas; these estimates are given in parentheses.

In summary, therefore, agronomic data for the region are lacking and need to be developed through an intensive program of research and trials within the local area. One aspect of this is that the experimental/demonstration farm should be a model facility. Wheat and forage crops should be considered, the latter in association with a livestock management program. Vegetables could clearly be grown well in the area, but cannot be encouraged, beyond local consumptive needs, because of distance to markets and lack of agro-industrial infrastructure. Continued trials of fruit trees are also encouraged.

Labor Availability. Keita (1983) observed that, "Farmers in the Bakel project area are adopting irrigated agriculture with the aim of complementing the traditional agricultural systems, not replacing one system with another. Traditional agriculture is characterized by a preponderance of small holdings of high fragmented nature. The average household operates in three major separate fields, including one irrigated field. The major crops grown include irrigated rice, rainfed millet/sorghum and corn."

Distances which the farmer has to travel from his/her house to the field is an important constraint for labor. Another constraint is the distribution of labor in space and time in view of the separated fields that the farmer has to attend and the various operations required for specific crops. This situation becomes complicated due to the fact that field operation are done manually, with a lot of time spent on most agricultural operations.

How much time does the farmer spend in travelling? The "economy of time-labor" is another factor directly related to the efficiency of production. How many operations are neglected because the farmer does not have the time available to do a proper job? Hiring labor, if available, and if the farmer can afford it, could be a solution. Animal traction might solve the problem partially, but the farmer would still have to travel from field to field and/or home. Animal traction will save some time in specific field operations: levelling, plowing, sowing and cultivating. The problem becomes more acute for some operations during the peak of the season, such as transplanting or harvesting rice. About 200 man days/ha have been recorded in Bakel for transplanting rice (Utah State report, p. 68). Therefore, animal traction cannot solve the major labor requirements for irrigated rice during transplanting and harvesting.

There are claims that there is a strong migration in the Bakel area. In Keita's report (page 13) migration estimates are from 12 to 20% of the adult male population. If perimeters are expanding and the migration continues, the labor situation is likely to become a major constraint.

Unfortunately this is an estimate, actual figures are not available. For example, the labor involved in rice production is given as 249 man days in the Utah State report (pages 65 and 68), as 647 man days in the Tuskegee report ("Bakel Small Irrigated Perimeters, Production Economics Study" by J. M. O'Sullivan and C.

Morgan, a Tuskegee Institute Report for USAID/Senegal, August 30, 1981) and the Utah team has a broad estimate of between 400 and 1000 man days, with indications that the figure is closer to 1000 than 400. Finally, in Keita's report (page 34), 495, 421 and 331 man days are given for the three zones in the Bakel area. Evidently, more time is needed for watching the whole rice cycle and doing a proper survey with accurate countings, in several rice field over several years.

In consideration of the problems related to labor shortages, the use of farm machinery may provide a solution.

Another alternative would be to use the irrigation facilities to grow crops like corn and sorghum, which are less demanding in labor (about 60 to 70 man days) and in water. With savings in water, which leads to savings in diesel fuel, motor oil, maintenance and spare parts (the pump would be running 25% of the time, versus 100% if rice were cultivated and needing less labor), corn becomes highly economical if compared to rice. Besides, corn would allow for three crops per year. If one of them were affected by the harmattan wind (interfering with the flowering stage), it could be harvested for silage. In other West African countries, as much as 40 tons/ha of silage have been harvested, and cattle can use the silage during the dry season when grazing is not available.

The male labor migration is partly compensated by women and children, and also hired labor from neighbors. To evaluate this work, most European countries are using the "Unite travailleur agricole annuel" (UTA) which by definition is the work performed by an adult man during 300 working days per year. The accepted equivalent work done by women, children and older people are:

1 adult man = 1 UTA
1 adult woman = 0.5-1 UTA
1 child or = 0.3 - 0.7 UTA
older person

According to Keita, these figures were adapted to the Bakel area and the conversion scale for women is 0.67 UTA, and for children under 14 and people older than 60 years, the factors used is 0.33 UTA. In the same report, a table is included with the corresponding parameters adapted to two ethnic groups in the area (the Soninkhe and the Toucouleur). The excellent work done by Keita on the labor force of the area should be expanded to a larger sample, per village, per crop, and per perimeter. The regional divisions (Lower Goye, Upper Goye and Faleme), should be kept separate in future statistical work.

The high demand for labor in the area is from August to October when planting rice and weeding of other crops takes place. A record high labor demand period is when corn, millet and sorghum are harvested, between the second half of October and November. Finally, another high labor demand period is when irrigated rice is harvested in December. During the dry season there is not a high demand for labor.

4.2.5 Economic Analysis

In general, the financial and economic concepts presented in the IDP Project Paper and in Volume III (Economic and Financial Analysis) are clearly stated. The Farm Budget tables are important because they should reflect the economic possibilities during the development stage of the project. The internal rate of return should be based on calculations that reflect the present reality of the project area, even if certain assumptions are used when facts are not available. This, even more so when the tables are considered as "models" (see paragraph 1.4.2, page 61). The farm budgets as shown in Volume III, page 64 are difficult to interpret, they are for manual operations and animal traction, and are considered "farm models" for each of the project regions. However, no specific parameters are provided for each crop which would allow evaluation of Table 59 - 62. All data are integrated, except for the total value of production (ha x yield x price). In order to review the irrigated, dieri and ouado crops, the economic calculations need to be separated. The amount of inputs (seeds, fertilizers, etc.) are very different for each soil, each crop and every situation. For example, seed value in Table 59 (Volume III, Section 1, page 94) is 8,070 CFA for every year of the project. Taking the coefficients from Table 41 (Traditional) and the prices from the Table 59, the results are as follows:

Rice 120 x 74.7 = 8,964 CFA

Corn 26.67 x 69.5 = 1,853 CFA

Sorghum 16.6 x 68.3 = 1,134 CFA

Niebe 25 x 85 = 2,125 CFA

Oualo 15 x 16.83 = 1,024 CFA

Dieri 15 x 68.3 = 1,024 CFA

Total Seed Value 16,125 CFA

This total is almost double the one quoted in Table 59.

For fertilizers, the figure for rice is 30,225 CFA and for corn 14,363 CFA, using the coefficients from Table 41. The total figure in Table 59 for all crops is only 27,970 CFA, lower than the combined figures for rice and corn. The difference would be even more if fertilizer for sorghum, niebe, etc. were added. The inputs on seeds and fertilizer appear to be much higher than the ones quoted in the IDP table. Higher input costs affect the net benefit, which in this case would become negative if the inputs for seeds and fertilizers are beter costed.

Until the sixth year of development of the project all input figures are the same. Only year six is different because the value of the pump is added. It is doubtful that in a learning process farmers will incur the same expenses for inputs since year one. It is also unrealistic that yields will not change through the years in line with the learning process.

A cash flow by crop revenue expected over a thirty year life of initial investment, including only manual labor and animal traction, is unrealistic. It is hard to believe that even in the next ten years some tractors, even small ones, are not going to substitute the manual labor as well as the oxen in some of the farms.

Sensitivity Analysis - The IDP Farm Budget tables cannot reflect a realistic internal rate of return of the project and provide some indication of economic feasibility. To fill this gap, thirteen tables are included in this report. The objective of these tables is to better establish the economic possibilities of agricultural development in the Senegal River Valley.

The tables include crop production budgets; the list of inputs is the same for both study areas, Bakel and Podor. The parameters are taken from a survey done by Mr. Morbidjan Keita, "The Bakel Small Scale Irrigated Perimeters: An Economic Analysis of Agricultural Production," (USAID/ADO, June 1983). The most recent prices included in our tables were also provided by Keita and by other official sources.

The cost of the pumps, amortization, and diesel consumption according to farm efficiency, have been taken from the "Project Review for Bakel Small Irrigated Perimeters" (Project No. 685-0208, Senegal/USAID, January 1982, p. 66-67, Utah State University).

In the Utah report the diesel fuel consumption cost assumptions (200 liter/ha, 150 liter/ha and 100 liter/ha) relate to farmer efficiencies, and are inversely correlated with yields obtained:

a highly efficient farmer will use less diesel fuel and will achieve a higher yield.

The capital cost for the pump is based on charging 60% of the initial equipment cost against paddy. The total cost for the pump, engine, float and pipe is about 5.5 million CFA (at a 1981 exchange rate of $1 = 300 CFA, the value is about $18,333). Of course this price can have a broad range of variation considering HP power, models and brands. The economies of scale applied to pumps might play a very important role in capital cost per ha.

The capital cost of the pump is amortized assuming a 5-year expected life, with no salvage value and no interest rate. The assumed irrigated areas are 5, 20 and 27 ha according to farmer efficiency.

The tools input quotation has been taken from Keita's report.

The profitability index is that total value of the output for selling the harvested crop at the farm gate, at domestic market prices, divided by the total inputs (expenses). This index is similar to the cost/benefit ratio.

Every crop involves a certain number of man days of labor. The figures included in the tables for rice and corn (sorghum and niebe are slightly lower than the man days for corn) are an average for the situation at Bakel, where the farmers are still in a "learning period." As time goes by, farmers become more efficient and these figures could be substantially lowered, perhaps 40% of the present situation in a ten-year period.

The inputs, such as seeds and fertilizers, are directly correlated to the yields obtained, which also reflects farmer efficiency, assuming the farmer has good credit facilities to buy large amounts of fertilizers. As regards credit facilities, if they were available to every farmer, the average fertilizer consumption per ha could go higher (i.e., for rice, from 400 to 600 kg of urea (nitrogen) is not uncommon). Using large amounts of fertilizer - in order to obtain higher yields - requires the use of highly selected seeds which currently are practically unavailable in the project area.

Higher yields for rice than 8 tons/ha have been reported elsewhere, but here it is assumed that 8 tons is the highest yield average that can be reached for the next few years. The yields reported in the IDP tables are considered too high to be applied for the first six years of project development.

Corn and sorghum are also promising crops for the area. Both crops are rather similar, therefore only three tables for corn are included in this sensitivity analysis, with varying yields. With a fair knowledge of the management of these crops, which are simpler to grow than rice, and using varieties well adapated to the ecological conditions of the area, good yields can be expected. In other tropical countries with conditions similar to those of the Bakel area, yields for corn of 7 to 10 tons/ha have been reported. In our sensitivity tables, yields of 1.5 - 2.5 in rainy season conditions are calculated. A 5 ton/ha yield under irrigation conditions has been included.

The following conclusions can be drawn for each of the 13 tables (Figures 30 to 42).

Figure 30 Rice crops with yields of 3.5 tons/ha give a low profitability index (PI) = 1.03, and the "return to labor" is very low. This is the case for a farm run with low efficiency, located in a soil unsuitable for rice (i.e., sandy soil), where a high consumption of diesel oil (to compensate water losses through deep percolation) makes this crop unprofitable.

Figure 31 With a yield of 5 tons/ha, rice is not very profitable. The opportunity cost of labor should be higher than 455 CFA, even if this example shows a farm with a moderate diesel fuel consumption and more fertilizer use than in Figure 30. The PI= 2.39 is not very high.

Figure 32 With a high yield of 8 tons/ha, the farmer obtains 709 CFA per day of work, which can be quite rewarding for him or her, or even for some hired labor. The PI = 3.14 is acceptable. These returns are obtained with a farm gate selling price for rice of 65 CFA per Kg. In Bakel, it seems that farmers are selling rice "across the river" for 125 CFA/Kg. In the following figures, the price is changed in order to determine the range of sensitivity.

Figure 33 With the same inputs as Figure 32, but with a 90 CFA/Kg selling price and 8 ton/ha, the cost of labor per day is 1109 CFA and the PI = 4.36, which is highly profitable.

Figure 34 The results obtained with a 100 CFA/Kg selling price are 1270 CFA cost of labor per day and PI = 4.84.

Figure 35 This table reflects the highly profitable situation of a 125 CFA/Kg selling price. The cost of labor is 1669 CFA/day with a PI = 6.05.

Figure 36 Due to the successful results obtained with a 125 CFA/Kg "across the river" selling price, calculations were made, including the construction of dikes (according to the Project Paper Economic Annex, Table 104), at a total average cost of $3952/ha, with a 30 year project life and an 8% interest, the annuity is 105,304 CFA (1981 value). With a correction for 1984 value, the annuity is 163,798 CFA (at an exchange rate of 400 CFA to the dollar). Similar calculations for other costs (such as extension services, administration) are 100,251 CFA (1984 value). The cost per cubic meter of water for repayment of the Manantali Dam is 52,283 CFA, assuming a consumption of 2,700 cubic meters for rice cultivation, the cost is 19,364 CFA/cubic meter of water. With all these expenses included, the farmer can still make a profit, such as 1037 CFA per day of work, and a PI = 2.08.

Figure 37 At a selling price of 100 CFA/Kg, the farmer still makes a profit, even paying a share of the investment costs. The income per day of work is 637 CFA, though the PI = 1.66 is low.

Figure 38 At a selling price of 90 CFA/Kg, it would not be profitable for the farmer to cultivate rice and share the investment costs. His or her labor per day is 477 CFA and the PI = 1.50.

The sensitivity analysis in Figures 39-42 concerns corn its yield variation. Two low yield tables are included for rainy season, and the other two are for irrigated corn, to show that this crop can be more profitable than rice as less water is consumed and fewer man days are required than for rice. The same can be said for sorghum, with even lower requirements for water.

Figure 39 The yield is relatively low, the crop is not irrigated. With a 1.5 ton/ha yield, the farmer can get 967 CFA per working day which is highly rewarding with a good PI = 2.82. Corn competes favorably with rice.

Figure 40 With 2.5 tons/ha 1649 CFA/day of work can be obtained, with a high PI = 3.37.

Figure 41 Under irrigated conditions the returns are even higher. A minimum yield of 5 tons/ha can be expected during the first years while the farmer is learning how to cultivate corn under irrigated conditions. Much higher yields can be expected later. In this table, the farmer gets 3507 CFA per labor day with a very high PI = 3.52.

Figure 42 This table, similar to Figure 41, addresses the issue of how much of the initial capital investment cost the farmer can repay by planting corn. As can be seen, the total capital investment cost cannot be repaid, but 50% of it can be, and the farmer will still have a good profit of 1008 CFA per day of labor, although the PI = 1.30 is quite low. However, the repayment which the farmer can afford can be considered excellent for the project as a whole.

Conclusions

1. Corn can compete favorably with rice, as corn uses less labor and less water than rice. The farmers will have more free time to work on something else, and have a supplemental income. If he or she grows corn, the farmer can have some livestock, such as poultry or cattle. Also, in comparing high yields for both crops, the farmer's net income is higher with corn than with rice, i.e., with 8 tons/ha of rice his or her labor gets 709 CFA (at the market price of 65 CFA/kg), and

with irrigated corn 5 tons/ha 3507 CFA per day of work.

2. In order to repay the capital investment cost, neither crop by itself at market selling prices would allow for any capital recovery. With the above sensitivity analysis, alternatives seem to exist to amortize the initial investment. For example, if the farmer can have one crop of rice and another crop of corn (or sorghum), assuming that the rice can be sold at 90 CFA/kg, charging 50% of the total investment cost (50% of 278,332 CFA) and charging the other 50% to corn, he or she can have a good return and pay for the capital recovery. These repayments include the cost of water and capital recovery for the Manantali Dam.

FIGURE 30. FARM BUDGET 1 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 3.5 MT/HA/YR, SELLING PRICE 65 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS	KG	65	86	5,590
	FERTILIZER (NPK)	KG	192	160	30,720
	FERTILIZER (UREA)	KG			
	FERTILIZER (KCL)	KG			
	TOOLS (/2)				4,755
	DIESEL FUEL	L	176	200	35,200
	TOTAL COST OF INPUTS				76,265
B.	VALUE OF OUTPUT	KG	65	3,500	227,500
C.	CAPITAL COST - PUMP (/3)				144,000
D.	PUMP & INPUTS (A+C)				220,265
E.	RETURN TO LABOR AND CAPITAL (B-A)				151,235
F.	RETURN TO LABOR (E-C)				7,235
G.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				416
H.	COST OF LABOR (F/G) IN FCFA/MAN DAY				17
I.	PROFITABILITY INDEX (B/D)				1.03

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 5 ha

FIGURE 31. FARM BUDGET 2 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 5 MT/HA/YR, SELLING PRICE 65 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS	KG	65	86	5,590
	FERTILIZER (NPK)	KG	192	500	81,000
	FERTILIZER (UREA)	KG			
	FERTILIZER (KCl)	KG			
	TOOLS (/2)				4,755
	DIESEL FUEL	L	176	100	17,600
	TOTAL COST OF INPUTS				108,945
B.	VALUE OF OUTPUT	KG	65	5,000	325,000
C.	CAPITAL COST - PUMP (/3)				26,700
D.	PUMP & INPUTS (A+C)				135,645
E.	RETURN TO LABOR AND CAPITAL (B-A)				216,055
F.	RETURN TO LABOR (E-C)				189,355
G.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				416
H.	COST OF LABOR (F/G) IN FCFA/MAN DAY				455
I.	PROFITABILITY INDEX (B/D)				2.39

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 32. FARM BUDGET 3 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 8 MT/HA/YR, SELLING PRICE 65 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS	KG	65	100	6,500
	FERTILIZER (NPK)	KG	192	500	96,000
	FERTILIZER (UREA)	KG	76	100	7,600
	FERTILIZER (KCl)	KG	40	150	6,000
	TOOLS (/2)				4,755
	DIESEL FUEL	L	176	100	17,600
	TOTAL COST OF INPUTS				138,455
B.	VALUE OF OUTPUT	KG	65	8,000	520,000
C.	CAPITAL COST - PUMP (/3)				26,700
D.	PUMP & INPUTS (A+C)				165,155
E.	RETURN TO LABOR AND CAPITAL (B-A)				381,545
F.	RETURN TO LABOR (E-C)				354,845
G.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H.	COST OF LABOR (F/G) IN FCFA/MAN DAY				709
I.	PROFITABILITY INDEX (B/D)				3.14

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 33. FARM BUDGET 4 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 8 MT/HA/YR, SELLING PRICE 90 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS	KG	65	100	6,500
	FERTILIZER (NPK)	KG	192	500	9,600
	FERTILIZER (UREA)	KG	76	100	7,600
	FERTILIZER (KCl)	KG	40	150	6,000
	TOOLS (/2)				4,755
	DIESEL FUEL	L	176	100	17,600
	TOTAL COST OF INPUTS				138,455
B.	VALUE OF OUTPUT	KG	90	8,000	720,000
C.	CAPITAL COST - PUMP (/3)				26,700
D.	PUMP & INPUTS (A+C)				165,155
E.	RETURN TO LABOR AND CAPITAL (B-A)				581,455
F.	RETURN TO LABOR (E-C)				554,845
G.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H.	COST OF LABOR (F/G) IN FCFA/MAN DAY				1,110
I.	PROFITABILITY INDEX (B/D)				4.36

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 34. FARM BUDGET 5 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 8 MT/HA/YR, SELLING PRICE 100 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS	KG	65	100	6,500
	FERTILIZER (NPK)	KG	192	500	96,000
	FERTILIZER (UREA)	KG	76	100	7,600
	FERTILIZER (KCl)	KG	40	150	6,000
	TOOLS (/2)				4,755
	DIESEL FUEL	L	176	100	17,600
	TOTAL COST OF INPUTS				138,455
B.	VALUE OF OUTPUT	KG	100	8,000	800,000
C.	CAPITAL COST - PUMP (/3)				26,700
D.	PUMP & INPUTS (A+C)				165,155
E.	RETURN TO LABOR AND CAPITAL (B-A)				661,545
F.	RETURN TO LABOR (E-C)				634,845
G.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H.	COST OF LABOR (F/G) IN FCFA/MAN DAY				1,270
I.	PROFITABILITY INDEX (B/D)				4.84

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 35. FARM BUDGET 6 (/1) (IN FCFA, 1984), ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT YIELD 8 MT/HA/YR, SELLING PRICE 125 FCFA/KG

A. COST OF INPUTS	UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
SEEDS	KG	65	100	6,500
FERTILIZER (NPK)	KG	192	500	96,000
FERTILIZER (UREA)	KG	76	100	7,600
FERTILIZER (KCl)	KG	40	150	6,000
TOOLS (/2)				4,755
DIESEL FUEL	L	176	100	17,600
TOTAL COST OF INPUTS				138,455
B. VALUE OF OUTPUT	KG	125	8,000	1,000,000
C. CAPITAL COST - PUMP (/3)				26,700
D. PUMP & INPUTS (A+C)				165,155
E. RETURN TO LABOR AND CAPITAL (B-A)				861,545
F. RETURN TO LABOR (E-C)				834,845
G. ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H. COST OF LABOR (F/G) IN FCFA/MAN DAY				1,670
I. PROFITABILITY INDEX (B/D)				6.05

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 36. FARM BUDGET 7 (/1) (IN FCFA, 1984), ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT YIELD 8 MT/HA/YR, SELLING PRICE 125 FCFA/KG

A1. COST OF INPUTS	UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
SEEDS	KG	65	100	6,500
FERTILIZER (NPK)	KG	192	500	96,000
FERTILIZER (UREA)	KG	76	100	7,600
FERTILIZER (KCl)	KG	40	150	6,000
TOOLS (/2)				4,755
DIESEL FUEL	L	176	100	17,600
SUB-TOTAL COST OF INPUTS				138,455
A2. OTHER COSTS				
PERIMETER DEVELOPMENT				163,798
EXTENSION, TECHNICAL ASST., COMMODITIES, O&M				100,251
COST OF WATER (MANANTALI DAM)				52,283
A. TOTAL INPUTS AND OTHER COSTS (A1 + A2)				454,787
B. VALUE OF OUTPUT	KG	125	8,000	1,000,000
C. CAPITAL COST - PUMP (/3)				26,700
D. PUMP & INPUTS (A+C)				481,487
E. RETURN TO LABOR AND CAPITAL (B-A)				545,213
F. RETURN TO LABOR (E-C)				518,513
G. ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H. COST OF LABOR (F/G) IN FCFA/MAN DAY				1,037
I. PROFITABILITY INDEX (B/D)				2.08

Notes:

1. Includes recovery of capital investment costs in dam, perimeter, and other operating/extension farm costs.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 37. FARM BUDGET 8 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 8 MT/HA/YR, SELLING PRICE 100 FCFA/KG

A1. COST OF INPUTS	UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
SEEDS	KG	65	100	6,500
FERTILIZER (NPK)	KG	192	500	96,000
FERTILIZER (UREA)	KG	76	100	7,600
FERTILIZER (KCl)	KG	40	150	6,000
TOOLS (/2)				4,755
DIESEL FUEL	L	176	100	17,600
SUB-TOTAL COST OF INPUTS				138,455
A2. OTHER COSTS SAME AS FARM BUDGET 7				316,332
A. TOTAL INPUTS AND OTHER COSTS (A1 + A2)				454,787
B. VALUE OF OUTPUT	KG	100	8,000	800,000
C. CAPITAL COST - PUMP (/3)				26,700
D. PUMP & INPUTS (A+C)				481,487
E. RETURN TO LABOR AND CAPITAL (B-A)				345,213
F. RETURN TO LABOR (E-C)				318,513
G. ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H. COST OF LABOR (F/G) IN FCFA/MAN DAY				637
I. PROFITABILITY INDEX (B/D)				1.66

Notes:

1. Includes recovery of capital investment costs in dam, perimeter, and other operating/extension farm costs.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 38. FARM BUDGET 9 (/1) (IN FCFA, 1984),
ONE CROP OF IRRIGATED PADDY RICE ON A ONE HA PLOT
YIELD 8 MT/HA/YR, SELLING PRICE 90 FCFA/KG

A1. COST OF INPUTS	UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
SEEDS	KG	65	100	6,500
FERTILIZER (NPK)	KG	192	500	96,000
FERTILIZER (UREA)	KG	76	100	7,600
FERTILIZER (KCl)	KG	40	150	6,000
TOOLS (/2)				4,755
DIESEL FUEL	L	176	100	17,600
SUB-TOTAL COST OF INPUTS				138,455
A2. OTHER COSTS SAME AS FARM BUDGET 7				316,332
A. TOTAL INPUTS AND OTHER COSTS (A1 + A2)				454,787
B. VALUE OF OUTPUT	KG	90	8,000	720,000
C. CAPITAL COST - PUMP (/3)				26,700
D. PUMP & INPUTS (A+C)				481,487
E. RETURN TO LABOR AND CAPITAL (B-A)				265,213
F. RETURN TO LABOR (E-C)				238,513
G. ESTIMATED LABOR REQUIRED IN MAN-DAYS				500
H. COST OF LABOR (F/G) IN FCFA/MAN DAY				477
I. PROFITABILITY INDEX (B/D)				1.50

Notes:

1. Includes recovery of capital investment costs in dam, perimeter, and other operating/extension farm costs.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 39. FARM BUDGET 10 (IN FCFA, 1984),
ONE CROP OF RAINFED CORN ON A ONE HA PLOT
YIELD 1.5 MT/HA/YR, SELLING PRICE 60 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS (/1)	KG	60	20	1,200
	FERTILIZER (NPK)	KG	192	100	19,200
	FERTILIZER (UREA)	KG	76	50	3,800
	FERTILIZER (KCl)	KG	40	75	3,000
	TOOLS (/1)				4,755
	DIESEL FUEL	L			0
	TOTAL COST OF INPUTS				31,955
B.	VALUE OF OUTPUT	KG	60	1500	90,000
C.	RETURN TO LABOR (B-A)				58,045
D.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				60
E.	COST OF LABOR (C/D) IN FCFA/MAN DAY				967
I.	PROFITABILITY INDEX (B/A)				2.82

Note:

1. After Keita, for 1984

FIGURE 40. FARM BUDGET 11 (IN FCFA, 1984),
ONE CROP OF RAINFED CORN ON A ONE HA PLOT
YIELD 2.5 MT/HA/YR, SELLING PRICE 60 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS (/1)	KG	60	20	1,200
	FERTILIZER (NPK)	KG	192	100	19,200
	FERTILIZER (UREA)	KG	76	50	3,800
	FERTILIZER (KCl)	KG	40	75	3,000
	TOOLS (/1)				4,755
	DIESEL FUEL	L			0
	TOTAL COST OF INPUTS				31,955
B.	VALUE OF OUTPUT	KG	60	2500	150,000
C.	RETURN TO LABOR (B-A)				105,545
D.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				64
E.	COST OF LABOR (C/D) IN FCFA/MAN DAY				1,649
I.	PROFITABILITY INDEX (B/A)				3.37

Note:

1. After Keita, for 1984

FIGURE 41. FARM BUDGET 12 (/1) (IN FCFA, 1984), ONE CROP OF IRRIGATED CORN ON A ONE HA PLOT YIELD 5 MT/HA/YR, SELLING PRICE 65 FCFA/KG

		UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
A.	COST OF INPUTS				
	SEEDS (Selected)	KG	85	23	1,955
	FERTILIZER (NPK)	KG	192	200	38,400
	FERTILIZER (UREA)	KG	76	100	7,600
	FERTILIZER (KCl)	KG	40	100	4,000
	TOOLS (/2)				4,755
	DIESEL FUEL	L	176	50	8,800
	TOTAL COST OF INPUTS				65,510
B.	VALUE OF OUTPUT	KG	65	5,000	325,000
C.	CAPITAL COST - PUMP (/3)				26,700
D.	PUMP & INPUTS (A+C)				92,210
E.	RETURN TO LABOR AND CAPITAL (B-A)				259,490
F.	RETURN TO LABOR (E-C)				232,790
G.	ESTIMATED LABOR REQUIRED IN MAN-DAYS				74
H.	COST OF LABOR (F/G) IN FCFA/MAN DAY				3,507
I.	PROFITABILITY INDEX (B/D)				3.52

Notes:

1. Does not include recovery of capital investment costs in dams, irrigation/drainage systems, roads.
2. After Keita, for 1984
3. Assumes 27 ha

FIGURE 42. FARM BUDGET 13 (/1) (IN FCFA, 1984), ONE CROP OF IRRIGATED CORN ON A ONE HA PLOT YIELD 5 MT/HA/YR, SELLING PRICE 65 FCFA/KG

A1. COST OF INPUTS	UNIT	UNIT COST	NO. OF UNITS	TOTAL COSTS
SEEDS (Selected)	KG	85	23	1,955
FERTILIZER (NPK)	KG	192	200	38,400
FERTILIZER (UREA)	KG	76	100	7,600
FERTILIZER (KCl)	KG	40	100	4,000
TOOLS (/2)				4,755
DIESEL FUEL	L	176	50	8,800
TOTAL COST OF INPUTS				65,510
A2. OTHER COSTS (50% OF FARM BUDGET 7)				158,166
A. TOTAL INPUTS AND OTHER COSTS				223,676
B. VALUE OF OUTPUT	KG	65	5,000	325,000
C. CAPITAL COST - PUMP (/3)				26,700
D. PUMP & INPUTS (A+C)				250,376
E. RETURN TO LABOR AND CAPITAL (B-A)				101,324
F. RETURN TO LABOR (E-C)				74,624
G. ESTIMATED LABOR REQUIRED IN MAN-DAYS				74
H. COST OF LABOR (F/G) IN FCFA/MAN DAY				1,008
I. PROFITABILITY INDEX (B/D)				1.30

Notes:

1. Includes recovery of capital investment costs in dam, perimeter and other operating/extension farm costs.
2. After Keita, for 1984
3. Assumes 27 ha

Figure 43
SENSITIVITY ANALYSIS
Selling Price of Paddy Rice vs. Income per Man/Day
Yield = 8 ton/ha./yr.

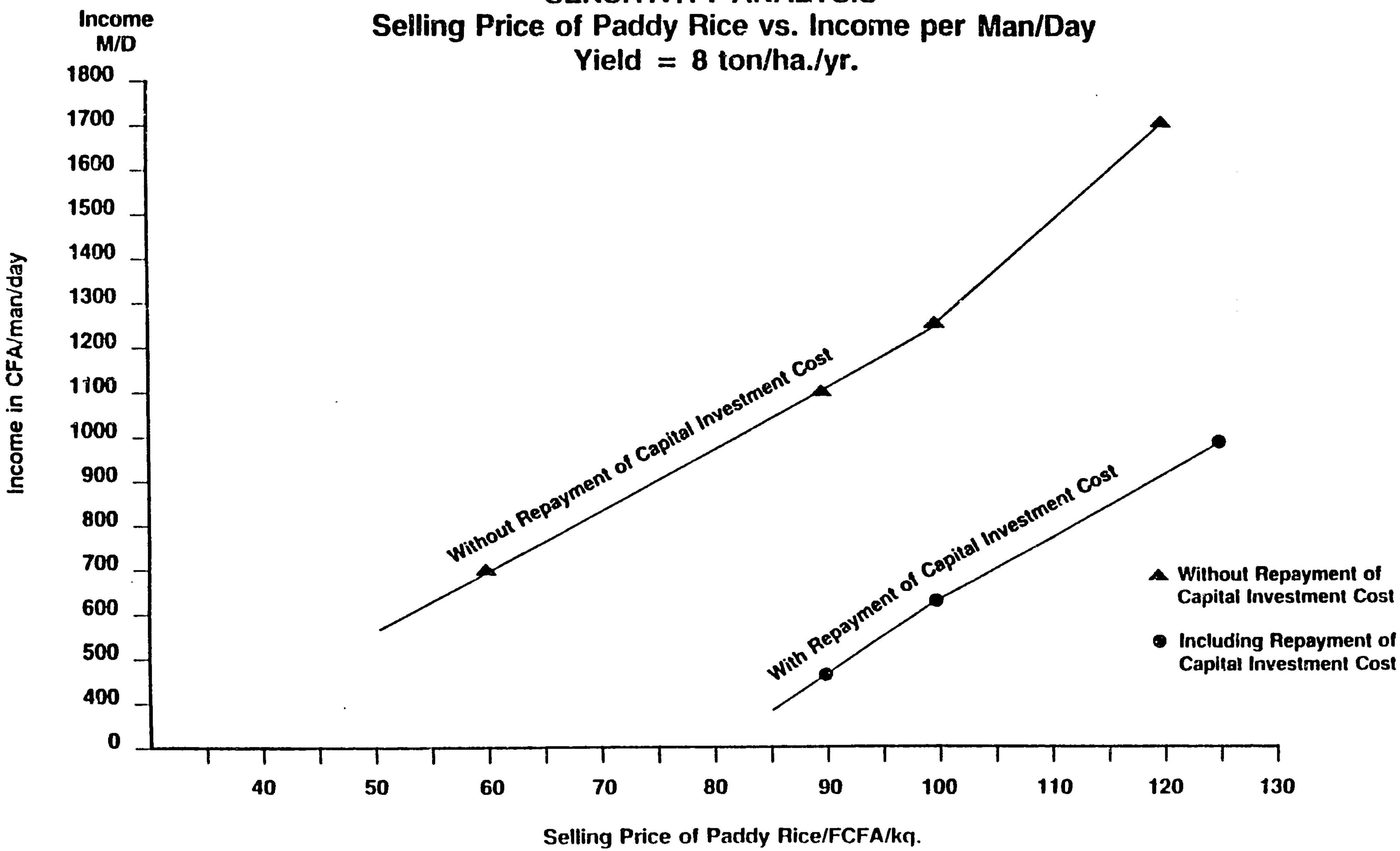
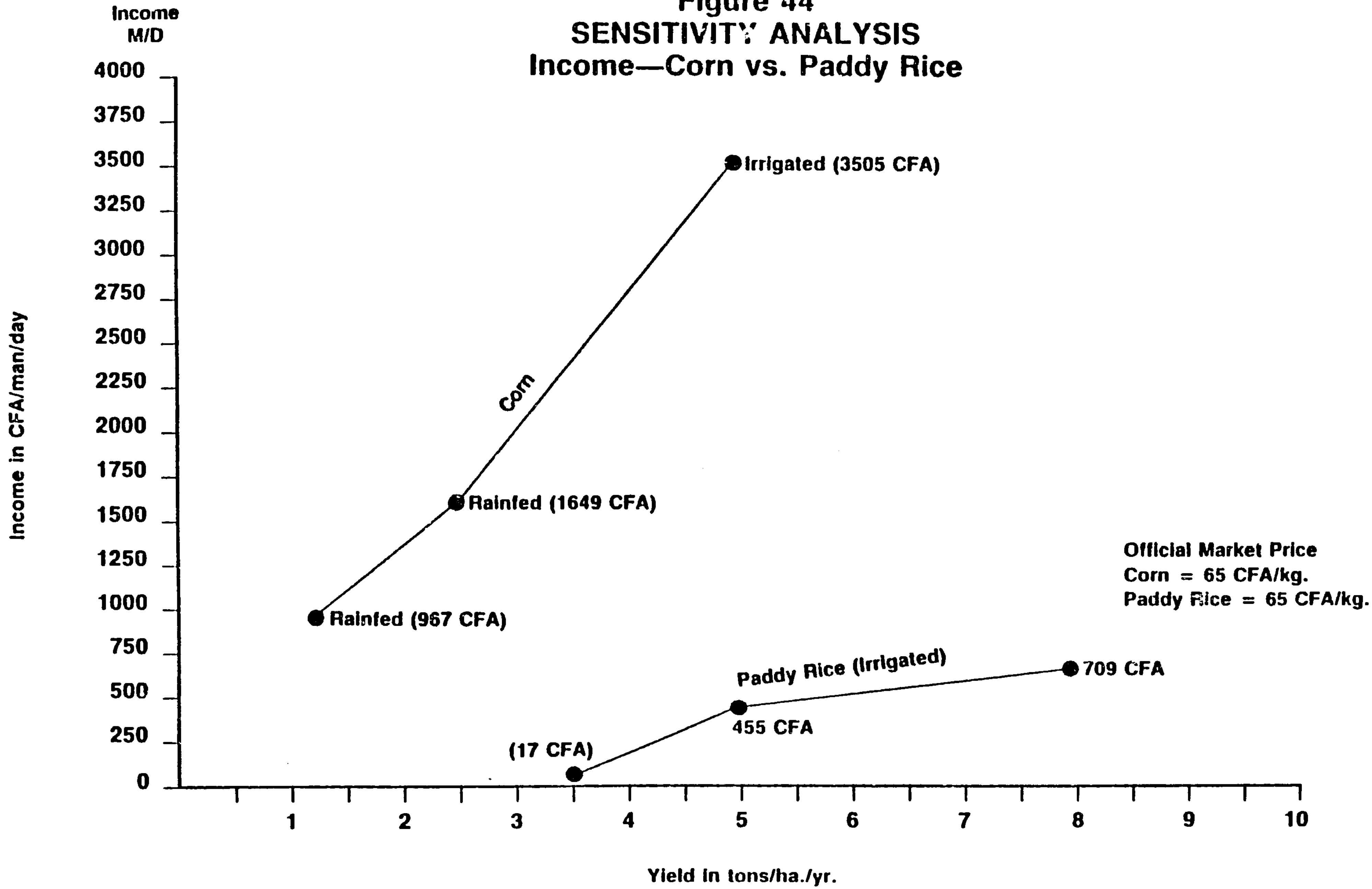


Figure 44
SENSITIVITY ANALYSIS
Income—Corn vs. Paddy Rice



4.3 Podor Area

4.3.1 Land

The GERSAR plan includes topographic and soils maps at 1/5,000 scale although, as noted previously (Part 3.1.2), the soils map was produced at 1/10,000 scale. The soils map shows that the soils are predominantly fine to very fine textured. Some sandy surface horizons are found in the southeast and southwest, but these are generally underlain by clays. Coarse textured lenses are noted in many of the mapping units. Many of the soils are said to be vertic, indicating a tendency to swell and seal when wet, and shrink and crack on drying. Some salinity problems were observed in the lower lying areas. Soil permeability is generally slow and drainage is a problem.

Overall, the soils information developed by GERSAR appears to be adequate, although the only way to be sure would be to verify it on the ground.

Topographic information exists in the GERSAR plan at 1/5,000. Likewise, ortho-photo maps, containing topographic information (Teledyne) exist at 1/10,000.

4.3.2 Water

Water Availability. The issue of water availability for the proposed project at Podor is not addressed in the Project Paper. During this review mission, this aspect is analyzed for the following three conditions:

Existing Streamflow Condition - To evaluate the availability of water for a proposed irrigation project, the first question to be answered is usually "How much water is needed?" As of July 1983, as shown on Figure 23 (Section 3.4), the irrigated areas developed in the Senegal River Basin at and upstream of Podor are:

Delegation	Area (ha)
Bakel	799
Matam	2,555
Podor	4,238

Total	7,592

Figure 45 indicates the monthly irrigation requirements for rice that were assumed by GERSAR (1983) in the feasibility study of the Left Bank irrigation perimeters. Based on the total area of 7,592 ha, the monthly water demands for areas to be irrigated at and upstream of Podor are also given in Figure 45.

FIGURE 45. WATER REQUIREMENTS FOR RICE FIELD IRRIGATION

Month	Water Requirement per Hectare (l/s)	Monthly Water Demand for Areas at and and Upstream of Podor (cubic meters/s)
January	-	-
February	3.0	22.8
March	1.7	12.9
April	2.3	17.5
May	2.3	17.5
June	0.6	4.5
July	2.4	18.2
August	1.2	9.1
September	2.0	15.2
October	1.8	13.7
November	0.7	5.3
December	-	-

Note: 1. Source of water requirements per hectare is from GERSAR (1983) for double cropping.

2. Monthly water demand for areas to be irrigated at and upstream of Podor is computed based on a figure of 7,592 hectares.

The next question to be answered is, "How much water is available?" There is no streamflow record at the Podor area. However, the streamflow data at Bakel can be used for the evaluation of water availability at Podor because the natural monthly flows between Bakel and Dagana (located about 100 kilometers downstream of Podor) should be virtually the same.

The monthly flows for selected return periods at Bakel are shown in Figure 46. Comparing flows from Figures 45 and 46, it is obvious that streamflows during the wet season are more than sufficient for irrigation on the proposed perimeters at Podor.

Nevertheless, water is not dependable for irrigation during the dry season, particularly from April through June.

FIGURE 46. MONTHLY FLOWS FOR SELECTED RETURN PERIODS AT BAKEL (Natural Condition)

Month	Average Flow	5-Year Flow	10-Year Flow
January	138	79	67
February	93	48	44
March	43	26	21
April	17	9	7
May	5	3	2.5
June	79.5	7.5	3.3
July	542	390	303
August	2006	1397	1070
September	3035	2340	1206
October	1480	822	556
November	587	303	230
December	238	138	120

Notes: 1. The source of data is from GERSAR (1983).

2. The period of data is from 1950 to 1978.

3. The flows are expressed in cubic meters/s.

4. The 5-year flow denotes that once in five years the flow will be less than indicated.

Streamflow After Completion of the Diama Dam - The situation of water availability for the proposed irrigation perimeters at Podor after the completion of the Diama Dam will be the same as that for the existing streamflow conditions because, even though the water level will be raised behind the Diama Dam, the water to be stored in the reservoir has been designated for municipal/industrial water supply and irrigation of the Delta area. Therefore, with the completion of the Diama Dam, water will still not be dependable for irrigation at Podor during the dry season.

Streamflow after Completion of the Manantali Dam. According to the OMVS development plan, the Manantali reservoir will provide a year-round supply for irrigation of 255,000 ha of land between Manantali and Saint-Louis. The controlled release for irrigation will be 190 cubic meters/second (Groupement Manantali, 1977). Therefore, after the completion of the Manantali Dam, water will be sufficient for irrigation of two crops per year on the proposed perimeters at Podor.

Flood Protection. The flooding characteristics of the Senegal River between Bakel and Saint-Louis were simulated by SOGREAH (1977) for the natural flow condition and the projected condition after the completion of the Diama Dam. The tool used for the simulations was a mathematical model which is based on the well-known equation of mass or continuity. The reports prepared by SOGREAH (1977 and 1978) did not five a detailed description of the input data. However, based on personal communication with staff members at SOGREAH in 1978, Gannett Fleming Corddry and Carpenter (1980) provided a detailed summary regarding the input data and calibration results of the SOGREAH model. The model seems to be suitable for the simulation of flooding characteristics in the Senegal River floodplain under present and future development conditions. SOGREAH (1978) concluded that the water level of a given flood after the completion of the Diama Dam will be much higher than the level under the natural condition.

During the study of the left bank irrigation perimeters (including the perimeter of Podor), GERSAR (1983) applied the SOGREAH model to examine the flooding characteristics of the Senegal River after completion of the Manantali Dam. The results indicated that for a given recurrence frequency, the magnitude of flood after the completion of the Manantali Dam will be slightly smaller than the flood magnitude with the Diama Dam alone.

The simulation results, in terms of water level elevations at Podor, for the present and future development conditions are summarized in Figure 47. According to the IDP Project Paper, Annex 3.2 and the Podor Project Data Sheet prepared by RBDO in June 1984, the crest elevation of the proposed diking system at Podor is 7.20 m IGN, which provides a protection against a 10-year flood under the present natural condition plus a freeboard of 1.0 m. As shown in Figure 47, however, this crest level of 7.2 m IGN will not be sufficient to provide the protection against a 10-year flood with a 1.0 m freeboard after the completion of the Diama Dam in 1985.

FIGURE 47. PROJECTED WATER LEVEL ELEVATIONS AT PODOR PERIMETER

Condition	10-Year Flood (m IGN)		100-Year Flood (m IGN)	
	Senegal River	Doue Creek	Senegal River	Doue Creek
Natural State	6.10	6.20	7.00	7.30
Diama Dam Only	6.82	6.85	7.87	7.92
Both Diama and Manantali Dams	6.10	6.20	7.41	7.47

Source: GERSAR (1983)

Therefore, in our opinion, if the diking system is going to be constructed to provide the protection of a 10-year flood with 1.0 m freeboard at Podor, the crest of the dike should be raised to 7.85 m IGN. With this crest elevation, the diking system will be able to confine the 100-year flood with a freeboard of 0.38 m after the completion of the Manantali Dam in 1989 or later.

As previously indicated, the criteria of site selection at Podor were not addressed in the Project Paper. Usually, the construction of diking systems is expensive. According to the Podor Project Data Sheet, the top of the existing paved road to Podor has an elevation of 7.2 m IGN, which is equal to the proposed crest elevation of the diking system. Thus, if the land on the south side of the paved Route Nationale 2 is suitable for agricultural development, it should be considered as an alternative site for the Podor development project.

4.3.3 Irrigation System

As previously stated, the Project Paper proposes the phased construction of the Podor irrigation project. The layout and designs are the same as in the avant projet detaille prepared by GERSAR.

As discussed in 4.3.2, the total area proposed for irrigation development would be protected against flooding. On the other hand, the lower portion of the cuvette would be left for traditional flood recession agriculture which could be practiced once the Manantali Dam becomes operations at the end of the present decade.

As shown on Figure 48, the proposed cuvette development is actually made of 5 medium sized individual irrigation systems (sectors) ranging from 182 to 329 gross ha (149 to 270 net ha) each, and each of the said systems would be supplied by a permanent (stationary) pumping station capable of lifting water from the variable river stages. The perimeter would be run by a federation of farmers. Each of these individual irrigation systems would be managed by a federation subdivision made of several groupements. The GERSAR development plan is based upon a study of theoretical demand for irrigation by the population. The Project Paper proposed to start by development of two such systems initially, one close to the Podor village (C1 sector, 247 net ha) along the Senegal and the other one (sector M2, 249 net ha) to the south of

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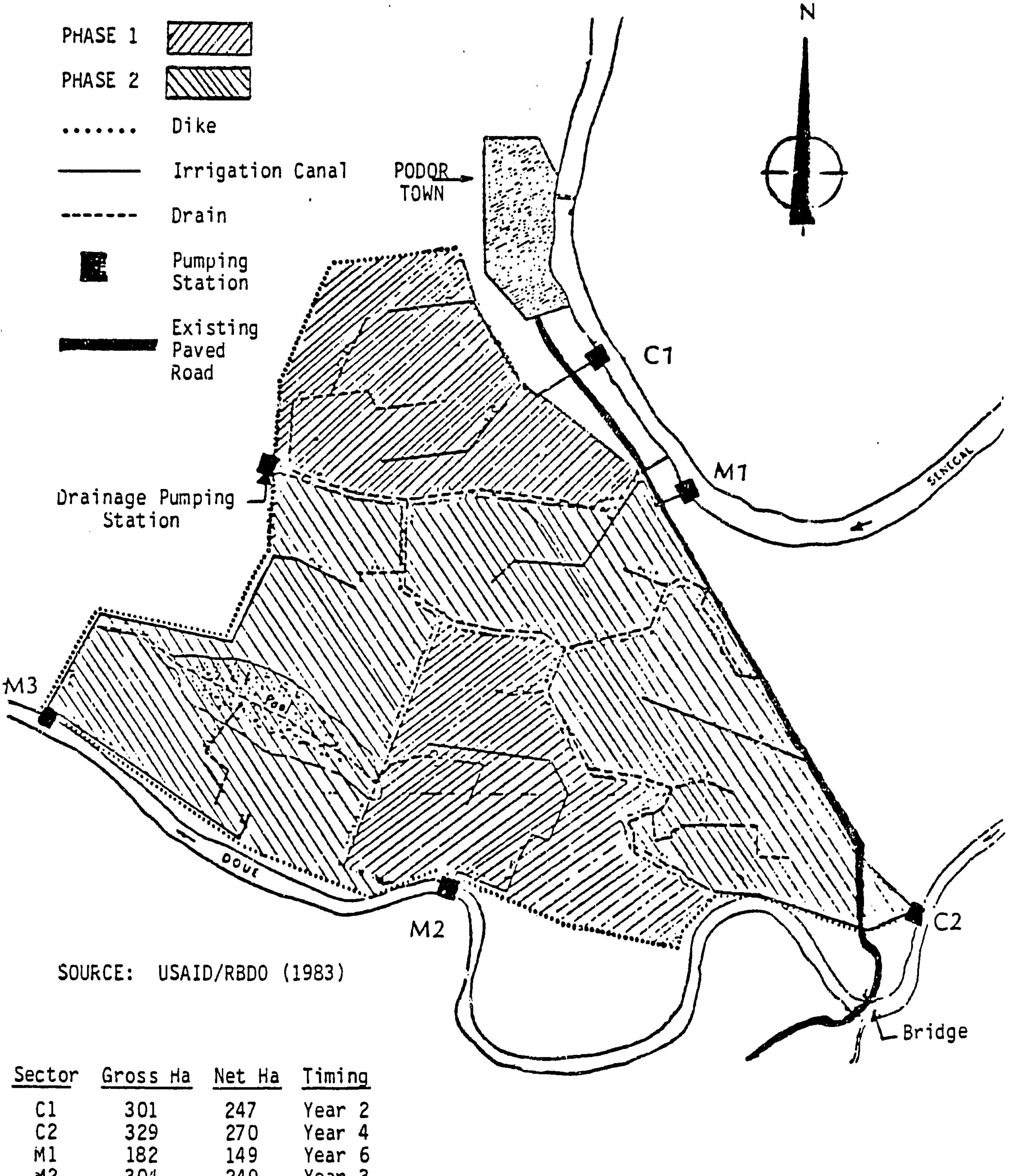
FIGURE 48. GENERAL LAYOUT OF PODOR PERIMETER AS DESIGNED BY GERSAR AND PHASED DEVELOPMENT AS ENVISAGED IN THE IDP



SOURCE: USAID/RBDO (1983)

Sector	Gross Ha	Net Ha	Timing
C1	301	247	Year 2
C2	329	270	Year 4
M1	182	149	Year 6
M2	304	249	Year 3
M3	312	256	Year 5
Total	1428	1171	

Podor on the Doue, plus all of the proposed diking and a drainage pumping station.

In the meantime, the Fond Europeen de Developpement (FED) is financing "temporary" small perimeter development along both the Doue and Senegal Rivers. This work is largely carried out by village groupements assisted by SAED. The method of development is similar to the one seen in Bakel, reportedly the gross area covered by these small developments is 170 ha.

Upon review of the existing design, the following comments appear to be appropriate:

1. The design flows are based on peak water demands for rice. The design is done to conserve head thus the end product is a system of large canal sections and low velocity flows.

2. The overall criteria for canal/drain/road systems is generous as far as right of way is concerned, thus the project facilities occupy a large part of the total irrigable land.

3. The proposed irrigation system is apparently the only one considered in the study. In other words, no alternatives appear to have been analyzed.

4. It is not clear why there should be 5 pumping stations.

5. Because of the adopted design criteria and the need for diking the resulting investment cost is high (in the order of $8,000 per ha, estimated in 1983).

6. The farmers will require considerable training before they can operate the pumping stations/gates. The operation of pumping stations by farmers will not be possible unless they learn to work together and acquire the necessary skills.

7. The open canal systems with low velocity flows will require considerable maintenance. This is rarely practiced in existing perimeters.

On the basis of the above, as indicated in Part 2 of this report, prior to proceeding with implementing this project, it is recommended that a feasibility review be carried out. Said review should include the study of alternative water systems such as use of low pressure buried pipe for water distribution and alternative layouts. Although buried pipe is likely to have higher head losses, this disadvantage might well be offset by higher efficiency, less need for maintenance, longer useful life, and lower water requirements and drainage water pumping requirements. Other items such as labor availability, management training and marketing studies should be included in said feasibility review.

4.3.4 Economic Analysis

In IDP Volume III, Section 1, page 168, the project economic costs for Podor and Bakel are summarized as below:

FIGURE 49. PROJECT ECONOMIC COST SUMMARY (million of $US)

	Podor	Bakel
On farm costs	5.81	5.85
Construction	5.08	1.96
Extension service	0.32	0.21
Technical assistance	1.16	0.86
Commodities	0.18	0.19
Operating costs	0.53	0.54
Total	13.08	9.61
Number of irrigated ha (Net)	782	496
Total cost per net ha ($US)	16,726	19,375
Construction cost net ha ($US)	6,496	3,952

On page 163 of the same report it is stated, "Aside from construction, Podor remains an important part of the project, however, because it represents a prototype irrigation system, which combines large-scale cultivation and water management at the groupement level. If the full potential for irrigation in the Senegal River Valley is to be developed over the longer run, it will have to be done with this type of scheme rather than by simply expanding the number of small perimeters since most of the best locations have already been developed. At Bakel and Kaedi, the most suitable lands for irrigated perimeters have already been taken hence most of the areas to be developed by the project will require diking and levelling and therefore will cost more."

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To evaluate the feasibility of the large capital investments necessary, the following calculations were made (see also Annex 6).

FIGURE 50. INVESTMENT COST (ESTIMATES)

		Gross Ha	Net Ha
Podor Perimeter (1982 value)	$	6,678	8,143
Podor Perimeter (1982 value)	CFA	2,337,000	2,850,000
Podor Perimeter (1984 value)	CFA	2,576,543	3,142,125

Considering that for capital recovery an annuity for 25 years at a modest 6% interest rate is minimal, the farmer would eventually have to pay a minimum of 245,798/ha/year.

On the basis of the sensitivity analysis of Farm Budget costs for irrigated rice production (Figures 30-38), the following calculations are made:

FIGURE 51. MAN DAY VALUES FOR RICE PRODUCTION

Yield (Ton/ha)	Return to Labor	-	Annuity Investment Cost	=	Total Return To Labor	Man Day CFA
3.5	7,235	-	245,798	=	-238,563	Negative
5	189,355	-	245,798	=	-56,443	Negative
8	354,845	-	245,798	=	109,047	218

This shows that the man day value (labor opportunity cost) with a farm that produces a high yield (8 ton/ha), is only 218 CFA/day.

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Therefore, if the selling price of rice is 65 CFA/Kg the Podor project is not financially feasible.

At a selling price of 125 CFA/Kg with a yield of 8 ton/ha,

Return to labor	834,845 CFA
Annuity investment	-245,798 CFA

Total return to labor is 589,047 or 1,178 CFA/day of work.

Rice from Thailand is imported at $232/ton or 92.8 CFA/Kg. At this market value:

Return to labor is	554,845 CFA
Annuity investment	-245,798 CFA

Total return to labor 309,047 or 618 CFA/day of work.

With this low daily labor income it is questionable if the farmer will be satisfied. Therefore, if the GOS is interested in import substitution then the market price of rice should be raised to the minimum import value of 92.82 CFA/Kg.

It is questionable whether the average farmer can obtain high yields of 8 ton/ha (in one crop). At a lower yield, even at 92.82 CFA/Kg, the farmer will get less, i.e., with 7 Ton/Ha only 438 CFA/Work day.

For the project to be economically feasible, the GOS should guarantee a price above 100 CFA/Kg or way above the import price of

92.82 CFA/Kg, which would not be economical for the country.

After weighing these alternatives a large perimeter such as Podor, requiring so much investment per ha to produce rice is not economically feasible.

4.4 N'Thiagar Area

4.4.1 Land

This existing perimeter is located in the Delta some 20 km west of Richard Toll. Soils (IRAT 1972, Etudes pedologiques du perimetre de Thiagar) and topographic information exist. The rehabilitation feasibility study (SEDES 1982) makes some very general comments on soils. Basically, the area contains soils which are dominantly fine textured, with a few patches of 'fonde' soils. Drainage is difficult and there are problems of salinity. Some areas have been left uncultivated because of high salinities. The principal crop is rice with some diversification found on the lighter soils.

The primary problems here are the infrastructure and drainage. As previously noted, drainage in the Delta is very difficult but is especially critical due to the problems of salinity.

4.4.2 Water

Water Availability. The water supply conditions are similar to those described for the Podor area. After the completion of Diama Dam, the problem of seawater intrusion in the Senegal River will be improved. However, there is a possibility that the groundwater table will be raised in the Delta due to the increased use of irrigation water in that area and to the dam itself. If the drainage pumping system of irrigation perimeters is not properly designed, the water table will eventually rise to the root zone which in turn may result in an increase in soil salinity. This will create a problem since most crops do not prosper with their roots in saturated soil, especially with high salt concentrations. Therefore, the drainage pumping system in the Delta area should be operated in close conjunction with the proposed groundwater monitoring program.

Flood Protection. The existing perimeter is protected against floods by an existing dike which is part of the 80 km long dike system along the left bank of he Senegal River in Senegal, conceived and built following the criteria set for the operation of the Diama Dam.

However, according to the Gannett-Fleming report, the town of N'Thiagar will have to be relocated due to the Diama Dam. This will be a further social interruption in a perimeter already beset by problems of alternative work opportunities available at Richard Toll.

4.4.3 Existing Irrigation System

The N'Thiagar perimeter covers a gross surface area of 1070 ha. The net irrigable area is 785 ha and the gross developed area is 870 ha.

Initially, the irrigation at N'Thiagar was intended to cover an area of 1900 ha protected by dikes against flooding. Irrigation was set up by uncontrolled flooding. Water (3500 lts) was pumped into flat sloping canals and fields were flooded by overflowing canals.

In 1974 studies for controlled irrigation were carried out but upon project completion in 1976 the area was reduced to its present size because of lack of funds. For the same reason, land levelling was not carried out and drainage was scaled down.

Following reports of poor operations, analyses conducted in 1981 indicated that the irrigation system was undersized, that the drainage system was insufficient, and the pumping stations needed improvements. In1982, a technical rehabilitation study (Rehabilitation du perimetre de Thiagar. Dossier d'executions du Developpement Rural, SAED, 1982) was carried out that was supposed to lead to the preparation of tender documents for construction of required improvements.

In the same year and following the above mentioned technical rehabilitation study, the French Government funded the preparation of a feasibility study completed in December 1982 (Rehabilitation of the Thiagar District, Feasibility Study, prepared by Societe d'Etudes pour le Developpement Economique et Social, Paris, for SAED and the French Ministry of Foreign Relations, Cooperation and Development). This feasibility report proposes the electrification of secondary pumping stations, resizing of pumping

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installations and of drainage and irrigation networks, building a pumping station and general improvement for drainage, setting up low power mechanized units in the cooperatives, construction of administrative and farm buildings for cooperatives, and setting up of an independent SAED structure for the district comprising maintenance equipment, vehicles and buildings. The technical data on rehabilitation presented in the feasibility report is an abstract of proposals contained in the rehabilitation study and cost estimates as required for feasibility analysis.

The total investment costs were estimated at 813 million CFA, broken down as follows, in million CFA (1982).

Infrastructure Improvements	196
Cooperatives	396
SAED District Unit	138
Miscellaneous & Contingencies	84

Total, million CFA	813

Total per hectare, 930,000 CFA
(for gross equipped area of 870 ha)

The above estimate does not include the following costs under separate SAED program:

- electrification of main water supply pumping station
- technical studies for rehabilitation

After its rehabilitation and upon completion of the Diama Dam, the feasibility study estimates that the N'Thiagar project will be able to produce 6000 MT of rice paddy yielding an estimated 4.5 T/ha in two crops (785 ha irrigated during the wet season and 628 ha irrigated during the dry season). The paddy would be transformed into 3925 T of white rice (65% of paddy) and products (straw and bran).

However, the above mentioned studies do not take into account the effects of the Diama Dam. We visited the N'Thiagar perimeter on August 24, 1984, accompanied by Mr. Wade, Director of the Richard Toll district, and by Mr. Sadibou Coly. We visited the main irrigation pumping station recently electrified/improved, one of the irrigation relift stations, general tour of the perimeter and area of the main drain. We were told that the two irrigation relift stations were not properly sized. We could notice the generally poor condition of the irrigation canals, drainage ditches, and irrigation relift station, the lack of maintenance, the inadequate levelling of rice fields. The drainage water cannot be evacuated and a pumping station and other major works appear to be required to dispose of drainage water. As stated before, the drainage problem will be aggravated by the higher water level created by the Diama Dam and more irrigation water supply from the Diama reservoir.

It is thus obvious that the existing infrastructure needs rehabilitation and that the existing studies need to be reviewed in order to incorporate the effects of the Diama Dam and address related technical, economic, social and organizational issues.

The IDP Project paper proposes carrying out a feasibility review of the proposed rehabilitation. We fully concurred with this approach. However, it is recommended that said study be conducted after an in-depth investigation of the soils/drainage problems and monitoring of the effect of the Diama reservoir. Our proposals are described in Part 2 of this report.

4.5 Review of Environmental Implications

Prediction of the environmental impact of developments, such as proposed for the Senegal River Basin, is a very difficult task. it is impossible to completely predict the type and degree of every environmental interaction which may take place. And in the final analysis, the assessment of the balance between beneficial and detrimental effects is not an absolute; it depends, to some degree, on the observer's priorities. The observers reporting in the Gannett-Fleming study concluded that the advantages of development proposed for the Senegal River Basin far outweigh the adverse consequences projected in their study. Advantages include, in particular, improved nutritional levels, improved quality of life, and possibilities for agro-industrial development.

The terms of reference for this review state, "Analyze environmental implications of widespread irrigation in targeted areas..." It is understood that "targeted areas" refers to the areas of Bakel, Podor and N'Thiagar. Development proposed in the IDP for these areas should be put in perspective. The total proposed new hectarage is only 1900 hectares, less than 10% of that already developed in the valley and less than 1% of that proposed for development, and only about 0.1% of the total valley (SRB) lands. In these terms, it may be seen, therefore, that the impact of the proposed USAID interventions can only be minimal, barring some extreme development. In terms of local effects, adverse effects are most likely to be linked to health, especially through the environment of poorly maintained canals which provide a breeding ground for schistosomiasis. The use of canals for animals, drinking, washing, laundry and defecating facilitates the transfer of other diseases.

In terms of health, Gannett-Fleming recommend the development of primary health care facilities and a regional health monitoring program. The latter proposal is incorporated into the IDP, through the proposed Health Surveillance program. While this program may have long-term benefits, many of the causes and solutions are already known, and preventive measures could be incorporated into the IDP. In particular, USAID might consider the provision of potable water for each village, alternate bathing/laundry facilities, separate water take-offs for livestock supply, and an intensive program of sanitary instruction at the village level. One other potential problem area, which may be prevented, is the handling and use of agricultural chemicals. As their use becomes

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more widespread with the intensification of agriculture, USAID should consider intensifying instruction in their storage, handling and use, and the provision of protective clothing, etc.

The broader perspective of development in the valley (including Senegal, Mali and Mauritania sections) is fully covered by Gannett-Fleming, who include 95 pages of recommendations. Most of these are for regional programs, and many of them deal with the effects of the Diama and Manantali Dams. The effects on the environment of these two dams is likely to be very substantial and to outweigh the environmental effects of any probable agricultural intensification within the forseeable future.