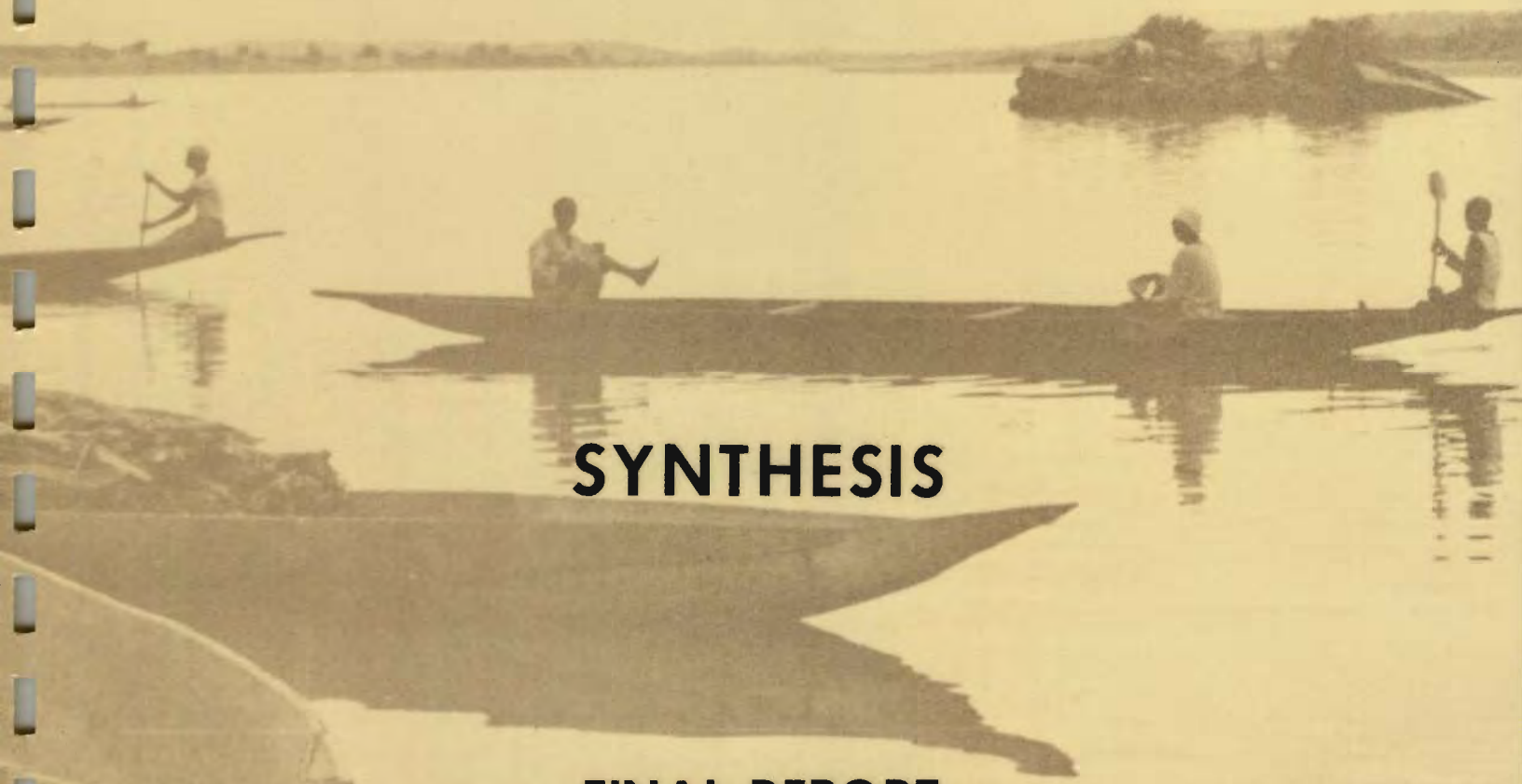
PN-AAJ-571 W-403 Duplicate

Organisation pour la Mise en Valeur du Fleuve Sénégal (O. M. V. S.)

ASSESSMENT OF ENVIRONMENTAL EFFECTS OF PROPOSED DEVELOPMENTS IN THE SENEGAL RIVER BASIN



SYNTHESIS

FINAL REPORT

1980

Gannett Fleming Corddry and Carpenter, Inc.
Harrisburg, Pennsylvania, USA

In association with

ORGATEC Société Africaine d'Etudes Techniques
Dakar, Sénégal

SYNTHESIS

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd.)

TABLE OF CONTENTS (cont'd.)

TABLE OF CONTENTS (cont'd.)

TABLE OF CONTENTS (cont'd.)

LIST OF FIGURES AND TABLES

LIST OF FIGURES AND TABLES (Cont'd.)

LIST OF FIGURES AND TABLES (Cont'd.)

LIST OF FIGURES AND TABLES (Cont'd.)

LIST OF PROJECT PARTICIPANTS

All members of the project staff were either full-time employees or consultants of Gannett Fleming Corddry and Carpenter, Inc., or employees of other firms that were utilized intermittently throughout the project. The project participants were as follows:

Senegal Project Staff

Team Discipline	Staff Member	Position/Specialty
Project Management	H. D. Hudgins	Project Director
	K. Sall	Asst. Project Director
	J. Bigosinski, Ph.D.	Economist
	P. Bierstein	Consultant
	A. Wolman, Sc.D.	Consultant
	R. A. Magnuson	Consultant
	T. Mooney	Chief of Field Missions
	D. Bilodeau	Chief of Technical Translations
Public Health	M. J. Miller, M.D.	Team Leader
	J. P. Chaine, M.P.H.	Chief, Field Medical Survey Team
	R. Winshall, M.D.	Asst. Chief, Medical Survey Team
	H. G. Scott, Ph.D.	Chief, Arthropod & Rodent-Borne Diseases
	E. A. Malek, Ph.D.	Schistosomiasis Specialist
	R. O. Hayes, Ph.D.	Medical Entomology
	E. B. Levy-Lambert, Ph.D.	Microbiologist/Nidalist
	W. Hubbert, D.V.M.	Veterinary Epidemiologist
	S. Gabrielian	Public Health Technician
	D. Diop	Public Health Technician

Team Discipline	Staff Member	Position/Specialty
River & Estuary Regimes	W. Stottmann, Ph.D.	Team Leader
	D. B. Babcock	Water Resources Engineer
	A. W. Johnson	Transportation Engineer
	L. E. Benander	Water Resources Engineer
	W. P. Wickwire, Jr.	Civil Engineer
	M. Watt	Computer Scientist
Water Quality	M. S. Gould, Ph.D.	Team Leader
Groundwater	B. Sall	Biochemist
Municipal & Industrial Development	D. N'Diaye	Computer Specialist
	M. Healey	Chemistry Laboratory Technician
	H. Thiem	Chemistry Laboratory Technician
Agricultural Development	W. Firestone	Team Leader
	H. Ly	Agronomist
	R. W. Duell, Ph.D	Soil Scientist
	J. F. Griffths	Meteorologist/Climatologist
	P. Schnurrenberger, D.V.M.	Livestock Specialist
Aquatic & Terrestrial Biota	D. Dorfman, Ph.D.	Team Leader
	M. L. Soumah	Fisheries Biologist
	D. P. Reagan, Ph.D.	Mammalogist & Herpetologist
	D. A. James, Ph.D.	Ornithologist
	D. J. Watt	Ornithologist
	R. Pellek	Vegetation Specialist
	A. Sagna	Fisheries Biologist

Team Discipline	Staff Member	Position/Specialty
Socioeconomic Conditions	A. Waldstein	Team Leader
	B. Diallo	Economist
	Y. Diallo	Economist
Home Office Coordination & Technical Support	J. W. Lipscomb	Vice President
	R. L. Brown	Project Coordinator
	T. M. Rachford	Project Coordinator
	F. J. Swit	Environmental Scientist
	T. V. Traino	Project Administrator
	P. A. DeGeorges	Fisheries Biologist
	N. M. Dininni	Regional Planner
	J. A. Gadek	Sanitary Engineer
	J. E. Wilk	Graphics Specialist

CHAPTER A

INTRODUCTION

Throughout a large portion of the Senegal River Basin, the lack of water or its uneven distribution has been an obstacle to the establishment of a desirable quality of life for the inhabitants. These factors have also deterred economic growth and stability. This has been particularly noteworthy in the portion of the River Basin located in Mali, Mauritania, and Senegal. The demands of the population exceed the ability of the Basin's resources in their present stage of development to support even the basic needs of the people. This deficiency has been especially critical during recent periods of adverse weather, when drought conditions prevailed over an extended period of time and Basin inhabitants were subjected to an intolerable subsistence level. These adverse conditions have also hindered and prevented capital investment in the Basin by the agricultural and industrial sectors of the economy.

To deal with these problems, the Governments of Mali, Mauritania, and Senegal formed the Organisation pour la Mise en Valeur du Fleuve Senegal (O.M.V.S.) in 1972. They assigned to it the responsibility for planning, coordinating, and implementing projects within the Senegal River Basin. The projects are to be directed toward developing, controlling, and using the resources of the Basin for the common good of the people. To accomplish these development goals, the O.M.V.S. was charged specifically with responsibility for implementing programs that will:

- Provide and improve incomes
- Stabilize the balance between man and his environment
- Cause Member State economies to be less vulnerable to climate and external factors
- Accelerate economic development and interstate cooperation.

In pursuing these objectives, the O.M.V.S. has planned and is currently engaged in implementing an integrated development scheme that provides for construction or administrative and technical support for the following:

- Manantali and Diama Dams
- River Navigation System
- Agricultural Perimeters
- Industrial Installations
- Urban Development

Following an initial evaluation of proposed programs, the Council of Ministers, which is responsible for implementing projects in the O.M.V.S., became aware of desirable and undesirable impacts that the O.M.V.S. Development Program could have on the environment of the Basin and the lifestyle of its people. The severe impacts resulting from development of similar projects on the African Continent confirm the need to weigh carefully all pertinent environmental factors when making decisions on the implementation of water resources development programs. It was recognized that detailed studies should be performed to evaluate inter-environmental trade-offs and the relationships of benefits to environmental costs in order that the Council of Ministers would have sufficient data available to assist them in developing projects. These environmental studies would also serve as a means for identifying programs that would enhance the beneficial effects of O.M.V.S. projects so as to insure that maximum benefits are realized by those having the greatest need.

In July 1974 at the prospective donors meeting held by O.M.V.S. in Nouakchott, Mauritania, the United States Agency for International Development (USAID) proposed that a detailed evaluation be undertaken to determine the potential effects of the integrated development plan on the environment of the River Basin and its population. USAID felt that a balanced approach between

the considerations of economic development and the protection of the environment must be considered by all potential donors to insure that maximum long range benefits would be derived from the O.M.V.S. development program. The early identification of adverse impacts would permit the application of corrective measures prior to the development of environmental damage. Likewise, avoidance of irreversible damage to national, human and natural resources would be a prime objective. USAID noted that such a study would comply with Title 40 of the National Environmental Policy Act of 1969 of the United States, permitting U.S. government participation in the O.M.V.S. development program. This proposal was supported by other prospective donors, as well as O.M.V.S., who were anxious to avoid problems that have arisen in similar water resource projects in tropical and sub-tropical areas of the world.

A grant agreement for the proposed environmental assessment was signed between USAID and O.M.V.S. on February 25, 1976. The objectives of the study were:

- To evaluate the interrelated effects on the environment caused by development in the Senegal River Basin;
- To optimize the long-term benefits by insuring that environmental and social factors have been identified and included in the cost-benefit analysis of individual projects;
- To provide the O.M.V.S. riparian states with a plan of action for formulating programs and projects that mitigate adverse environmental effects and capitalize on those deemed beneficial.

Presented as a multi-volume report, the assessment was developed in compliance with the contract signed on January 21, 1977 between the O.M.V.S. and Gannett Fleming Corddry and Carpenter, Inc. of Harrisburg, Pennsylvania, U.S.A. in association with ORGATEC Societe Africaine d'Etudes Techniques of Dakar, Senegal.

The terms of reference for the study required that the consultant follow basic approaches to environmental assessment as outlined in paragraph 1500.8 of the document, "Guidelines, Preparation of Environmental Impact Statements," Council on Environmental Quality, Federal Register, Vol. 38, No. 147, August 1, 1973 and "Environmental Assessment Guidelines Manual", AID, September 1974 and the update contained in Federal Register, Vol. 41, No. 127, June 30, 1976.

A.1. Scope and Activities Performed

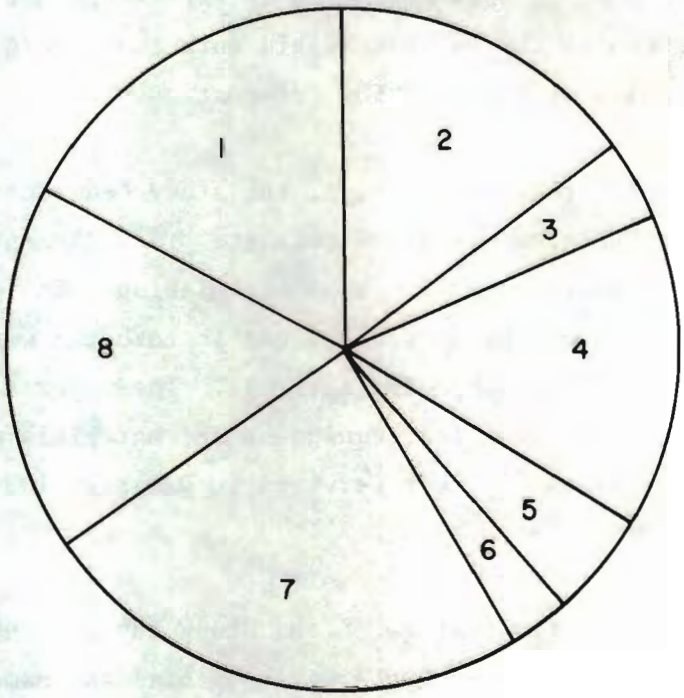
Following receipt of the Notification to Commence Work from the O.M.V.S., the Firm initiated project activities in the O.M.V.S. Member States on April 1, 1977. Operations for this thirty-six month study were based in Dakar, Senegal to provide ready access to the O.M.V.S. for consultation and administrative purposes. Dakar, likewise, provided the best simultaneous access to the River Basin for field operations and to areas outside the O.M.V.S. Member States.

The accomplishment of project goals was achieved through the organization of activities under nine study teams as follows:

- River and Estuary Regime
- Groundwater
- Water Quality
- Agricultural Development
- Municipal and Industrial Development
- Socioeconomic Conditions
- Public Health
- Aquatic Biota
- Terrestrial Biota

The time allocations of over 400 man months of professional and technical effort expended in these major study disciplines is presented graphically in the following diagram:

1. AGRICULTURAL DEVELOPMENT
2. WATER QUALITY AND GROUNDWATER
3. MUNICIPAL AND INDUSTRIAL DEVELOPMENT
4. AQUATIC BIOTA
5. TERRESTRIAL BIOTA
6. SOCIOECONOMICS
7. PUBLIC HEALTH
8. RIVER AND ESTUARY REGIME



RELATIVE DISTRIBUTION OF STUDY EFFORT

This relative distribution of effort was programmed at the beginning of the project and only slight adjustments were made where desirable.

The study teams were composed of technical experts who were supported by laboratory technicians, biological technicians, engineering technicians, computer programmers, interpreters, and others as necessary to assure the advancement of project activities. Likewise, both technical and administrative assistance were provided to the project by the Firm's home office in Harrisburg, Pennsylvania.

In order to achieve project goals, the Study was divided into several stages. The first stage involved a review of available literature and data in order to develop a profile of existing conditions in the Basin and to determine the level of field work that would be required to complete or supplement the existing information.

In the second stage, the study teams conducted field studies throughout the Basin necessary to complete or supplement each of the study disciplines' data base. Over 150 separate missions with durations of several days to several months were conducted in both the wet and dry seasons in order to provide comprehensive coverage. The experts were provided with full support services, technical equipment and materials needed for completion of field operations. Backup services in Dakar included water quality and medical laboratories.

The final stage of the Study involved synthesis and analysis of data and the formulation of the environmental assessment. This included identifying impacts, providing mitigating and enhancement measures, and developing a plan of action.

Data analyses, which varied depending upon the discipline, included the use of statistical computer analyses and mathematical modeling of water quality and flood characteristics. The existing SOGREAH model was utilized to determine future river flow characteristics at various stages of development within the Basin. The interpretations obtained from those analyses were then applied to various environmental assessment techniques involving the use of overlays, check lists and narrative matrices.

The other models used dealt with the following areas of study:

- Estuary salinity gradient
- Pollution assimilation by the Senegal River

Each of these models was also installed and operated on computers located at the Senegalese Ministry of Finance in Dakar. All models have been furnished to the O.M.V.S. in an operational status so that they can be used in the future to compute river response to variations in Basin characteristics as well as modifications to the O.M.V.S. development plans. The models will serve as a tool that can be used by the O.M.V.S. in evaluating the effects of future actions on hydrology and water quality within the Basin. The insights obtained from these models will also provide a basis for monitoring environmental factors that will be impacted by construction and operation of the facilities included in the development program.

A.2. Acknowledgements

In addition to consultations with governmental officials of the O.M.V.S. Member States, with officials and experts of O.M.V.S., and with experts from private and international organizations in the Member States, the Firm's technical staff also traveled outside the O.M.V.S. Member States to visit projects and organizations in tropical and sub-tropical areas similar to the Senegal River Basin. During the Study, visits were made to projects and organizations including but not limited to the following:

- Food & Agriculture Organization of the United Nations in Rome, Italy
- World Health Organization, Geneva, Rome, Mali, Upper Volta
- International Union for the Conservation of Nature, Switzerland
- World Wildlife Fund, Switzerland
- O.M.V.S. Documentation Center in St.-Louis and Dakar, Senegal
- USAID, Dakar
- Senegal Ministry of Finance (Computer Center), Dakar
- Ministry of Water and Forestry, Dakar, Senegal, Mali, Mauritania

- University of Dakar
- SAED Headquarters
- ASECNA (Agency pour la Securite de la Navigation Aerienne)
- UNESCO Library, Niamey, Niger
- Centre Regional de Formation et Application en Agrometeorologie et Hydrologie Operationnelle, Niamey, Niger
- Center for Overseas Pest Control, London, England
- Royal Geographical Society, London, England
- IFAN, Dakar
- Centre De Peche De M'Bane, Senegal
- Smithsonian Institution, Washington, DC
- SOGREAH, Grenoble, France
- O.R.S.T.O.M., Senegal, France
- Biological Lab of SOR, St.-Louis
- Direction de la Statistique, Ministere des Finances et des Affaires Economiques
- Bureau National de Recensement
- Mali Ministry of Public Health
- World Bank
- United Nations Development Program
- Malian Statistical Services
- National Center for Secondary Education, Mali
- U.S. Bureau of Reclamation
- U.S. Geological Survey
- Cooperative des Pecheurs de Gandiole
- Peches Maritimes de St.-Louis
- Compagnie Sucriere Senegalaise at Richard-Toll, Senegal
- African Office for Development and Cooperation
- SONED
- Groupement Manantali
- ORANA, Organisme de Recherches sur l'Alimentation et la Nutrition Africaines
- Hydraulic Service, Mali

- Pasteur Institute, Dakar
- Laboratories Nationales de l'Elevage et de Recherches Veterinaires, Dakar
- Lackner, Dorsch, Electrowatt
- Senegal Dept. of Road Maintenance
- UNICEF, Dakar
- National Oceanographic and Atmospheric Administration (NOAA), USA
- New Jersey Marine Science Consortium
- American Museum of Natural History, New York, USA
- Rutgers University, USA
- SONEES
- Energie du Mali
- Agence de l'Institut Geographique National
- U.S. Peace Corps
- West African Rice Development Association
- Ministries of Health, Senegal, Mali, Mauritania
- Ministries of Rural Development, Senegal, Mali, Mauritania
- Ministry of Planning, Senegal, Mali, Mauritania
- Ministry of Nature Protection, Mali
- Ministry of Industrialization and Mining, Mali
- SONADER, Mauritania
- FED, European Development Fund, Mali
- OPI, Mali
- Guede Chantiers, People's Republic of China Agricultural Mission, Senegal
- I.S.R.A. Agronomic Experiment Station, Bombay
- British Museum of Natural History, London
- Museum of Natural History, New York, USA
- Ministere d'Oceanographie et Peche Maritime, Senegal

The assistance of these organizations and other organizations and individuals too numerous to mention is gratefully acknowledged.

A.3. Reporting Format

This volume of the Final Report presents a synthesis of the supporting Partial Reports from each of the disciplines involved in the environmental assessment. A companion Final Report volume, the Plan of Action, provides the O.M.V.S. and its Member States with the basic tools to enhance and mitigate the predictable environmental consequences of the O.M.V.S. development program.

The various reports produced during the course of this study are organized as follows:

Final Reports:
- Synthesis
- Plan of Action

Partial Reports:
- River and Estuary Regime plus Appendix
- Groundwater
- Water Quality
- Agricultural Conditions plus Appendix
  - Section 1: Agricultural Development
  - Section 2: Atmospheric Conditions
- Navigation
- Municipal and Industrial Development
- Socioeconomics
- Public Health plus Appendix
- Aquatic and Terrestrial Biota
  - Section 1: Fisheries
  - Section 2: Aquatic Vegetation
  - Section 3: Forestry
  - Section 4: Mammalogy and Herpetology
  - Section 5: Ornithology

The technical reader may wish to explore appropriate volumes of the Partial Reports as a basis for in-depth study. For an overview of the technical findings of the project, reading may be confined to this synthesis

volume of the Final Report. The Plan of Action volume of the Final Report will be of more interest to policy makers and program managers.

CHAPTER B

PROPOSED DEVELOPMENTS

B.1. Introduction

In the past, the lack of abundant water, food and capital investment has hindered economic growth within the Senegal River Basin. In order to eliminate these constraints to economic growth, the current planning by O.M.V.S. calls for an integrated development scheme comprised of construction projects for dams at Diama and Manantali, development of a deep water harbor at St.-Louis with a navigation infrastructure upriver as far as Kayes, Mali, development of 255,000 hectares of irrigated agricultural perimeters, and industrial development at various municipalities in the River Basin. The Diama dam, to be constructed 27 kilometers upstream of St.-Louis, will prevent saltwater intrusion into the Basin above the dam site. The Manantali dam, to be located 1200 kilometers upstream of St.-Louis will provide the Basin with low flow augmentation for river navigation and a constant source of water for irrigation as well as hydroelectric power. The figure shows the locations of the proposed dams relative to the principal municipalities.

B.2. The Proposed Dam at Diama and Associated Developments in the Delta

The first phase of the O.M.V.S. development program involves the construction of a dam at the village of Diama and construction of retention dikes on both sides of the Senegal River extending from Diama to Rosso. The dam at Diama is designed as a saltwater barrier to prevent salinity intrusion from the ocean to areas upstream of the dam site during the dry season. The dam will maintain the water level above Diama at 1.5 meters IGN (SOGREAH, 1977). This dam, together with the proposed dike system will allow:

a) Diversion of water to Lac de Guiers for a more extended annual period;


LEGENDE
LIMITE DU BASSIN
BASIN BOUNDARY
FRONTIERE
INTERCOUNTRY BOUNDARY
ROUTE GOUDRONNEE
MAIN ROAD
COURS D'EAU
STREAMS
CAPITALES
CAPITALS
VILLES
TOWNS
PARC NATIONAL DE DJOUDJ
DJOUDJ PARK
SITES DES BARRAGES
DAM SITES
NOUAKCHOTT
ATLANTIQUE
OCEAN
Es Sahel
MAURITANIE
Aleg
LAC RKIZ
SÉNÉGAL
Podor
Rosso
Dagana
Aftout
LAC DE GUIERS
DIAMA
St-Louis
SENEGAL
Louga
Kaedi
Kiffa
Matam
Nioro du Sahel
Nara
Bakel
Thies
Mbaké
DAKAR
Diourbel
Mbour
Kaolack
Kaffrine
Kidira
Kayes
MALI
Tambacounda
GAMBIA
BANJUL
Brikama
Velingara
MANANTALI
Kita
BAMAKO
Bignona
Kolda
Ziguinchor
Oussouye
Cap Skiring
Kédougou
GUINÉE BISSAU
GUINÉE
AFRIQUE
Bassin du fleuve Sénégal
Senegal River Basin
CARTE LOCATIVE
LOCATION MAP
REGION
DELTA
SAINT-LOUIS à DAGANA
DELTA
MOYENNE VALLEE
DAGANA à BAKEL
MIDDLE VALLEY
HAUTE VALLEE
AMONT DE BAKEL
ABOVE BAKEL
UPPER VALLEY
BASSIN DU FLEUVE SENEGAL
SENEGAL RIVER BASIN

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

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

Tender documents for the construction of Diama Dam were received for evaluation by O.M.V.S. in early 1979. Accordingly, the construction of the Diama dam is expected to be completed by the mid 1980's. The dam will produce an impoundment with the characteristics listed in Table B.2-1. The dam has been designed to provide additional water for irrigated agriculture by increasing the reservoir storage capacity through elevation of the water level to 2.5 meters IGN.

TABLE B.2-1

Diama Impoundment Characteristics
at Water Levels of 1.5 Meters and 2.5 Meters IGN

	At 1.5 m IGN	At 2.5 m IGN
Reservoir Length	360 km extending to Guede-Boghe area	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 cu. meters	0.58 billion cu. meters

SOGREAH (1977) predicted that a flood with a return frequency of once in 1,000 years will produce a maximum water level of 3.2 meters IGN in the impoundment upstream of the dam. The elevation at the top of the dam is designed to be 4.0 meters IGN.

With the construction of this dam, a new channel will reroute the Senegal River through a combination of gates and spillways. A navigation lock, measuring 190 meters by 25 meters, with docking facilities will be constructed to allow passage of river traffic. The dam will serve as part of a proposed highway between St.-Louis, Senegal and Nouakchott, Mauritania.

The proposed Diama-to-Rosso dikes in Mauritania have been designed to retain the maximum water level projected for a flood with a return frequency of once in 100 years plus a 0.75 meter freeboard (SOGREAH, 1977). The top width of the dike will be six meters except for those sections that will be used for the St.-Louis-to-Nouakchott highway. Those sections will be 13 meters in width. Existing dikes on the Senegal side of the river will be upgraded to the same height and width as the new dike that is proposed for construction. Outlet gates will be incorporated in the dikes to provide water to selected marigots on both sides of the impoundment.

B.3. The Proposed Dam at Manantali

An important element in the Senegal River Basin development program is the augmentation of low flows for the purposes of providing a year-round supply of water for municipal, industrial and agricultural development along the river. O.M.V.S. plans to construct a dam on the Bafing River approximately 1200 kilometers upstream of St.-Louis. Controlled releases from the reservoir created by this dam will permit the following:

a) Year-round irrigation of 255,000 hectares of land between Manantali and St.-Louis.

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

c) The production of 800 gigawatt-hours per year of electric power at the Manantali dam.

To accomplish these goals, the impoundment at Manantali will have the characteristics that are listed in Table B.3-1. The elevation of the spillway at the reservoir will be 208.0 meters IGN. With this spillway elevation, the reservoir will extend for approximately 125 km upstream from the dam. The dam is designed to effectively control releases for a flood with a return frequency of once in 10,000 years. During such a flood, the water in the reservoir would rise to an elevation of 211.1 meters IGN. The elevation of the top of the dam is designed to be 212.0 meters IGN.

TABLE B.3-1

Manantali Impoundment Characteristics

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

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

The information presented in Table B.3-1 is based on calculations made by Groupement Manantali (1977) and assumes that water requirements downstream of Manantali are not entirely satisfied during one year of every ten. The bases for operating the Manantali reservoir, as proposed by Groupement Manantali, have been incorporated into the O.M.V.S. development plan. Regulated releases from the dam will take place throughout the dry season and during each annual flood until the reservoir is full. After the dam has filled, unregulated spillway discharge will take place until inflows are less than releases required for downstream water uses.

In addition to regulated low-flow releases, the O.M.V.S. proposal provides for a period of transition from recession farming to irrigated agriculture. This transition period will extend 15 to 20 years beyond the completion date of the Manantali dam and is to provide a minimum flow of 2500 cubic meters per second at Bakel between August 15 and September 15 of each year. These releases will create an "artificial flood" that will inundate approximately 100,000 hectares of land in the Senegal River floodplain that can continue to be used for recession agriculture.

Construction in the Manantali area is expected to be completed six years after construction begins.

B.4. Proposed Agricultural Development

To increase crop production in the Senegal River Basin, the O.M.V.S. development plan will alter traditional agricultural practices. Traditional practices include recession agriculture involving land naturally inundated by floodwaters, and rainfed (dieri) agriculture. Recession farming will be greatly diminished as reduced inundation of floodplains occurs from flow regulation and prime recession lands are converted into irrigated perimeters. By 2028, dieri lands will be used primarily for grazing livestock, and 255,000 hectares of diked agricultural perimeters are scheduled for completion in the River Valley. Modern intensive irrigation agricultural techniques will allow production of two crop harvests yearly after the Manantali dam is operational and dry-season releases begin. The proposed rates of development are as follows:

Years	Rate of Development Hectares Per Year
1977 through 1986	4800
1987 - 1996	4400
1997 - 2006	4800
2007 - 2016	5300
2017 - 2026	5800

Over the next 50 years Mali is programmed for a maximum of 8,200 hectares under irrigation all of which are scheduled for development by 1987. Senegal and Mauritania are not programed to attain maximum irrigation of 185,000 and 62,000 hectares, respectively, until 2028.

B.5. Proposed Development Related to Navigation

Year-round navigation between the Atlantic Ocean and Mali is considered important to the development of the Basin as well as the interior of Mali. Regulated flow releases from the proposed Manantali dam in combination with alterations to the river channel will make possible navigation to Kayes, Mali. Navigation-related development along the Senegal River will encompass the following:

a) A navigation channel to Kayes, Mali with a minimum channel width of 55 meters and a minimum bend radius of 700 meters;

b) Sufficient flow to maintain a water depth of at least two meters;

c) Development and improvements to port facilities at Rosso, Richard Toll, Dagana, Podor, Boghe, Kaedi, Matam, Bakel, Ambidedi and Kayes;

d) An entry channel between the estuary and the ocean to be located 7 kilometers downstream of the Faidherbe Bridge at St.-Louis. In

addition to the channel, a breakwater extending into the ocean from the shoreline, and an approach channel extending into the ocean to a distance of two kilometers from the shore will be constructed;

e) An estuarine approach channel connecting the entry channel to the proposed harbor facilities;

f) A deep-water harbor along the left bank of the River south of St.-Louis to transfer goods from ocean-going to river-going vessels;

g) Modification of the Faidherbe Bridge at St.-Louis to facilitate the passage of vessels.

Assuming flow regulation provides 300 cubic meters per second of flow in the River at Kayes and 150 cubic meters per second in the River at Podor, improvements necessary to obtain the desired channel characteristics will include excavation of approximately 200,000 cubic meters of rock and 175,000 cubic meters of sand. Lackner, Dorsch and Electrowatt (1978) has also recommended specific channel improvements between Podor and Kayes which, together with rock and sand removal, include jetties, dikes parallel to the River and bank stabilization. No channel modifications will be needed downstream of Podor.

Information presented in Table B.5-1 concerns the channels, breakwaters, and harbor south of St.-Louis. All of these planned developments associated with navigation are to be updated in a study funded by the Canadian Agency for International Development (CAID), however the basic development strategy outlined in this chapter is expected to remain unchanged.

Planning related to navigation must also include development and improvement of port facilities along the River. The major port facilities planned for Kayes will make this city Mali's primary access to the ocean. For the municipalities of Rosso, Richard Toll, Dagana, Podor, Boghe, Kaedi, Matam, Bakel and Ambidedi, smaller port facilities are planned that include one to two piers and an oil storage facility.

Table B.5 - 1

Proposed Developments Associated with Navigation-Senegal River Estuary

Development	Purpose	Location	Data
Off-shore Approach Channel in Atlantic Ocean	To provide shipping access from the ocean to the proposed entry channel	Extension of proposed entry channel into the ocean perpendicular to shoreline	Length: 1500 meters Width: 150 meters Depth: 8.5 meters
Ocean Breakwaters	To protect off-shore approach channel and entry channel from wave action and sand deposition	Ocean side of Langue de Barbarie parallel to off-shore approach channel	
	northern breakwater: primary sand trap		800 m length initially with extensions as sand accumulates
	southern breakwater: prevent channel filling by occasional northerly drifts		250 m length initially with extensions added when needed
Entry Channel and Channel to Proposed Port Facilities	To provide shipping access from the off-shore approach channel to the Senegal River	7 kilometers south of Faidherbe Bridge	Length: 2000 meters Width: 150 meters Depth: 10 meters
Estuary Port Facilities	To transfer goods from ocean-going to river-going vessels		Length: 1500 meters Width: 300 meters Depth: 8.5 meters
Modifications to Faidherbe Bridge	To allow river-going vessels access to areas further upstream	Senegal River at Saint-Louis	Not available

Source of Information: Groupement LDE (1978)

B.6. Proposed Municipal-Industrial Development

Municipal and industrial development in the River Basin is inter-related with the construction and operation of the proposed dams and irrigated perimeters. National development plans as approved by each Member State are for the most part contingent on the execution of the plans for the Diama and Manantali dams and the agricultural perimeter development schemes. A summary of the currently proposed industrial development in the Basin is given in Table B.6-1. This summary indicates the importance of agricultural and livestock dependent industries to the future economic growth of the Basin.

Exploratory prospecting for various ores has taken place in the River Basin. National agencies such as MIFERSO in Senegal, SONAREM in Mali and SNIM in Mauritania have undertaken exploration and feasibility studies for the mining of mineral resources located in their countries. Table B.6-2 shows the location and status of mineral exploration in the Senegal River Basin. The viability of many of these schemes will depend on the availability of energy and transportation to be provided through the realization of the O.M.V.S. development plan.

Populations in the Senegal River Basin are expected to increase dramatically over the next 50 years due to natural growth rates coupled with infrastructural growth required to support the O.M.V.S. development program. Urban populations in the Basin are expected to grow from 241,200 inhabitants in 1980 to 1,490,000 in 2028 considering the combined effect of natural and program related growth rates. The primary spur to urban population growth is expected to be the O.M.V.S. programs for navigation and agro-industries.

Municipalities on the River will be faced with providing an adequate corresponding infrastructure for these populations in areas such as housing, water, waste disposal, police and fire protection, power and transportation facilities. Currently, the planning for municipal development in the Basin is a responsibility of each Member State. The need for early planning to accommodate the requirements of growing urban populations is recognized by the governments of the Member States.

Table B.6 - 1

Summary of Proposed Industrial Development in the Senegal River Basin

Industry (listed alphabetically)	Proposed Plant Location(s)	Projected Time Schedule
Bauxite Processing	Manantali, Mali	After 1990
	Moussali, Mali	After 1990
	Kayes, Mali	After 1990
Brewery	Kayes, Mali	NA
Brick Manufacturing	Rosso, Maur.	NA
Cotton Mill	Kayes, Mali	NA
	Bogue, Maur.	NA
	Maghama, Maur.	NA
	Leggah, Maur.	NA
Dairy	Rosso, Maur.	NA
Edible Oil Refinery	Rosso, Maur.	NA
Fertilizer Factory	Kaedi, Maur.	NA
Flour Production	Matam, Sen.	Project Implementation 1985-1989
Lime Processing	Diamou, Mali	Commence construction in 1978-1979
Peanut Oil Refining	Kita, Mali	Included in present 5-yr. plan for Kayes Region
Refrigerated Abattoir	Rosso, Maur.	NA
Rice Processing	Kayes, Mali Matam, Sen. Thilogne, Sen. Aere Lao, Sen. Podor, Sen.	Processing by 1985
Shoe Factory	Kayes, Mali	NA
Sugar Cane Processing	Same, Mali	Commence construction 1984-1985
	Gorgol Valley, Maur.	Processing by 1983
	Matam, Sen. or Richard Toll, Sen.	NA

Table B.6 - 1 (Cont'd.)

Summary of Proposed Industrial Development in the Senegal River Basin

Industry (listed alphabetically)	Proposed Plant Location(s)	Projected Time Schedule
Tanning	Trapoma, Mali	First Production in 1979
	Kayes, Mali	NA
	Kaedi, Maur.	Enlargement of existing tannery: first stage to be in production by 1983
Textile	Kayes, Mali	NA
	Rosso, Maur.	NA
	Saint-Louis, Sen.	NA
Tomato Canning	Rosso, Maur.	Commence construction in 1979
	Matam, Sen.	First stage to be in production by 1983

Table B.6-2

Summary of Projected Mining Activities in the Senegal River Basin

Mineral	Country	Location	Est. Quantity	Comments
Copper	Senegal	Bakel Region	Unknown	In this same region, there are indices of chrome.
Iron	Senegal	Farangalia	105 million tons	These four areas are located within the region of Kedougou. In the same region there are marble deposits which are presently being exploited and also small quantities of gold.
Iron	Senegal	Goto	175 million tons	
Iron	Senegal	Kouroudiako	22 million tons	
Iron	Senegal	Koudekourou	75 million tons	
Iron	Mali	Bafing-Bakoye (Bale)	500-600 million tons	Exploitation is envisioned for 1985-1990 if energy is available and extraction is found to be economically feasible.
Magnetite	Mali	Djidian-Kenieba	10 million tons	Exploitation feasibility studies are underway.
Iron	Mali	Diamou-Baufoulabe	150 million tons	Both of these sites are considered to be of less importance than Bale.
Iron	Mali	Nioro	10 million tons	
Bauxite	Mali	Balea	400 million tons	Deposits do not appear to be rich enough for extraction at this time.

Table B.6-2 (Cont'd.)

Summary of Projected Mining Activities in the Senegal River Basin

Mineral	Country	Location	Est. Quantity	Comments
Bauxite	Mali	Bamako-West	175 million tons	Highest quality with an Al_2O_3 content of 40-44%.
Bauxite	Mali	Kenieba-South	165 million tons	Deposits do not appear to be rich enough for extraction at this time.
Copper	Mauritania	Diaguili	----	No exploitable strata have been found as yet.
Copper	Mauritania	Massif de l'Affole	----	No exploitable strata have been found as yet.
Phosphate	Mauritania	Cive	4 million tons	High quality but exploitation is not feasible at this time.
Phosphate	Mauritania	Aleg	30 million tons	Other explorations began in mid-1977. If results are favorable, exploitation could start in 1983.

CHAPTER C

SUMMARIES OF INDIVIDUAL REPORTS

This chapter presents summaries of all the detailed Partial Reports for the assessment's individual study disciplines. Each summary describes existing conditions, impacts of proposed developments, and mitigating and enhancement measures as presented in the plans of actions of the detailed volumes. Where appropriate, each summary is followed by a table presenting the impacts and mitigating measures in condensed form.

C.1. River and Estuary Regime

C.1.1. Existing Conditions

The Senegal River is one of the largest rivers in West Africa, draining an area of approximately 290,000 square kilometers. The Senegal River Basin lies within different climatic zones, resulting in extreme fluctuations in rainfall.

In the northern part of the Basin, the average annual rainfall of 300 mm is limited to the months of July through September. In the southern portion of the Basin, the average annual rainfall of 2000 mm occurs from May until October. Annual variations in rainfall are also extreme, especially in lower reaches of the River. At Rosso, for example, annual rainfalls as low as 110 mm and as high as 610 mm have been recorded between 1930 and 1965.

Due to these characteristics of rainfall in the Basin, nearly all of the River's flow originates from the rainy southern portion of the Basin in the Fouta Djalon mountains of Guinea. The three major tributaries of the Senegal River are the Bakoye, Bafing and Faleme Rivers. The Bafing River provides more than 50 percent of the Senegal River's streamflow, although it drains no more than 13 percent of the total Senegal River watershed. Variations in annual stream flow are great and reflect the variations in annual precipitation. Maximum, minimum and average annual streamflows for selected

stations in the Senegal River Basin are summarized in Table C.1-1. The seasonal characteristics of the rainfall determine the Senegal River's floodplain configuration, consisting of a single flood wave moving down the River. The floodplain is inundated annually between Bakel and St.-Louis. As the flood moves through the Middle Valley and Delta regime, it becomes significantly altered as peak flows decrease due to floodplain storage, evaporation and infiltration losses. With the end of the annual rains, the flood gradually recedes. At the end of the dry season (April to mid-June), flows decrease during most years to approximately 10 cu m/sec. at Bakel.

Sediment transport in the Senegal River follows a pattern dictated by the annual flood cycle. More than 90 percent of the total annual sediment load is carried down the river during the annual flood period. For an average flood year, the suspended load at Bakel is estimated to be 2,100,000 metric tons. Only 1,200,000 metric tons of this load reach St.-Louis. Thus, each year about 900,000 tons of suspended materials are deposited on the floodplain between Bakel and St.-Louis.

C.1.2. Environmental Impacts

The construction of the Diama and Manantali reservoirs, the development of irrigated perimeters on the Senegal River floodplain and the modifications planned for the estuary will have an impact on the existing flow, sedimentation and erosion regimes of the Senegal River. These development activities will also affect water quality, aquatic and terrestrial biota and other aspects of the environment. These impacts or changes are discussed in this section under the following topics:

a) Changes in flow regime;
b) Changes in sedimentation and erosion regime;
c) Impacts due to construction.

C.1.2.1. Changes in Flow Regime

Manantali Reservoir Water Level Fluctuations and Inundations - During average flow years, water surface levels in the Manantali reservoir will vary between

Table C.1 - 1

Annual Flows for Selected Stations in the Senegal River Basin

Station	River	Drainage Area (km^2)	Annual Flows (m^3/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	757	266	1247	1903-1975
Matam	Senegal	253,000	776	283	1394	1903-1965
Dagana	Senegal	268,000	691	292	969	1903-1965

196 m IGN and 208 m IGN. During years with low flood flows, the reservoir may be drawn down to 187 m IGN. Consequently, if a very dry year was followed by a wet year, a maximum water level change of approximately 20 m would occur during one annual flood cycle.

With the annual filling and drawing down of the impoundment, a portion of the land surrounding the reservoir will be alternately inundated and then subjected to aerial exposure. At the minimum pool operating level of 187 m IGN, water will cover a surface area of 272 square km. The amount of land inundated within the reservoir during a year of extremely large flows in the Bafing River could reach approximately 500 square km. Consequently, there are 228 square km of land that could be exposed and inundated again during one annual cycle. During an average cycle with water level fluctuation between 208 m IGN and 196 m IGN, 111 square km of land would be first exposed and then inundated.

Changes in Flood Hydrographs in the Bafing River Below the Manantali Dam - To demonstrate the effect of the Manantali reservoir on the streamflow characteristics of the Bafing River, future regulated flood hydrographs at Soukoutali (near Manantali dam) were determined for five annual floods of varying magnitude and compared with unregulated flood hydrographs observed at the same station. As will be seen below, the effect of the Manantali dam on the downstream flood hydrograph for the Bafing River will depend on the size of the annual Bafing River flood and the operational mode of the Manantali reservoir at the end of the dry season.

During the generation of the artificial flood, the Manantali reservoir will be programmed to release sufficient water, guaranteeing a flow of 2500 cubic meters per second at Bakel from August 15 through September 15. During very large floods, a difference between regulated and unregulated flows will be observed only during the initial flood period, as water from the Bafing River fills the reservoir. Once the reservoir is filled, regulated and unregulated flows will be almost identical. As the size of the annual flood decreases, the difference between regulated and unregulated flows will increase. During an average flood year, significant flow releases from the

dam will be necessary to create 2500 cubic meters per second of flow at Bakel. As a result of these flow releases, reservoir storage by September 15 will not be significantly greater than pre-flood season levels. Therefore, for the remainder of the flood season most of the Bafing River flow must be withheld to fill the reservoir. During small annual floods, considerable releases from the Manantali reservoir will be required to augment the natural flow in the Bafing River to create artificial flood flows at Bakel. Almost all of the artificial flood releases during years with a very low flood will stem from water stored during previous floods.

During the final phase of Basin development and after the discontinuation of artificial flood releases, several changes in the Bafing River flood hydrograph are predicted. During a very large flood year, the change between regulated and unregulated flows will be noticeable only during the initial phase of the flood. As the magnitude of the annual flood decreases, discrepancies between regulated and unregulated flows will increase. During an average flood year, regulated flows downstream of Manantali will be only a fraction of the natural flows prior to construction of the reservoir. The reservoir will fill towards the end of the flood season and regulated flows will approach natural flows. During very small floods, the reservoir will provide water only to satisfy minimum demands for power-generation and irrigation. During such years, flood flows from the Bafing River will essentially be eliminated.

Changes in Flooding Patterns Downstream of Bakel - A mathematical model developed by SOGREAH was used to evaluate future changes in the Senegal River's flow, water level and floodplain inundation regimes between Bakel and St.-Louis. Both existing and future regimes were simulated. Scenarios depicting various stages of proposed OMVS development, were simulated as shown in Table C.1-2.

Flows from the Bakoye and Faleme Rivers will not be regulated as a result of the proposed development program. The Manantali reservoir will regulate flows in the Bafing River downstream of Manantali and in the Senegal River. Because the Senegal River receives these unregulated flows from the Bakoye and

Faleme Rivers, flows, areas inundated in the floodplain and water levels will not be completely controlled by the Manantali reservoir and the proposed irrigated perimeters.

TABLE C.1-2

Scenarios Reflecting Proposed O.M.V.S. Development

Scenario	Year	Diama Dam	Manantali Dam	Perimeter Development (hectare)
1	Present	--	--	12,000
2	1986	In operation	--	47,000
3	1987	In operation	Transitional*	47,000
4	2002	In operation	Transitional*	117,000
5	2003	In operation	Final**	117,000
6	2028	In operation	Final**	247,000

* transitional phase of operation; artificial flood releases.

** final phase of operation; no artificial flood releases.

Flood Peaks - A summary of changes predicted for flood peaks is presented in Table C.1-3. Changes in flood peaks are influenced by the magnitude of an annual flood and the state of floodplain development. However, only downstream of Bakel will alterations of the flood peak occur from the changes in the floodplain's physical configuration, irrigation water withdrawals, and the loss of flood water during the initial period of filling the Manantali reservoir. By the year 2003, the first year in the final phase operation of the Manantali reservoir, during higher than average flows, at Kaedi, Podor and Dagana, flood peaks will be reduced by 4 percent, 14 percent, and 15 percent, respectively. At Podor and Diama, the flood peaks are predicted to recover slightly between 2003 and 2028. This increase will occur because of decreased floodplain storage as a significant amount of the floodplain is converted to irrigated perimeters.

During average flood years substantial reductions in peak flows are predicted. The first major reduction will occur in 1987 when transitional operation of the Manantali reservoir limits flood peaks at Bakel to 2500 cubic meters per second as simulated by Scenario 3. During low flood years, artificial flood releases from the Manantali reservoir will augment natural peak flood flows. If present and 1987 flood peaks are compared for the smallest recorded flood, increases between 50 percent and 80 percent are projected for the stations listed in Table C.1-3. After the discontinuation of the artificial flood in 2002, there will be further decreases in flood peaks throughout the Senegal River Valley. By 2028, during the smallest recorded flood years, changes in flood peaks compared to smallest recorded floods without the proposed developments are predicted to drop by 46 percent, 61 percent, 64 percent and 69 percent at Bakel, Kaedi, Podor, and Diama, respectively (Table C.1-3).

Inundation - Table C.1-4 presents a summary of modeling results concerning future inundation patterns in the Senegal River Valley below Bakel.

For average and above average floods, the amount of area inundated in the Senegal River downstream of Bakel is predicted to decrease significantly as the flow in the Senegal River is regulated and more and more irrigated perimeters occupy previously flooded land. For example, the largest flood recorded for the Senegal River would inundate 840,000 hectares under present conditions. With the development programmed for 2028, this same flood would inundate only 560,000 hectares, a reduction of 33 percent. During an average flood year, total inundation is predicted to drop from 459,000 hectares with present development conditions to 190,000 hectares by the year 2028, a reduction of 65 percent.

With the beginning of the transitional operation of the Manantali reservoir, flooding in the Senegal River Valley between Dagana and Bakel will be reduced drastically. For example, flooding in the River Valley between Matam and Bakel will be cut in half during an average flood year. Between Boghe and Matam, the discontinuation of artificial flood releases and the construction of irrigated perimeters during an average flood year are expected

Table C.1 - 3

Future and Present Peak Flows in the Senegal River Basin
SOGREAH Modeling Results

Scenario	Flood	Peak Flow, in cu. m per sec.			
		Bakel	Kaedi	Podor	Diama
Present	Largest recorded	5880	5220	4780	4100
	5 year high	7160	5270	4430	3500
	Average	4100	3260	2810	2400
	5 year low	2060	1830	1700	1440
	Smallest recorded	1380	1200	1100	1020
1986	Largest recorded	5870	5200	4630	4070
	5 year high	7150	5090	4180	3490
	Average	4020	3100	2680	2310
	5 year low	2050	1830	1660	1510
	Smallest recorded	1360	1220	1070	860
1987	Largest recorded	5870	5200	4470	3850
	5 year high	5470	3610	3080	2570
	Average	2500	2280	2010	1720
	5 year low	2500	2270	1980	1770
	Smallest recorded	2500	2160	1890	1540
2002	Largest recorded	5870	4800	3900	3400
	5 year high	5490	3300	2700	2280
	Average	2500	2000	1800	1600
	5 year low	2500	2180	1730	1490
	Smallest recorded	2500	2100	1700	1400
2003	Largest recorded	5870	4800	3900	3400
	5 year high	6070	3740	2960	2490
	Average	2300	1800	1600	1500
	5 year low	1460	1220	1130	1070
	Smallest recorded	750	560	530	330
2028	Largest recorded	5870	4800	4100	3500
	5 year high	6060	3790	3050	2500
	Average	2300	1800	1600	1400
	5 year low	1460	1200	1100	980
	Smallest recorded	750	470	400	320

Note: This table is available in the River & Estuary Regimes Report.

Table C.1 - 4
Maximum Surface Areas Flooded by Region During Five Representative Floods
in the Senegal River Floodplain

Flood	Region*	Maximum Surface Area Flooded, in 1000 ha.					
		Scenario 1 present	Scenario 2 1986	Scenario 3 1987	Scenario 4 2002	Scenario 5 2003	Scenario 6 2028
Largest recorded flood (1924)	HMV	141	139	140	130	133	99
	CMV	291	269	270	230	234	157
	LMV	257	252	246	220	223	180
	Delta	174	153	150	130	133	142
	Total	838	797	777	680	690	560
Once-in-5-year high flood (1964)	HMV	139	138	119	110	125	99
	CMV	286	263	211	210	221	156
	LMV	240	236	185	160	178	143
	Delta	168	143	130	110	117	120
	Total	766	733	605	550	565	470
Average Flood (1969)	HMV	105	102	50	48	28	20
	CMV	212	187	119	114	66	50
	LMV	160	160	91	79	51	41
	Delta	143	124	110	98	91	92
	Total	549	525	340	320	230	190

Table C.1 - 4 (Cont'd.)

Maximum Surface Areas Flooded by Region During Five Representative Floods in the Senegal River Floodplain

Flood	Region*	Maximum Surface Area Flooded, in 1000 ha.					
		Scenario 1 present	Scenario 2 1986	Scenario 3 1987	Scenario 4 2002	Scenario 5 2003	Scenario 6 2028
Once-in-5-Year low flood (1926)	HMV	25	25	50	48	10	9
	CMV	66	61	113	108	22	19
	LMV	47	53	78	70	16	13
	Delta	84	99	108	98	85	89
	Total	215	232	328	300	130	130
Smallest recorded flood (1972)	HMV	10	10	50	47	9	8
	CMV	22	21	100	93	16	14
	LMV	15	18	65	57	12	11
	Delta	60	84	103	91	77	81
	Total	104	130	300	280	107	110

*HMV: High Middle Valley; Matam - Bakel
CMV: Central Middle Valley; Boghe - Matam
LMV: Low Middle Valley; Dagana - Boghe
Delta: Saint-Louis - Dagana

Notes: (1) Flooding includes inundation of the main channels of the Senegal River and Doue Marigot.

(2) Total flooding does not equal the sum of areas flooded in the four regions, because the date of maximum flooding is different in each region.

to result in a loss of approximately 50,000 hectares of inundated floodplain between 2003 and 2028. In the Delta, the loss of inundated areas will be less pronounced due to the influence of the Diama reservoir.

During years with below average flooding, artificial flood releases will boost inundation in all regions downstream of Bakel (compare Scenarios 2 and 3, Table C.1-4). For the smallest flood of record, for example, a five fold increase in inundation from 10,000 hectares to 50,000 hectares is predicted for the region between Matam and Bakel as a result of artificial flood releases. After the discontinuation of the artificial flood, flooding in the valley between Bakel and Dagana will essentially disappear during smaller-than-average floods.

Water Levels - Present and future water levels predicted for the year 2028 are compared in Table C.1-5. For smaller-than-average floods, the effect of artificial flood releases is reflected in elevated peak water levels throughout the Basin. For average and moderately above average flood years, the opposite effect is predicted. During very large flood years, exemplified by the largest flood recorded since 1903, modeling results show increased water levels for all stations between Podor and Bakel (Table C.1-5) although lower peak flood flows are predicted (Table C.1-3). This can be explained by perimeter construction in the floodplain that will cause a decrease in area available for water storage and result in a redistribution of flows across the floodplain. As substantial portions of the floodplain are occupied by perimeters, flow paths in the floodplain will be obstructed and increased quantities of water will be diverted, causing elevated flows and water levels in the main channel.

Diama Reservoir - Monthly water balance calculations based on SOGREAH data provide some interesting insight into the operation of the Diama reservoir before the construction of the Manantali reservoir. The storage function of the Diama reservoir will be so small that even during a low flood year there will be a complete exchange of water during the flood season; most of the water entering the reservoir will be passed downstream, as shown in Table C.1-6. This flushing effect will persist even after regulation of

Table C.1 - 5

Peak Water Levels (PWL) Throughout the Senegal River Floodplain
for 2028 Proposed Development Conditions
SOGREAH Modeling Results

	Largest Recorded Flood		Once-in-5-Year High Flood		Average Flood		Once-in-5-Year-Low Flood		Smallest Recorded Flood	
	PWL, m.IGN	Change in PWL: 1979 to 2028 Scenario	PWL, m.IGN	Change in PWL: 1979 to 2028 Scenario	PWL, m.IGN	Change in PWL: 1979 to 2028 Scenario	PWL, m.IGN	Change in PWL: 1979 to 2028 Scenario	PWL, m.IGN	Change in PWL: 1979 to 2028 Scenario
BAKEL	23.5	+0.6	23.2	-0.1	18.0	-2.8	16.3	-1.4	14.9	-1.5
MATAM	18.0	+2.0	16.9	+0.9	13.3	-1.6	11.7	-1.1	10.0	-1.4
KAEDI	15.2	+2.4	13.9	+1.2	10.7	-1.1	9.1	-1.2	8.4	-0.7
SALDE	13.3	+1.8	12.3	+1.0	8.8	-1.5	7.3	-1.3	5.3	-2.1
BOGHE	10.6	+1.4	9.7	+0.7	7.1	-1.0	5.5	-1.4	3.6	-2.0
PODOR	6.9	+0.4	6.3	+0.1	4.8	-0.7	3.6	-1.0	2.0	-1.3
DAGANA	4.1	-0.1	3.5	-0.5	2.4	-0.9	2.0	-0.4	1.6	+0.2
ROSSO	3.3	-0.4	2.9	-0.5	2.0	-0.8	1.7	-0.1	1.6	+0.4
DIAMA	1.8	-0.3	1.6	-0.3	1.5	0.0	1.5	+0.4	1.5	+0.6
SAINT-LOUIS	1.1	-0.1	1.0	-0.1	0.8	-0.2	0.8	0.0	0.8	0.0

Table C.1 - 6

Monthly Average Inflows and Outflows for the Diama Reservoir
Projected for the 1984/85 Demand Year

	Average Flood			Low Flood		
	Inflow m^3/s	Outflow m^3/s	Outflow % of inflow	Inflow m^3/s	Outflow m^3/s	Outflow % of inflow
July	420	250	59.5	420	221	52.6
August	1250	950	76.0	840	550	65.5
September	2000	1665	83.3	1570	1260	80.3
October	2300	2075	90.2	1470	1370	93.2
November	1900	1895	99.7	455	385	84.6
December	440	370	84.1	210	138	65.7
January	180	139	77.2	120	62	51.7
February	106	58	54.7	67	2	3.0
March	59	11	18.6	35	0	0
April	30	0	0	15	0	0
May	14	0	0	5	0	0
June	10	0	0	9	0	0
Average	730	620	84.9	430	330	76.7

flows by the Manantali Reservoir thereby allowing saltwater that entered the Basin during the dry season to continue to be pushed back toward the ocean during most annual floods.

C.1.2.2. Changes in Sedimentation and Erosion Regime

As a result of the O.M.V.S. development program, the existing sedimentation and erosion regime in the Senegal River Basin will change. To quantitatively predict changes in the sedimentation and erosion regime of a natural watercourse is an almost impossible task because of the extreme complexity of sedimentation and erosion processes taking place in a river system such as the Senegal. Lack of sufficient data complicates this task. Therefore, the following assessment of the changes in the sedimentation and erosion regime cannot offer more than qualitative descriptions and analyses.

Channel Aggradation in Bafing River Upstream of Manantali Reservoir - The low bed load in the Bafing River, and large annual water level variations at the Bafing River-Manantali reservoir interface, both before and after the Manantali dam is in place, suggest that there will be no danger of sediment deposition in the channel in the Bafing river.

Sedimentation in Manantali Reservoir - Bed load transport into the Manantali reservoir will be low. The annual suspended load to the reservoir is estimated to be 530,000 metric tons per year. Most of the suspended material is very fine; particles less than 0.002 millimeters in diameter account for more than 50% of the incoming material. It is estimated that, under these sediment inflow conditions, the dead storage of the Manantali reservoir will require at least 450 years to fill.

Bafing River Downstream of Manantali - The naturally low suspended load and the absence of any significant bed load material in the Bafing River indicate that the sediment supply from upstream, and not the sediment capacity of the river discharge, governs sediment transport in the Bafing River. Considering also that the Bafing River is carved out of erosion resistant bedrock, it is reasonable to expect that neither flow regulation nor sediment interruption by

the Manantali reservoir will have an adverse effect on the stability of the Bafing River channel.

Senegal River Between Bafoulabe and Bakel - Between Bafoulabe and Bakel the Senegal River receives significant suspended and bed load material from its tributaries, mainly from the Ketiou-Ko, Kolimbine, Parpara, Bakoye and Faleme Rivers. Since only a minor portion of the bed load transported in this river stretch originates from the Bafing River watershed, bedload movement and associated erosion and deposition processes will not be affected by the loss of sediments to the Manantali reservoir. The stability of the Senegal River channel will, however, be affected greatly by the loss of the river's sediment transport capacity due to flow regulation from the Manantali reservoir. Lower flows during the rainy season will result in the accumulation of sediment material in the channel. Channel instabilities will take place especially near the points of confluence of Senegal River tributaries. These tributaries, not influenced by flow regulation, will continue to carry their natural sediment loads into the regulated Senegal River that will no longer have the strength to move these sediment contributions downstream. Another factor to be considered is that water levels in the Senegal River will drop, causing a steeper gradient in the lower reaches of unregulated tributaries, which in turn will lead to increased channel and bank erosion until eventually an equilibrium situation is established.

Senegal River Between Bakel and Boghe - No major tributaries enter the Senegal River between Bakel and Boghe. Therefore, the aforementioned problems will not occur in this stretch of the River. During average and below average flood years, flow regulation will result in a reduction of tractional forces on the Senegal River channel leading to less bank erosion and cave-ins than observed today. Instead, sediment deposition in the channel and sand bar development will become more pronounced as the Senegal River will no longer be able to carry away the material supplied from upstream banks and from minor tributaries. During above-average flood years, increased flows in the main channel and elevated water levels will lead to increased erosion activity removing sediment accumulated during lower flood years. During such years the banks of the River will be attacked severely.

Senegal River Between Boghe and Diama - Beginning at Boghe, the impact of the Diama dam will be felt. Before the construction of the Manantali dam, the decrease in flow velocities in the Diama impoundment will result in sediment depositions, especially during the early stages of a flood. During the second half of the flood wave, some of the sediment deposited earlier will be flushed out again as flows pass through the reservoir almost unobstructed. The net result will be a gradual filling of the Diama reservoir with sediments. Only the main channel will be kept open by the annual flushing of sediment by the flood waves.

After construction of the Manantali reservoir, flows entering the Diama reservoir will be regulated and more evenly distributed throughout the year. Except during very large floods, the annual flushing action be reduced. Although after flow regulation less sediment will reach the Diama reservoir, it is believed that flow regulation by the Manantali reservoir will accelerate the sedimentation in the Diama reservoir.

Senegal River Between Diama and St.-Louis - Little change is expected in sedimentation and erosion between Diama and St.-Louis. Flow regulation by both the Diama and the Manantali dams will reduce erosional and scouring activities below the Diama dam, since there will be no break in the supply of bed and suspended loads when the gates are opened during the flood season.

Estuary Below St.-Louis - The construction of the entry channel through the Langue de Barbarie will have two profound impacts on the sedimentation and erosion regime of the estuary and the coast line on both sides of the entry channel. These impacts are:

a) The formation of a permanent lagoon in the estuary south of the entry channel;

b) Sand accretion on the beachline immediately north of the breakwater and coastal erosion south of the entry channel.

Coastal erosion and sedimentation processes are too complex to be predicted adequately by analytical techniques. Only hydraulic modeling can provide a realistic assessment of what will happen and will allow development of effective mitigating measures. O.M.V.S. has recognized the lack of sufficient in-depth study of the estuarine problem and, with the cooperation of the Canadian Agency for International Development, is considering a new study of the estuary. One of the major tasks of this new study will be to redesign the entry channel and harbor, and evaluate the new designs through a hydraulic model study. Accordingly, the forthcoming O.M.V.S./CAID study will provide a definitive analysis of environmental impacts and mitigative measures.

As soon as the entry channel through the Langue de Barbarie is constructed, the existing mouth of the Senegal River will close and the estuary south of the entry channel will develop into a lagoon with greatly decreased water circulation. The loss of flushing will make the lagoon extremely vulnerable to pollution created by the harbor at St.-Louis. At present the southern-most portion of the lagoon is occupied by the Langue de Barbarie National Park, an important estuarine and wetland habitat. If oil or chemical spills from boat traffic were to reach this area, the survival of birds and marine life in the park would be seriously threatened. Another long term impact created by the construction of the entry channel will be a gradual filling of the lagoon with sediment.

The breakwaters required to protect the new navigation channel through the Langue de Barbarie will interfere with sand transport by littoral drift. The partial blockage of the littoral drift will cause sand deposition on the northern side of the breakwater system and create beach erosion to the south of the breakwaters. Some preliminary estimates of the rate of coastal erosion predict that, during the initial years, strong beach erosion will affect up to five kilometers of beach front south of the entry channel at an erosion rate of 200 cubic meters per meter of shoreline. Within ten to twenty years after completion of the breakwater system, the erosion zone is predicted to expand and erosion will be experienced as far away as 20 kilometers from the entry channel. There is the danger that eventually the Langue de Barbarie may completely erode away allowing access of highly saline ocean water into the lagoon.

C.1.2.3. Construction-Related Impacts

Construction of dams, ports and the navigation channel in the Senegal River Basin will disturb the land and its natural cover, leading to soil erosion and increased sediment pollution of watercourses. Fortunately these impacts are generally restricted to the vicinity of construction sites and usually end with the completion of the construction work. The following construction projects envisioned for the Senegal River Basin have the potential to create short term adverse environmental impacts:

a) Manantali and Diama Dams;
b) River Navigation Channel;
c) Estuary Harbor and Entry Channel.

Manantali and Diama Dams - Both Manantali dam and Diama dam construction activities will inevitably impair water quality through the flow of eroded sediments into the Bafing River and the Senegal River respectively. Because of larger rainfalls and steeper slopes, the erosion potential at Manantali is greater than that at Diama. The major sources of sediment pollution from both construction sites include river diversion, exposed surfaces at the construction site, roadways, quarry areas and stockpilings of excavated materials. The degree of pollution will depend on the construction methods used, the layout of the construction site and on the care taken to avoid erosion.

River Navigation Channel - To achieve a navigable depth of two meters in the Senegal River between Kayes and St.-Louis, substantial quantities of sand and rock must be excavated and disposed. Environmental impacts created by the dredging operation in the River itself are judged to be minor, since the bottom material is free from pollutants or undesirable chemicals and consists of fine to medium grain size particles that will settle out quickly after suspension during the dredging operation.

Disposal of dredged material will cause more problems. Basically, two economically feasible alternatives exist for the disposal of dredge spoil:

Thalweg disposal and bank line disposal. Thalweg disposal, which involves the deposition of spoils into deep pockets of the main channel may not be possible everywhere and may lead to increased maintenance dredging. Bank line disposal without costly slurry detention measures should be possible in most parts of the Senegal River Valley. The key to minimizing environmental impacts from land disposal is a careful selection of disposal sites.

Estuarine Harbor and Entry Channel - According to preliminary estuarine development plans, approximately 3,700,000 cubic meters of sand and silt will be dredged in the estuary. About 1,000,000 cubic meters of sand will be placed on the proposed harbor site to create more favorable foundation conditions. The dredging operation itself should not create any major environmental impacts. Harm to aquatic life will be confined to the dredging site and will be an adverse impact, terminating shortly after cessation of dredging activities. The magnitude of environmental impacts from dredge spoil disposal will depend on the mode of disposal. Careful disposal of the excavated material in the ocean or in the southern part of the estuary will result in only minor short term impacts on aquatic life. Proper backfilling of the harbor construction site will not create any major problems to the estuarine environment.

C.1.3. Proposed Mitigating Measures

C.1.3.1. Changes in Flow Regime

Flow regime changes are an integral part of the O.M.V.S. development program. A major concern is the projected rise in flood peak water levels in the Middle Valley during large floods after substantial floodplain development. Even though elevated water levels are not likely to occur in the near future, they must be considered in the design of irrigated perimeters to be located in the Senegal River floodplain. When perimeters are planned, care should be taken not to disrupt flow paths through the Senegal River floodplain. Conservation of the natural floodplain flow patterns must be one of the major considerations in the design and placement of irrigated perimeters.

It is recommended that O.M.V.S. participate in the development of irrigated perimeters in order to introduce hydraulic considerations into the placement and design of perimeters. To accomplish this task, O.M.V.S. is urged to make efforts to help assure that natural floodplain marigots are not haphazardly eliminated during the construction of agricultural perimeters. O.M.V.S. is also urged to continue utilizing the SOGREAH model to check the effect of planned irrigated perimeters on flood flows and water levels. Simulation with this model will permit the identification of undesirable effects of elevated water levels before construction and the evaluation of alternative arrangements.

C.1.3.2. Changes in the Sedimentation and Erosion Regime

Since the predicted changes in the Senegal River's sedimentation and erosion regime are not expected to do any harm to human settlements or otherwise valuable land in the near future, no mitigating measures are proposed at this time. Surveillance of erosional processes throughout the River Valley, however, is strongly recommended. The identification and reporting of major erosion damage after each annual flood can be performed most effectively at no extra cost by the maintenance crews of the Direction de la Voie Navigable, whose responsibilities include an annual check on the river navigation channel. The crew's observations should be transmitted to O.M.V.S. in the form of an annual report. Based on these annual reports, O.M.V.S. will have the opportunity to identify erosional problems as they develop and take appropriate measures if necessary.

Measures mitigating beach erosion on the Langue de Barbarie will depend on the extent of the erosional problem identified by the proposed estuary and harbor study. It is recommended that O.M.V.S. proceed as soon as possible with the proposed study.

C.1.3.3. Mitigating Measures Related to Construction

O.M.V.S. should be responsible for assuring that appropriate erosion control measures are included in the construction work and are enforced throughout the duration of construction activities.

Manantali and Diama Dams - This Report recommends that O.M.V.S. take the following three actions to minimize erosion from reservoir construction activities:

a) Include in tender documents a provision for detailed erosion and sediment control measures as part of the construction works;

b) Make the compliance for specified erosion and sediment control measures a criterion in the selection of the contractor;

c) Instruct supervising engineers in order to insure that proposed control measures are carried out throughout the duration of construction.

Estuary Harbor and Entry Channel - To date, no plan exists for the disposal of several million cubic meters of sand and silt to be excavated in the estuary. It is therefore recommended that O.M.V.S. commission a dredge spoil disposal plan for the estuary. The execution of this plan should be added to the terms of reference of the proposed estuary and port study. During the dredging and disposal activities it should be O.M.V.S.'s responsibility to assure compliance by the contractor to the terms of the dredge spoil disposal plan.

River Navigation Channel - Adverse environmental impacts of dredging in the Senegal River can be minimized through the use of mechanical dredges and the adherence to good dredging practices. O.M.V.S. has the responsibility to insure that the selected contractor employ good dredging practices by taking appropriate steps in the bidding procedure and by strict construction supervision. The most important step will be the identification of environmentally safe disposal sites for the material dredged from the Senegal River. O.M.V.S. and the dredging contractor should collaborate in designating suitable disposal areas, based on field observations and general site selection guidelines provided in the Rivers and Estuary Partial Report.

Table C.1 - 7

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Rivers and Estuary Regime

Factors Creating Impact	Impact Description	Magnitude of Impact	Mitigating Measure
Construction of Manantali Dam	Erosion and sediment pollution in Bafing River downstream of dam.	Light to severe, adverse, short-term, depending on erosion and pollution control measures taken	Prepare and enforce erosion and pollution control measure.
Construction of Diama Dam	Erosion and sediment pollution in Senegal River downstream of dam.	Same as above	Same as above.
Construction of Saint-Louis Harbor and entry channel through Langue de Barbarie			
- Dredging operations	Turbidity plume and bottom destruction in vicinity of dredging site.	Light, adverse, short-term	Employ "good dredging" practices; prepare and enforce master plan for dredge spoil disposal in estuary.
- Dredge spoil disposal in ocean or southern estuary	Turbidity plume and bottom destruction at disposal site.	Moderate, adverse, short-term	
- Maintenance dredging	Turbidity plume and bottom destruction at disposal site.	Light, adverse, short-term	Same as above.
Construction of river navigation channel			
- Initial dredging and rock excavation and maintenance dredging	Turbidity plume and bottom destruction at dredging sites.	Light, adverse, short-term	Employ "good dredging" practices
- Dredge spoil disposal	Covering of river banks with spoils, sediment pollution of Senegal River and bottom destruction.	Moderate, adverse, short-term	Selection of suitable disposal sites and methods (Thalweg or bankline).

Table C.1 - 7 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Rivers and Estuary Regime

Factors Creating Impact	Impact Description	Magnitude of Impact	Mitigating Measure
Construction of river ports.	Erosion and sediment pollution.	Light, adverse, short-term	Supervision of construction activities.
Operation of reservoirs and floodplain development.	Land inundations: Manantali and Diama Reservoirs, Lac de Guiers, Aftout es Sahel, and Lac R' Kiz.	Severe, long-term, irreversible and most significant during the dry season.	None
	Changes in flow and inundation regime.	Severe, long-term, varies with magnitude of annual flood and phase of Manantali Reservoir operation	None
	Water level increases between Bakel and Podor caused by perimeter construction.	Potentially severe depending on implementation of mitigating measure, long-term, periodically reoccurring during large flood years	Keep floodplain flow paths open when planning perimeters.
Operation of reservoir and flow regime changes.	Changes in sedimentation and erosion regime.		
	Channel gradation during average and below average floods.	Moderate, adverse, long-term	Monitor changes in sedimentation and erosion regime.
	General increase in bank stability.	Light, beneficial, long-term	
	Channel instabilities in vicinity of tributary influences.	Moderate, adverse, long-term	
Presence of river navigation channel and low flow augmentation.	Stabilization of low flow channel.	Moderate, beneficial, long-term	Maintenance and improvement of river navigation channel.
	Increase in low flow.	Exceptional for agricultural development, beneficial and long-term during dry seasons	None

Table C.1-7 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Rivers and Estuary Regime

Factors Creating Impact	Impact Description	Magnitude of Impact	Mitigating Measure
Presence of entry channel through Langue de Barbarie.	Creation of lagoon in southern estuary.		
	- Decrease in water circulation leading to higher pollution potential.	Moderate to severe, adverse, long-term extent of impact not known, to be determined by estuary modelling	Execution of proposed estuary and harbor study. Prevention of pollution from Saint-Louis and harbor.
	- Sedimentation of lagoon.	Moderate, long-term, extent of sedimentation not known, to be determined by estuary modelling	Execution of proposed estuary and harbor study.
	Coastal erosion south of entry channel.	Potentially severe, adverse, long-term extent of erosion to be determined by estuary modelling	Execution of proposed estuary and harbor study. Potential mitigating measures and entry channel design to be evaluated by hydraulic modelling.

Note: Changes in river flow, floodplain inundation, and sedimentation characteristics can lead to various beneficial and adverse impacts on the basin's people and natural resources.

C.2. Groundwater

C.2.1. Existing Groundwater Resources

There are nine water-bearing, geologic formations underlying various portions of the Senegal River Basin. Of these nine formations, six contain water only in fractures or pockets of sand and clay. A Cambrian sandstone formation, one of the six geologic formations in the Basin containing localized pockets of groundwater, surrounds the Manantali reservoir site. The remaining three aquifers contain the largest amounts of groundwater available for use in the Basin. As their major source of recharge is the Senegal River, these three formations will be most affected by the proposed development. Characteristics of these three aquifers are as follows:

TABLE C.2-1

Major Aquifers

Aquifer Name & Country Where Located	Total Area Parallel to Earth Surface, sq. km.	Typical Well Depth, Meters	Potential Well Yield, cu. m of water Per day
Senegal River Alluvium			
Mauritania	1500	2 to 15	As high as
Senegal	4100	2 to 15	1100
Continental Terminal (sand/sandstone)			
Mauritania	54,000	no data	As high as
Senegal	110,000	available	2200

TABLE C.2-1 (cont'd.)

Major Aquifers

Aquifer Name & Country Where Located	Total Area Parallel to Earth Surface, sq. km.	Typical Well Depth, Meters	Potential Well Yield, cu. m of water Per day
Maestrichtien Sands			
Senegal	150,000	50 to 500	As high as 6000

The extent of present or future use of groundwater resources within the Basin is not known. Aquifers located downstream from Podor are possibly affected to a certain, undefined degree by salt intrusion from the River. It has been suggested, however, that much or all of the saline groundwater in this region is due to the presence of salt-bearing deposits in that region. No aquifer water quality information is available for areas upstream of Bakel.

A field survey of 40 wells conducted during 1977-1978 as part of this environmental assessment leads to the following conclusions:

a) Water from certain wells had contaminant concentrations that exceed WHO criteria for drinking water or surface water. Well contamination is more frequent during the dry season and most extreme in the delta;

b) Reasons for excessive contaminant levels cannot be determined without more extensive study;

c) Construction and maintenance practices at some of these wells encourages contamination;

d) Salinity concentrations at wells surveyed in the delta increased between December 1977 and June 1978, possibly due to the movement of the salt tongue up the river from the Atlantic Ocean.

C.2.2. Projected Impacts of Proposed Developments

The proposed Diama dam will have two impacts on groundwater resources: the increase in water levels and surface area inundated by the impoundment during the dry season as a result of the dam will result in larger amounts of freshwater being conveyed to the groundwater in the vicinity of the Diama impoundment, and the prevention of saltwater intrusion upstream of the Diama dam will eliminate any annual groundwater recharge upstream of the dam with salt water that might enter the aquifer through its hydraulic connection with the river. As a result, well water quality in a three to five kilometer-wide band on both sides of the River may improve.

The proposed Manantali dam will alter the amounts of water infiltrating the soil in the area of the reservoir and in the floodplain downstream of Bakel. The permanent inundation of several hundred square kilometers of land behind the Manantali dam will increase the quantities of groundwater available in the reservoir vicinity.

The water balance of aquifers whose recharge depends on infiltration of water from the floodplain during the annual flood will change in response to the future flow and inundation regime of the Senegal River. In the future, the floodplain inundation period will decrease and only during smaller-than-average flood years will artificial flood releases from the Manantali reservoir cause moderate increases in floodplain inundation. The net result of future development will be an overall reduction of infiltration from the floodplain and subsequent recharge of related aquifers. Given the current level of aquifer utilization in the Senegal River Basin; it is reasonable to assume that the reduction in aquifer recharge will not measurably affect present use with the possible exception of a requirement to deepen some shallow wells. Recharge to surface aquifers could, however, limit the potential of future large-scale exploitation of these aquifers in the Senegal River Basin.

Adverse impacts on groundwater quality are projected to result from agricultural development, the entry channel south of St.-Louis and municipal-industrial development. The use of pesticides and fertilizers at irrigated perimeters could lead to increases in pesticide and nutrient concentrations in underlying groundwater supplies that are adjacent to perimeters and within several meters of the irrigated surface. Irrigation in perimeters placed in the Delta where the groundwater is saline and close to the surface could result in soil surface salinization due to the rising of salt to the surface from the groundwater due to capillary forces. The proposed entry channel through the Langue de Barbarie south of St.-Louis is projected to increase dry-season salinity levels in the river downstream of the Diama dam according to mathematical modeling results presented in this study's Water Quality Partial Report. This increase may result in a rise of salt concentrations in the groundwater as far as three to five kilometers away from the river downstream of the Diama dam. Such an impact on the Basin's groundwater resources will be adverse but of minor importance because the amount of groundwater affected and the expected changes in groundwater salinity levels will not be significant. Municipal and industrial development in areas where groundwater is present near the soil surface could result in local areas of groundwater contamination where wastes are disposed. This impact is also considered minor, because it is expected only in small areas, although contamination could make the groundwater unacceptable for human consumption in these areas.

C.2.3. Proposed Mitigating Measures

The most economical methods of combating detrimental impacts on groundwater resources are measures that prevent these impacts from occurring. This includes plans that propose a water pollution control program involving environmental monitoring, measures to help prevent unnecessary detrimental impacts on groundwater resources in the future, and planning of alternative actions should a detrimental impact become significant.

The three primary issues of concern relating to future impacts that could be detrimental to human use of groundwater supplies are:

a) groundwater levels;
b) groundwater contamination;
c) soil salinization.

It is recommended that a hydrogeological study of the Basin be conducted to accurately define the effects of proposed developments on groundwater recharge, and the possible use of groundwater in certain regions to supplement surface water for irrigation and municipal/industrial uses. A long term program of monitoring well characteristics, groundwater quality, and water levels of wells and aquifers should also be established to provide information on groundwater resources and the significance of changing groundwater characteristics as future development takes place.

The following points should be considered in the planning of future aquifer use:

a) Operating and maintenance practices at existing wells that can inhibit well contamination;

b) Consideration of the possibility of occasionally changing water release patterns from the Manantali reservoir to increase floodplain inundation and thus aquifer recharge. Such a measure should only be seriously contemplated if, in the future, groundwater levels drop drastically, causing impairment of groundwater withdrawal. In addition, the technical and economic feasibility of the measure would need to be established before this measure could be implemented;

c) Development of groundwater pollution control activities that would specify criteria for determining if a well or aquifer is polluted. Criteria for the safe disposal of potentially harmful wastes in areas with important groundwater resources could also be developed.

Regular monitoring of groundwater quality is recommended to identify the occurrence and the development of groundwater quality problems;

d) Placement, construction and maintenance of future wells that reduce contamination possibilities;

e) Location, construction, operation and maintenance of sources of contamination such as latrines, waste lagoons, agricultural areas and land disposal of solid wastes that reduce possiblities of groundwater contamination;

f) Consideration of the depth of the groundwater table as an important criterion in the selection of agricultural perimeter locations. If necessary, artificial subsurface drainage should be installed;

g) Placement of agricultural perimeters away from areas with saline water tables close to the surface or installation of artificial drainage;

h) Methods of storage, handling and use of pesticides and fertilizers that minimize adverse impacts on groundwater quality.

Table C.2 - 2

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Groundwater

Component	Factor Creating Impact	Impact Description	Magnitude	Mitigating Measure
Diama Dam	Construction of Diama Impoundment	Increase in quantities of non-saline water infiltrating the soil.	Light, beneficial, long-term and year-round	
		Intrusion of salt water upstream of dam will no longer occur.	Light, beneficial & long-term	
Manantali Dam	Construction of Manantali Impoundment	Permanent inundation behind dam, increasing infiltration.	Moderate, beneficial, long-term & year-round	
Manantali Dam & Agricultural Development	Flow regulation and perimeter development	Changes in floodplain infiltration and aquifer recharge.	Moderate, adverse, long-term	Monitoring of floodplain groundwater levels. Use of artificial floodplain inundation during large floods if necessary to inhibit dramatic groundwater level reductions.
Agricultural Development	Use of pesticides and fertilizers	Contamination of groundwater.	Adverse, long-term, extent depending on mitigating measures	Proper handling, storage and use of pesticides and fertilizers. Monitoring of groundwater quality.
	Irrigation of areas with high saline groundwater table	Rise in groundwater levels resulting in water logging and increase in soil salinization through capillary rise.	Adverse, long-term, depending on mitigating measures	Regarding artificial subsurface drainage, consider proximity of groundwater table in location of perimeters. Monitoring of groundwater quality.
Navigation	Entry channel through Langue de Barbarie	Increased saline water intrusion below Diama Dam.	Light, adverse, long-term, during dry season only	Monitoring of groundwater quality.
Municipal/ Industrial Development	Land disposal of wastes	Contamination of groundwater.	Adverse, long-term extent depending on mitigating measures	Consider proximity of groundwater table in location of disposal files. Monitoring of ground water quality.
All Components	Development of dams, perimeters and municipal/ industrial areas.	Changes in both recharge and utilization of groundwater resources.	Moderate, adverse, long-term and year-round.	Hydrogeologic study.

C.3. Atmospheric Conditions

C.3.1. Existing Conditions

Climate in the Senegal River Basin is primarily dictated by changing wind patterns throughout the year. Between May and October, winds from the south and southwest carry moisture into the Basin, while during other months, winds from the arid regions northeast of the Basin predominate. Nevertheless, the limited northward movement of the Intertropical Convergence Zone (I.T.C.Z.) explains the rather abundant wet season rainfalls in the southern portion of the River Basin compared to the northern area. As much as 1,500 to 2,000 millimeters of rain fall annually in the Guinea portion of the Basin from May to October while 300 millimeters fall, on the average, in the Podor-Rosso area. August is normally the month when the most precipitation occurs.

Analysis of 30 to 60 years of rainfall records throughout the basin reveals the following characteristics:

a) The smaller the mean annual rainfall, the greater is this rainfall's variation from average amounts;

b) There exists a greater chance of a year having less-than-average rainfall than there is that a year will have greater-than-average rainfall.

Hence, the number of drought years exceed the number of wetter-than-average years, which is a major factor in the noticeable increase in the size of arid areas in the Senegal River Basin. The process by which these arid areas increase in size is called desertification.

Evaporation characteristics based on 14 years of measurements show that average evaporation rates range from 1600 to 1800 millimeters per year. These measurements show small monthly and annual variations when compared to the wide fluctuations of rainfall. This is because solar radiation and

temperatures are fairly constant throughout a 12-month period. Humidity varies from day to day and from dry season to wet season due to wind and solar radiation changes.

Local climatic changes can occur due to topography or a nearby water body. Climate in the Upper Basin is locally affected by sharp changes in land elevations not present in the Valley or Delta. These changes affect local wind circulations. The Atlantic Ocean alters wind patterns in the Delta, but it has little or no effect on precipitation levels.

C.3.2. Impacts of Proposed Developments

Proposed development activities related to land use variations are not expected to cause significant climatic changes in the Basin. Increases in the amount of land inundated, irrigated as agricultural perimeters, or developed as population centers are expected to account for less than two percent of the land in the River Basin by 2028. Additional amounts of evaporation will not significantly increase the amounts of water in the atmosphere.

Micro-climatical changes may occur from winds sweeping across the increased surface area of the Manantali impoundment resulting in a local raise in evaporation. If properly placed, tree farms around agricultural perimeters will act as wind breaks, decreasing evaporation and minimizing aerial losses of soil.

C.3.3. Proposed Mitigating Measures

No mitigating measures are warranted regarding atmospheric conditions. Since it will not be possible to determine micro-climatic impacts effectively until after the various development projects have been implemented, it is recommended that the Basin's climate continue to be monitored to provide data needed to further understand month-to-month and year-to-year climatic variations. This monitoring should continue to be the responsibility of the meteorological services within the O.M.V.S. member countries. Climatological

monitoring is included in the proposed monitoring program presented in the Plan of Action. Additionally, the installation of lysimeters in selected agricultural areas to periodically monitor crop water consumption is recommended.

C.4. Water Quality

The water quality survey, conducted as part of this environmental assessment, supports previous water quality observations in the Basin and adds quantitative information from various locations for the 1977-1978 dry season. Mathematical simulations of existing dry season salinity in the estuary and dissolved oxygen concentrations in the River from Kayes to Richard Toll support historical conclusions regarding existing water quality and project future water quality conditions.

C.4.1. Existing Conditions

The elimination of pollutants from surface waters in the Senegal River Basin is presently controlled by naturally occurring phenomena. The effects of human activities on water quality are hardly noticeable. As river flows change from season to season, water quality changes also take place. These changes affect aquatic life and, at times, the use of surface waters by terrestrial life including humans.

During the wet season, watersheds receive precipitation that flows into the Bafing, Bakoye and Faleme Rivers and smaller tributaries of the Senegal River. The discharge from these three rivers, located in the upper basin, constitutes the majority of the flow in the Senegal River. Nutrients, organic materials and minerals are washed from these watersheds into the rivers where they are carried downstream, primarily in a dissolved state. With increased flows, the river water is well-mixed and dissolved oxygen concentrations are fairly uniform, regardless of depth. At this time, the majority of reoxygenation in the water column occurs from the atmosphere. By the end of the wet season in November, flows in the Delta begin to recede as the last stages of an annual flood pass through the river.

After inundation of the floodplains, and when the main channel becomes ponded, these nutrients, along with nutrients of terrestrial origin become tied-up in the particulate state in the form of plankton and higher aquatic plants. With the receding flood waters and the dessicating condition of the

dry season, the plants die and decay. In turn, these nutrients contribute to the growth of terrestrial vegetation and crops produced by the traditional methods, such as recession farming. With the coming of the next floods, the cycle begins anew.

During the dry season, river flows originate from the Guinea Highlands, where rainfalls occur all year round, and from groundwater releases. Dry-season flows are approximately one to three percent of the typical flows from an average-sized flood and water velocities are therefore subsequently lower. As a result of the decreased velocity, turbidity diminishes. As lacustrine conditions become prevalent and light penetration increases, primary production by algae plays a major role in reaerating the water column. Development of thermal stratification results in decreased mixing and diminished oxygen concentrations with increased depth.

In the Delta by December, river water levels ususally become low enough to allow highly saline ocean waters, rich in minerals and nutrients, to move up river. The extent of such intrusion varies from dry season to dry season, depending primarily on flows from upstream areas between November and June. Salinity levels are highest in the denser bottom waters of the river. During some years, salinity can be detected by June as far upstream as the Doue Marigot near Podor. Nutrient and mineral concentrations associated with the introduction of ocean waters to the River are higher during the dry season than during the annual flood when freshwater conditions prevail throughout the river. The near-shore ocean upwelling from December through May is believed to be a major source of nutrients throughout the Delta during the dry season.

Lac de Guiers receives annual recharge from the Senegal River through the Taouey Canal at Richard Toll. As soon as the flood waters flush the River of saline conditions at Richard Toll, the gates of the canal are opened, allowing water to flow into Lac de Guiers. The gates are then closed when the flow reverses direction at the peak of the flood. Due to these recharge conditions, the surface area of Lac de Guiers varies annually between approximately 140 and 300 square kilometers. Strong year-round wind and wave

action acts to keep this shallow body of water throughly mixed. If thermal stratification occurs, it is diurnal in nature from the superficial heating of the turbid waters. Sediments, nutrients and minerals in the lake originate from local runoff, from the Upper Basin where river flows first arise and from the land that is periodically inundated by the lake. Evaporation, particularly during the dry season, concentrates dissolved nutrients, minerals and salts within the lake waters. The negligible salinity concentrations within Lac de Guiers are reduced by recharge from annual floods.

Lac R'Kiz receives surface water recharge from the River about once in every ten years. It is presumed to have water quality characteristics similar to those of Lac de Guiers because of similar recharge by rainfall and floodwaters and similarity in soil and topographic characteristics.

C.4.2. Changes Due to Proposed Development

Due to the proposed development and the projected increases in population within the Senegal River Basin, the quality of surface waters will undergo some changes. These water quality changes cannot be classified as beneficial or adverse until the changes are applied to agriculture, aquatic life, municipal-industrial development and other portions of the environment. Hence, these changes are not impacts, but they are instead factors that contribute to environmental impacts of the various resources proposed for development.

Overall changes in water quality due to proposed developments are predicted to be light to moderate. The most significant change will result from the Diama dam preventing salinity intrusion during the dry season to areas upstream of the dam. This change will significantly alter water chemistry and aquatic communities in the portion of the River between Diama and the Doue marigot where water will remain fresh year round.

In the Lower Delta, the Diama dam and the proposed entry channel through the Langue de Barbarie will have profound effects on water quality, especially in modifying the natural salinity regime. Computer modeling during this study indicates that augmentation of dry season flows in the Delta to 100 cubic

meters per second, at Diama, by regulated releases from the Manantali reservoir will not prevent salinity intrusion from extending to the Dagana area if the Diama dam is not constructed.

As with most dams, the one at Diama will encourage the settling of some sediments within its reservoir, particularly in the later stages of the annual flood. However, these solid particles and associated nutrients and minerals will, for the most part, enter the reservoir with annual flood flows and pass through the area before settling to the bottom of the reservoir.

Lac de Guiers will continue to be replenished with nutrients, organic materials, minerals and sediments from flood flows. Flows into the lake will become possible during part of the dry season once the Diama dam is in place. Lac R'Kiz and depressions in the Aftout es Sahel will be recharged more frequently than presently occurs. Due to existing saline soil conditions, salinity levels in the Aftout es Sahel depression will be high, particularly during the first few years of inundation.

The Manantali reservoir will experience thermal stratification and little mixing of the water column throughout much of each year. This will result in reduced oxygen concentrations with depth. Under these stratified conditions, the lower hypolimnial waters may develop anoxic conditions resulting in elevated levels of hydrogen sulfide, and dissolution of nutrients into the water column from both the bottom muds and, for a number of years, from the decomposition of inundated terrestrial vegetation. Discharge below the Manantali dam of hypolimnial waters could result in fish kills from hydrogen sulfide up to 7 km downstream of the reservoir. Increases of aquatic plants or algae biomass could occur even further downstream from elevated nutrient levels. A yearly overturn of the reservoir is expected to occur from atmospheric cooling of the surface waters during December or January. This will result in a complete mixing of the water column and redistribution of

hydrogen sulfide and nutrients to the surface waters where similar impacts are expected. The redistribution of nutrients to the surface waters will be beneficial by increasing primary production and, correspondingly, fish production.

Changes in water quality in the Senegal River between the Kayes, Mali and the Diama reservoir were predicted by the water quality modeling performed as part of this environmental assessment. During the next fifty years, with increased waste discharges due to municipal and industrial development, dissolved oxygen concentrations will not drop below 6 milligrams per liter, even during low flow periods. Fertilizers and pesticides used at irrigated perimeters and minerals leached from cultivated soils are not expected to reach the River in large quantities if drainage waters from perimeters are not discharged directly to the River and if pesticide and fertilizer use is controlled.

Changes in water quality will result from development and use of the Senegal River for navigation. In addition to the effects of the new entry channel on salinity levels in the estuary, the introduction of oils, waste discharges from boats and barges and the resuspension of some river-bottom sediments, nutrients, minerals and organic materials in the River as a result of dredging activities will cause some water quality changes in the estuary.

Short-term water quality changes due to dam and perimeter construction activities will include increases in the amounts of sediments reaching the Bafing and Senegal Rivers via runoff during the wet season. This water quality change will be felt more heavily in the Manantali area where runoff contains fewer sediments than at the Diama dam site or in the floodplain.

Future water quality changes will depend, in part, on measures taken to reduce negative impacts of the proposed development discussed in other sections of this study. No mitigating measures or plan of action are presented because the predicted water quality changes are neither beneficial nor detrimental until they are applied to an aspect of the environment affected by such changes. A monitoring program designed to quantify

environmental changes resulting from future developments is proposed in the Plan of Action and includes monitoring of surface water quality as one method of detecting water quality changes before they become moderately or severely detrimental to the environment.

Table C.4-1

Changes in Water Quality Due to Proposed Developments in the Senegal River Basin

Component	Factor Creating Change	Description of Changes	Magnitude	Overall Change In Water Quality
Diama Dam	Creation of dam and reservoir.	Prevention of salinity, mineral and nutrient intrusion from the ocean to areas upstream of Diama.	Prominent and long-term during dry season	
		Settling of sediments and associated minerals, nutrients and organic materials to reservoir bottom.	Light, long-term and year-round	
	Construction activities	Increased runoff of sediments and associated materials to the Senegal River.	Light to moderate and short-term during annual flood[1]	Light
Diama Dam and Manantali Dam	More frequent water releases to Lac de Guiers and other depressions.	Dilution of sediments, minerals and nutrients in the depressions.	Light and long-term during dry season	To
Diama Dam and Navigation	Creation of Diama dam and ocean-to-estuary entry channel.	Alteration of salinity gradients and concentrations of minerals and nutrients downstream of Diama dam.	Moderate and long-term during dry season	Moderate[1]
Manantali Dam	Creation of Manantali Impoundment.	Creation of water body stratified during portions of the year. Settling of sediments and associated materials to reservoir bottom.	Moderate and light (respectively), long-term and year-round	
		Inundation of terrestrial vegetation.	Light, short-term (2 to 5 years) and year-round	
	Flow releases from impoundment.	Lower dissolved oxygen concentrations and higher dissolved mineral concentrations downstream within at least 7 km. of dam.	Moderate and long-term[2]	
	Construction activities	Increased runoff of sediments and associated materials to the Senegal River.	Light to moderate, short-term and during annual flood[1]	

[1] Depends on extent of implementing mitigating measures discussed in other sections of this study.

[2] Occurs during periods of regulated downstream releases when the reservoir is thermally stratified.

Table C.4-1 (Cont'd.)

Changes in Water Quality Due to Proposed Developments in the Senegal River Basin

Component	Factor Creating Change	Description of Changes	Magnitude	Overall Change In Water Quality
Manantali Dam & Municipal Industrial Development	Flow releases from Manantali impoundment in conjunction with waste discharges to the Senegal River.	Changes in amounts of organic materials, industrial wastes & dissolved oxygen concentrations in the river.	Light, long-term & year-round. Depends on future use of sewers to replace latrines	
Manantali Dam and Agricultural Development	Flow releases from Manantali impoundment in conjunction with creation of agricultural perimeters.	Changes in concentrations of sediments and associated materials in the Senegal River.	Light long-term and during annual floods.	
Agricultural Development	Use of fertilizers and pesticides together with discharge of agricultural drainage to the Senegal River.	Increases in concentrations of nutrients and pesticides reaching the river together with minerals leached from cultivated soils.	Light to moderate, long-term and year-round if drainage water reaches the river[1]	Light To Moderate[1]
Navigation	Discharges and accidental spills of oils and wastes from ports, boats and barges on the Senegal River.	Periodic, unpredictable increases in concentrations of oil and organic materials in the river.	Light, long-term and year-round[1]	
	Disposal of dredged materials onto land.	Resuspension of disturbed minerals and nutrients from river bottom.	Light, long-term and year-round occurring during and immediately following dreding activities	

[1]Depends on extent of implementing mitigating measures discussed in other sections of this study.

[2]Occurs during periods of regulated downstream releases when the reservoir is thermally stratified.

C.5. Agricultural Development

C.5.1. Existing Conditions

The economies of Senegal, Mali and Mauritania depend heavily on agriculture. At present, agricultural production is subject to high risks because of the erratic rainfall and river flood patterns. For example, even in years when rainfall and flood levels are adequate, the Member States have to import foodstuffs. In order to reduce the reliance on imported foodstuffs to supplement rainfed and recession agriculture, the three O.M.V.S. governments are making strenuous efforts to develop the irrigated crop potential of their lands lying in the Senegal River Basin.

The River Basin represents a large underdeveloped area with great potential for improved water use in a part of the world that has suffered in recent years from devastating droughts. The majority of the 1,200,000 people living in the Senegal River Basin are farmers whose livelihoods depend upon the Senegal River floods to provide water for recession crops (cereals and vegetables), or upon rainfall for water to grow millet, sorghum and vegetables. Few agricultural inputs, such as fertilizers, are used, as the farmers are reluctant to make any additional investment because of the uncertain rainfall pattern of recent years. As a result, yields and overall production are low and most agriculture is at a subsistence level.

Presently, farmers in the River Basin are shifting progressively from dryland and flood recession cultivation to irrigated perimeters as the perimeters are developed by the O.M.V.S. governments, with the assistance of bilateral and international agencies. The total area under irrigation throughout the Senegal River Basin at the present time is approximately 11,800 hectares, predominantly located in the Delta region. Rice and sugar cane are the primary crops grown at the perimeters. Implementation of the proposed developments will make it possible for the three Member States to increase the pace of irrigated agricultural development and to improve the quantity and quality of food production.

Saline groundwater and soil conditions in the Delta have hindered development of irrigated agriculture in the region of the Basin. Research carried out on the rice paddies at Richard Toll, the Kossak (deep drainage) and the M'Pourie paddies have failed to find a solution to this problem.

O.M.V.S., assisted by UNDP, has prepared long-range agricultural development programs to achieve, over a period of the next 50 years, the year-round irrigation of about 255,000 hectares along the Senegal River. Approximately 185,000 hectares of this land are proposed to be in Senegal, 62,000 in Mauritania and 8000 in Mali.

The government of Senegal has appointed SAED as the national development agency to construct and manage all of the Senegalese agricultural projects associated with O.M.V.S. The counterpart of SAED in Mali is OPI, while SONADER assumes this role in Mauritania with responsibilities similar to those of SAED with regards to the development of irrigated agriculture in their respective countries.

Livestock raising is an important activity in the Senegal River Basin, although presently it is at a subsistence level. The proposed developments will make it possible to employ applied research to improve and integrate livestock activities in the River Basin.

The only college for veterinary medicine in francophone West Africa is at Dakar. Schools are scattered throughout the three Member States to train veterinary nurses and technical assistants. Organizations such as the Direction de l'Elevage et des Industries Animal (Bureau of Livestock and Animal Industries) in Senegal and similar governmental organizations in Mali and Mauritania are responsible for the health and husbandry of livestock. Vaccinations are conducted at parks and corrals from October to July. Vaccines are obtained from Dakar-Hann, the Central Veterinary Laboratory in Bamako, Mali and at times from non-African sources.

It has been estimated that approximately 9% of the cattle presently abort annually. Surviving calves must compete with man for milk. Heifer calves,

which are of greater economic importance than bull calves, have a higher survival rate than bulls because the herders allot the heifer calves a larger portion of milk. Parasitism in bull calves and abortion by pregnant livestock are aggravated by undernourishment as are the animals' susceptibility to attack by disease. In the upper portion of the River Basin, livestock mortality from predation is also a problem.

One of the major hindrances to cattle exports from the Senegal River Basin to other continents is foot and mouth disease (FMD). Although eradicated from most of West Africa in the late 1960's and still under control in Mali and Senegal, it has returned to nearly precontrol levels in Mauritania.

C.5.2. Environmental Impacts

C.5.2.1. Diama Dam

Beneficial Impacts - The construction of the Diama dam will result in several extremely beneficial impacts on agriculture, which will be long-term and year-round. These include:

a) Elimination of saltwater intrusion upstream of the Diama dam site;

b) Storage of sufficient freshwater to allow for expansion of irrigated agriculture in the Delta and low Middle Valley areas of the Senegal River Basin. If the Diama impoundment is operated at a 1.5 meter IGN level, 65,800 hectares of land in these areas could be irrigated; at a 2.5 meter IGN level, it would be possible to irrigate 98,000 hectares during a low annual flood predicted to occur once in ten years.

c) Storage of sufficient freshwater to provide irrigation for a double-cropping irrigated agricultural system in the area adjacent to the Diama reservoir.

d) Recharge of Lac de Guiers, the Aftout es Sahel and Lac R'Kiz depressions allowing these waters to be used more extensively for irrigation.

Adverse Impacts - The present and proposed agricultural development projects located on the left and right sides of the Senegal River in the Delta area are endangered by several conditions:

a) The existing groundwater table is shallow and highly saline:

b) Soils in the Delta are saline/sodic:

c) Natural drainage is difficult in many locations due to the flatness of the terrain.

After completion of the Diama dam and and its impoundment, the annual application of irrigation water could contribute to rises in groundwater levels, which could conceivably cause waterlogged soil conditions. Also, through capillary rise from the saline groundwater, salts could accumulate in the root zone. These factors would be detrimental to the rice and other crop cultures and will adversely affect crop productivity.

C.5.2.2. Manantali Dam

Beneficial Impacts - One of the main objectives for the creation of the Manantali dam and reservoir is to provide sufficient water year-round to irrigate 255,000 hectares of land within Mali, Mauritania and Senegal. This land is to be developed over a 50-year period, beginning in 1979.

Additional, short term beneficial impacts are associated with the Manantali dam through the release of an "artificial flood", which will occur on a seasonal basis, starting one year after the completion of the dam and continuing for a 15-year period. The objective of the artifical flood is to

provide water for 100,000 hectares of recession farming, and for the irrigated perimeters in existence at that time. This will allow a more orderly transition from traditional to intensive irrigated agriculture.

Adverse Impacts - A permanent, adverse impact will be created by low flow augmentation of the Senegal River from the Manantali impoundment. Approximately 5000 hectares of recession falo land along the river banks will be permanently lost from inundation.

C.5.2.3. Agricultural Development

The development of the irrigated perimeter systems within the Senegal River Basin will have a profound and beneficial impact on the River Basin environment, especially in the agricultural sector. The change from traditional farming to an intensive, integrated, multicropping culture will result in the following beneficial long-term, year-round effects:

a) Increased employment opportunities in agriculture and related activities as land development is accelerated;

b) An improved agricultural economy, which in turn will stimulate and contribute to the overall national economies;

c) Improved incomes and living standards for the farmers of the Senegal River Basin;

d) An increase in national food supplies, with increased quantity and quality of food.

The 255,000 hectares of River Basin land that are designated for development into irrigated perimeters are being utilized at the present time by the peasant cultivators as follows:

a) 67,000 hectares are in recession agriculture during the months of November to March in the walo;

b) 179,000 hectares are utilized as marginal grazing land;

c) 9000 hectares are used for charcoal production.

In order to adequately assess benefits that will result from the transformation in land use, a determination was made of projected crop yields and land values as they would be without the proposed developments. For comparative purposes, a quantification was made of projected annual yields and crop values for irrigated perimeters as they are to be developed over the 50-year period after implementation of the proposed developments.

A comparison of the projected land use value without the implementation of the proposed developments and the projected value with the proposed developments indicates that, without a doubt, intensive irrigated agricultural development in the River Basin will have a beneficial impact of exceptional magnitude.

Adverse impacts will occur during the construction of irrigated perimeters when there will be a temporary decrease in the income of the peasant cultivators due to loss of walo land. There is the possibility that this negative effect can be prevented or mitigated by increasing the amount of dieri land to be farmed and by locating other falo areas in order to maintain a level of subsistence agriculture.

Use of Agricultural Chemicals - It is reasonable to assume that agriculture chemicals will be used in increasing amounts as irrigated agriculture expands and becomes more intensive in the Senegal River Basin.

As irrigated agriculture becomes more widespread in the River Basin, there is a possibility that drainage water containing fertilizer, pesticide and/or herbicide residuals may eventually percolate into the groundwater table

or enter the River via drainage water runoff. If or when this occurs, the magnitude of the effect will depend upon a number of factors, among which are:

a) Percolation rate;
b) Exchange capacity of soils;
c) Rate of aquifer recharge;
d) Concentration of contaminants in the drainage water;
e) Type of contaminants;
f) Whether or not drainage waters are discharged to the River.

Such adverse effects of agricultural chemicals on the River Basin environment will therefore vary as these factors vary in different areas.

The use of fertilizers and pesticides, if they are properly chosen and applied correctly, will be beneficial, as they will maximize the amount and quality of crop yields and will minimize loss and damage to crops from disease, pests and predators.

Impacts Due to Pests - As irrigated agriculture becomes more intensive and as new crop species are introduced into the cropping patterns, there may be an increase in pest populations that damage crops. The potentials vary from continuing or increased crop damage from birds, nematodes and insects, to population explosions of pests as was seen with rodent populations following the recent drought. It is not possible, however, to predict the magnitude of this problem in the future.

C.5.2.4. Impacts on Livestock

Associated with agricultural management, it is projected by 2028 that 28,250 hectares of the 255,000 hectares to be used for irrigated agriculture will be placed into forage production. 572,750,000 forage units (UF) will be produced which will greatly increase livestock production. Approximately 1022 forage units annually are required to maintain a mature cow in the Basin. Other estimates place the number of available forage units from

irrigation agriculture at 260 to 311 million. Forage can be used for fattening cattle in preparation for slaughter, primarily young males from the range herds. This will leave more range space for females of reproductive age, thereby increasing the effective number of breeding stock without altering the range load. This change in sex ratios will increase the frequency of infectious reproductive diseases and alter the age distribution, increasing chronic diseases. Grouping of cattle from many herds in feedlots for fattening will increase the transmittance of disease-related pathogens.

Increased irrigation and resulting elevated soil moistures will enhance the survival of bacterial and parasitic disease agents and improve habitat for other livestock disease vectors as well.

Increased pressure will be placed on herding activities by limiting available dry season forage through the conversion of flood recession lands into irrigated perimeters. This may force herds into marginal and managed range lands enhancing desertification unless herding activities are programmed into a Basin-wide land use management plan.

Improved navigation on the Senegal River will benefit livestock by decreasing cost of supplies, by opening up new markets including exportation possibilities and by decreasing weight loss during transportation to market, which is often quite high by the conventional means of trekking.

C.5.3. Proposed Mitigating Measures

Further development of irrigated agriculture in the Delta region will require the monitoring of groundwater level fluctuations as a preliminary step to implementing properly designed subsurface drainage systems. Subsurface drainage systems are recommended for existing perimeters as well as future perimeters to be developed in the Delta. The economic feasibility of the drainage systems is considered great enough to even warrant unforeseen costs if the need to absorb such costs arises.

C.5.3.1. Agricultural Development

More extensive use of agricultural extension services is considered vital to the success of irrigation agriculture in the Senegal River Basin. Extension services must be strengthened to assist farmers in adopting efficient agricultural practices and maintaining the perimeters. Of special concern to the extension agent is assisting the farmer in the correct use of chemicals and fertilizers, and in the control of crop pests.

Use of Agricultural Chemicals - If the development plan for intensive irrigated agriculture is to be successfully implemented, the use of fertilizers to maintain and improve crop production and the use of pesticides to protect crops and prevent crop losses will be essential.

The adverse effects of agricultural chemicals on the environment can be prevented or minimized by the following:

a) A monitoring program to maintain a continuing check on the quality of water in the Senegal River in order to detect any changes;

b) Thorough training of farmers in the proper choice of chemicals, the amounts in which they should be used, proper time and method of application, and safe handling and disposal of these materials. This should be a function of the agricultural extension services;

c) Research programs to determine the best fertilizers to use, the rates at which they are to be employed and application methods specific to the River Basin;

d) Close and continuing contact with research and other agencies working to develop more efficient and safe plant protection programs;

e) Research programs to determine specific crop pests, disease and predator problems in the River Basin so that the best possible plant protection methods can be used.

Measures to Protect Crops from Pests - Past experience shows that unless crop diseases and insect pests are controlled, productivity of major food crops (e.g., sorghum, millet and maize) will remain submarginal. As more and more land is converted from traditional agricultural methods to intensive irrigated agriculture, the use of carefully selected chemicals for the control of plant diseases, insects and other pests will be essential if agriculture is to fulfill its potential in the Senegal River Basin.

Within the past few years, crop protection programs have been started in some of the Sahelian countries, but there are no programs in the Senegal River Basin at this time. The U.S. AID-sponsored Sahel Food Crop Protection Project (SFCPP) is now in the process of implementing crop protection services in the O.M.V.S. Member States. As these services are expanded and strengthened, the peasant cultivators will develop greater dependence upon crop protection. A major contribution toward the solution of crop pest problems and assisting the farmers in the selection and use of the proper pesticides can be made by well trained extension agents.

Nematodes - The control of nematodes requires specific information. Diagnostic soil sample analyses must be made in a laboratory to determine the specific nematode, whether it is beneficial or detrimental, and population densities, before a decision can be made as to whether or not an area should be treated.

Birds - Control of nuisance birds is already difficult in the Senegal River Basin. Protection of the fields from attacks by birds is now usually the responsibility of children, however, the methods that children can utilize are usually of little effectiveness.

The most widely used methods for controlling Quelea quelea (one of the common bird pests in the River Basin) are to destroy them with explosives or to spray aerial insecticides on roosting and nesting sites.

With regard to the grain pest, Passer luteus, which inhabits sugar cane fields, there should be rigid surveillance and an in-depth study of the problem, because grain production will be important in the irrigated perimeters.

Present research is emphasizing the search for an effective bird repellent so that control can be achieved without causing damage to the nontarget bird populations.

Rodents - Some rodent control measures can be carried out by the farmers. These include keeping dikes, irrigation canals and ditch banks cleared of plant growth, and removing litter from the fields after harvests to reduce rodent habitat.

Chemical control can also be carried out by the farmers. This control method involves the use of poison bait treated with an anticoagulant agent, which the farmers can place in or around their parcels. This type of rodent control program can be very effective if it is done correctly. It should be an activity of the extension service to advise the farmers on how to use this control method, and on the proper handling of the chemical.

Continued Research - Continued research on the irrigated perimeters is needed to resolve the saline/water logging conditions of the Delta, to classify soils and determine what crops and crop varieties will provide the greatest yields under the given conditions.

C.5.3.2. Livestock

One of the main goals of livestock development in the Senegal River Basin should be to establish an effective extension service to educate the community on the new skills needed and the problems to be faced under the changing agricultural patterns and economic system. Under the new agricultural scheme,

livestock should be allowed to graze during the rainy season while being fed fodder in the dry season that has been produced from irrigated and natural forage. Not only will this benefit livestock but it will also take pressure off the rangelands during the dry season, thereby decreasing the encroachment of desertification from overgrazing. Such a scheme will decrease the susceptabilities of livestock to diseases and reduce the number of livestock abortions. Other goals should be improvement of genetic stocks, increased emphasis on production of drought resistant herds as well as development of poultry, and fast breeding rabbits and cobays. Long-range plans should be to reactivate the powdered milk plant at St.-Louis, to construct rendering, tanning and meat canning facilities near major abattoirs and most importantly to integrate livestock practices into a Basin-wide land use management plan.

Since increased risk of disease is very likely under the proposed developments, animal health services must be expanded with emphasis placed on prevention rather than control including initiation of programs such as improved nutrition, feedlot and well design, and herdsmen education. Focus should be on environmental and ecological means of eliminating pathogen transmission.

Table C.5 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Agricultural Development

Component	Factor Creating Impact	Impact Description	Magnitude	Mitigating or Enhancement Measure
Diama Dam	Creation of Diama Impoundment	Elimination of saltwater intrusion; double-cropping system assured.		
		Recharge of Lac de Guiers, Aftout-es-Sahel & Lac R' Kiz depressions.	Exceptional, beneficial, long-term and year-round	
		Irrigation of 65,800 ha at 1.5 meter pool level, 98,000 ha at 2.5 meter pool level of Diama Impoundment.		
Agricultural Development	Expansion of irrigation in the delta	Rise in groundwater level perhaps leading to waterlogged soil conditions	Minor to severe* adverse, long-term and year-round	Observation wells & piezometers established to study ground water level fluctuations for drainage design-monitoring system of ground-water. Installation of plastic subsurface drainage system in perimeter parcels.
		Increase in soil salinity, and reduction in agricultural production in a one or two kilometer zone adjacent to the Diama Impoundment.	Minor to severe*, adverse, long-term and year-round	
	Irrigation development within Senegal River Basin	Increased employment and improved agricultural economy will stimulate national economy, improve incomes & living standards for farmers, and increase national food resources.	Exceptional, beneficial, long-term, and year-round if enhancement measure is implemented	Use of agricultural extension for all types of needed technical assistance associated with irrigation agriculture.
	Agricultural chemicals	Fertilizers will increase and maintain productivity.	Moderate, beneficial*, short-term, and year-round	Proper storage, handling and use of pesticides and fertilizers under guidance of extension agents to avoid environmental pollution problems.
		Pesticides will control crop pests & maintain production.		
	Insects, nematodes, birds and rodents	Losses in crop production due to pests.	Moderate to severe*, adverse, short-term, seasonal	Control of crop pests & diseases.

*Depends on extent that proposed mitigating or enhancement measure is implemented.

Table C.5 - 1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Agricultural Development

Component	Factor Creating Impact	Impact Description	Magnitude*	Mitigating or Enhancement Measure
Agricultural Development (cont'd.)	Transition period from traditional to irrigated agriculture.	Temporary loss of income for walo farmers	Moderate, adverse, short-term, seasonal	Provide other lands useable for agriculture during the transition period.
	Irrigation Agriculture	By 2028, 38,250 hectares of agriculture perimeters placed into forage production	Beneficial	Creation of an extension service to insure proper management. Integrate perimeters into basin-wide land use plan.
	Irrigation Agriculture	Alteration of sex ratio favoring females on open range. Fattening young males in feed lots on grown forage will increase effective number of breeding stock on open range. This impact favors increases in reproductive and age-related diseases on range.	Beneficial/ Adverse	Creation of extension and educational programs. Increase nutrition of livestock thereby decreasing disease susceptibility. Creation of disease prevention program. Use of environmental and ecological means of eliminating pathogen transmission.
	Irrigation Agriculture	Increased disease transmission in feedlots	Adverse	Extension service including education, disease prevention and control.
	Irrigation Agriculture	Enhanced habitat for disease organisms and vectors by increasing soil moisture on irrigated perimeters	Adverse	Integration of herding activities into basin-wide land use master plan.
	Irrigation Agriculture	Increased conflicts with herding and irrigated agriculture in competition for grazing lands	Adverse	Integration of herding activities into basin-wide land use master plan.

*Depends on extent that proposed mitigating or enhancement measure is implemented.

Table C.5 - 1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Agricultural Development

Component	Factor Creating Impact	Impact Description	Magnitude*	Mitigating or Enhancement Measure
Manantali Dam Agricultural Development	Creation of Manantali Impoundment	Artificial flood releases to allow recession agriculture during the transition period	Exceptional, beneficial, short-term, seasonal	-
		Permanent inundation of 5,000 hectares of recession land along riverbanks	Light, adverse, long-term and year-round	-
Navigation	Improved Transportation	Decreased cost of livestock supplies. Creation of new markets including exportation possibilities. Decreased weight loss of livestock during transportation to markets.	Beneficial	Proper institutionalization and management of navigation to assure optimum use.

*Depends on extent that proposed mitigating or enhancement measure is implemented.

C.6. Navigation

C.6.1. Existing Conditions

At present, navigation does not exist to any significant degree in the Senegal River. The improvement of navigation on the Senegal River between St.-Louis and Kayes is among the objectives of the O.M.V.S. development program for the Senegal River Basin. The measures proposed include the construction of an entry channel through the Langue de Barbarie south of St.-Louis, the construction of a lock at the Diama dam, the creation of a permanent navigation channel between Kayes and Podor and construction of port facilities at St.-Louis, Dagana, Rosso, Richard Toll, Podor, Boghe, Kaedi, Matam, Bakel, Ambidedi, and Kayes.

C.6.2. Impacts of Proposed Developments

The construction and maintenance of ports, the entry channel, the river navigation channel and low flow augmentation will lead to physical changes in the Senegal River's flow, sedimentation and erosion regime. In addition, future navigation schemes will introduce pollutant discharges from ships and port facilities, some of which are listed below:

a) Oil and petroleum products;
b) Sewage and waste water;
c) Garbage and trash;
d) Smoke;
e) Noise;
f) Hazardous cargo, primarily agricultural chemicals such as pesticides and fertilizers.

Of these pollutants, oil will constitute a major threat to the environment and could enter the water from the following sources:

a) Discharge of ballast, bilge and tank wastewater:

b) Accidents or collisions resulting in ruptured tanks containing oil:

c) Spills during ship to port transfers:

d) Accidental discharges from oil storage facilities at the ports.

The environmental impact of pollutants other than oil will only be of minor consequence, even if no mitigating measures are observed. For example, it is estimated that, by the year 2028, wastewater and sewage generated from vessels will exert a biological oxygen demand of no more than 40 kilograms per day. Compared to the assimilative capacity of the Senegal River and waste contributions from municipal and industrial sources, the waste load exerted by navigation is projected to be negligible. Nevertheless, it is recommended that a regulation be adopted requiring collection of sewage, wastewater, garbage and trash on board of ships for later disposal on land.

C.6.3. Proposed Mitigating Measures

The extent of future pollution from navigation in the Senegal River Basin will depend on the measures taken to avoid accidental or intentional spills of oil. To minimize the discharges of oil products into the Senegal River, it will be necessary to adopt and enforce a strict pollution control code. A brief summary of the most important rules and regulations to be included in the pollution control code are listed below:

a) Licensing and periodic inspection of all vessels allowed to operate on the Senegal River to ensure that vessels are designed and equipped so that accidental spills of oil are minimized;

b) Training and licensing of crews and port workers in handling oil;

c) Strict regulations regarding oil transfer from ship to port;

d) Accident and collision prevention measures;

e) Spill containment and cleanup program;

f) Proper operation of oil storage facilities in ports;

g) Proper disposal of oily wastes;

h) A system of penalties to be imposed against violators of the pollution control code.

Futher development of the proposed navigation code for the Senegal River Basin is recommended. The code should include environmental recommendations from this study, the Inter-Governmental Maritime Consultative Organization regulations for transport of hazardous materials, and the 1972 UNDP/OERS navigation code developed by N. H. Naguib for the Senegal River and results from the 1978 Lackner, Dorsch and Electrowatt navigation study. The outcome of this code should be:

- The promulgation and enforcement of a comprehensive pollution code for riverine and estuarine areas regulating discharge of pollutants from shipping;

- Promulgation and enforcement of navigation safety codes including ship construction, equipment standards, navigational systems and regulations;

- Enactment and enforcement of port transfer and storage codes regulating equipment and procedures for the handling of hazardous materials, primarily oil and toxic substances;

- Preparation and operation of emergency abatement measures to contain and clean up spillage based on prepared contingency plans.

According to the 1978 study by Lackner, Dorsch and Electrowatt, enforcement of the pollution control regulations for navigation will become the responsibility of the Directorate of Navigation to be established soon. Compliance with pollution control regulations should be enforced by the Directorate through port officers given police power over all navigation on the Senegal River and Estuary.

Efficient and environmentally safe navigation will be possible only with skilled and experienced personnel. At present, such personnel are not available in sufficient numbers within the three O.M.V.S. Member States. The need for a comprehensive training program for future captains, pilots, and sailors, as well as key harbor personnel, is critical.

Table C.6 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin.

Navigation

Factor Creating Impact	Impact	Magnitude of Impact	Enhancement or Mitigating Measure
Emission of oil products from boats, barges and port facilities.	Oil pollution of river and estuary.	Severe to light, adverse, and long-term, depending on implementation of control measures.	Formulation and enforcement of oil pollution control measures concerning equipment and operation.
Emission of wastewater, garbage and trash from boats, barges and port facilities.	Pollution of river and estuary.	Light even without mitigating measures, adverse and long-term.	Formulation and enforcement of control measures calling for land disposal of wastes.
Barge accidents and collisions leading to spills of oil or other hazardous cargo.	Pollution of river and estuary.	Potentially severe and adverse, periodically occuring, and short-term.	Accident prevention measures: - Good equipment and operational standards - Well-trained personnel - Well-maintained river navigation channel and beaconing system Spill containment and clean-up.

C.7. Municipal and Industrial Development

C.7.1. Existing Conditions

Most of the 1.4 million people presently living in the Senegal River Basin reside adjacent to the Senegal River or one of its tributaries. The River is the source of water for most of these people, both in the urban and rural areas. Away from the River, rural villagers take their water from rainfed and floodfed pools or shallow wells. Most inhabitants of the Delta have wells because of the intrusion of saltwater into the River during low-flow periods. Also, some Delta villagers have their water brought in by truck during the dry season as the wells become salty.

The water supply systems that presently exist in the urban centers are generally in poor condition. Of major importance is the insufficient capacity of the water treatment plants, as well as their inability to treat water properly at certain times of the year. Also, the distribution systems in all the cities, except St.-Louis, fail to serve all the inhabitants. Therefore, many people in the urban areas still must rely on wells or the River for water.

In Richard Toll, many people obtain their water from the irrigation canal of the sugar company. As more and more perimeters are developed, this unsanitary practice of utilizing irrigation canal water for domestic use is expected to increase throughout the Basin.

Adequate excreta collection, treatment and disposal are essential for the existence and maintenance of a good standard of health as well as a desirable life style. At present, facilities for dealing with human excreta disposal within the River Basin are quite limited. There are no community-type facilities that are considered to be effectively dealing with a significant portion of the problem.

Most cities in the Basin do not have sewers. For the people living in non-sewered and rural areas, a variety of excreta disposal methods are employed. These methods include night soil collection, open field defecation, latrines and other methods of on-site disposal.

The presence of refuse materials that are improperly stored degrades the quality of life and the general environment. Refuse serves as food and harborage for vermin that are vectors for many diseases prevalent in the area. Presently, the removal of refuse from populated areas to disposal sites is done too infrequently. Disposal sites are too often located within or adjacent to the living environments of the people. These practices adversely affect the health of the people. Without mitigating measures, this problem is expected to increase in the future with the expected rises in population.

Few industries presently exist in the Senegal River Basin. These industries are listed below.

Table C.7-1

Existing Industries

Enterprise	Location
Cement factory	Diamou, Mali
Abattoir	Kayes, Mali
Groundnut decorticating plant	Kayes, Mali
	Sadiola, Mali
Tomato cannery	Saviogne, Senegal
	Dagana, Senegal
Rice mill	Richard Toll, Senegal
	Ross Bethio, Senegal
Sugar refinery	Richard Toll, Senegal
Quicklime plant	Richard Toll, Senegal
Plastics plant	Richard Toll, Senegal
Fish refrigeration plant	St.-Louis, Senegal
Industrial abattoir	St.-Louis, Senegal

It should also be noted that small abattoirs serving villages and small towns are scattered throughout the Basin. Those located along the river dispose of their liquid wastes by channeling them into the River while solid wastes are disposed on the land.

C.7.2. Impacts of Proposed Development

Expanded agricultural production will lead to the development of agro-industries to process and market agricultural products. As the economy of the Senegal River Basin is strengthened, industries other than those associated with agriculture are likely to develop.

Municipal growth and industrial development that are anticipated for the Basin will cause a need for additional and expanded physical infrastructures for water supply and excreta, wastewater, and refuse disposal. If these basic needs of the people are not met, adverse environmental impacts will occur.

Presently, the flow in the Senegal River all but ceases each year near the end of the dry season. During this period, the water that remains in the upper reaches of the River exists in pools. The quality of water in these pools deteriorates as the dry season progresses, because the pools are used daily for washing and bathing.

Following construction of the Diama and Manantali dams, and subsequent low flow augmentation from Manantali, the water in the Senegal River upstream of Diama will be useable for human consumption throughout the year. This improvement will be a beneficial impact for the people living along the River.

The projected reduction in the annual flooding along the Senegal River will decrease the potential for contamination of wells located within the Basin's floodplain. Flooding will continue in the future as both a controlled and uncontrolled event. However, it is expected that the reduction in contamination of shallow rural wells will be significant if contamination resulting from larger numbers of people within the Basin can be controlled.

The reduction in the annual flooding due to the operation of the Manantali dam and the construction of diked perimeters will create adverse impacts related to the recharge of groundwater strata. The majority of rural wells are subject to local recharge. The extent of this recharge is directly related to the length of the period of flooding. The length of the flooding period is expected to be reduced as a result of the O.M.V.S. projects. It is likely that some of the wells located in the periphery area of the floodplain will not receive sufficient recharge and will become dry. When this occurs, it may be necessary to have the wells deepened or new wells dug.

Each year, during the flood, the estuary is flushed out by the flood waters. When this occurs, the gates at Dakar Bango are opened to allow freshwater to flow into the Lampsar and Djeuss marigots. As the flood waters begin to recede, the gates are closed, storing freshwater for the City of St.-Louis. Modification of the River regime in the Lower Delta, due to the construction of the Manantali and Diama dams, may adversely impact this water supply. There is the possibility that the estuary will not be completely flushed during lower than average floods after the Manantali dam is in operation. The water in the River at Dakar Bango could remain saline, preventing the Lampsar and Djeuss marigots from being filled with freshwater from the estuary thereby making the water supply of St.-Louis unusable during that period.

As city populations grow, both naturally and due to the O.M.V.S. developments, it will be essential that the water supply and treatment facilities, as well as the distribution systems, be expanded or significant segments of the new population will be without adequate water service. Without expansion, the quality of water served to the population can only be expected to deteriorate further as additional demands for water are placed upon the system.

Results presented in the Water Quality Partial Report indicate that the discharge of projected amounts of municipal and industrial wastes into the Senegal River will not render the water undesirable as a source of raw water supply. This is made on the assumption that adequate water treatment

facilities will be provided. The increase of pollutants into the River will, however, impact upon the rural users of untreated river water. Consumption of river water without treatment is considered unsanitary, but it is now the normal practice of the people in the rural areas.

Significant increases in population in the Senegal River Basin will cause a proportional increase in the amount of fecal and solid wastes to be generated in the Basin and likewise intensify the problems associated with the proper disposal of these materials.

Another concern that must be dealt with and which has the potential of adversely impacting Basin residents is the removal of solid and liquid waste materials from the population centers. Resolution of this problem is essential and should be given high priority. Unless a program is implemented that will adequately deal with the total solid waste problem, many of the general benefits to the quality of life within the Basin resulting from the O.M.V.S. programs will be less significant. If solid wastes are allowed to accumulate in neighborhoods, the environment may significantly degrade and health problems could occur. Proper disposal of refuse is therefore very important and should be dealt with accordingly.

There is the possibility that toxic substances could be introduced into the River from industrial activities in the Basin. Based on an analysis of the wastewater characteristics from proposed industries, there is a clear potential for negative environmental impacts from toxic substances. Close monitoring of industrial wastes will therefore be necessary for the safety and well being of the people and the environment of the Basin.

The number of air pollution sources and the total quantity of air pollutants will increase within the Basin as existing industries grow and as new industries are developed. Considering air pollution from existing, proposed and projected industries on a macro and mesoscale, no substantial negative environmental impacts are anticipated over the next fifty years. However, on a microscale, the results of a particulate dispersion analysis conducted for a few sample industries indicate that negative impacts could

occur. In addition, although particulate emissions were the focus of the dispersion analysis, other pollutants that can cause negative environmental impacts on a microscale include fluorides, hydrocarbons, sulfur dioxides and nitrogen oxides and other compounds.

C.7.3. Proposed Mitigating Measures

A detailed engineering study should be performed to identify the most cost effective solution to supplying St.-Louis with water. There are several options for recharging the Lampsar and Djeuss marigots with fresh water from the Diama reservoir. It is essential that these studies be undertaken, completed and the required facilities constructed prior to the Manantali dam being in operation.

A program should be undertaken for the purpose of improving the rural water supplies in the River Basin. Present methods and materials used in construction of rural wells are crude. No casings are provided in many wells, which permits the earth walls to disintegrate with time. No actions are being taken to prevent surface runoff in the vicinity of the well from flowing into the well. This condition causes serious contamination of the water in the well. Most of the rural people of the Basin who reside adjacent to the Senegal River obtain their drinking water directly from the River and the adjacent marigots; this is not a satisfactory water supply for these people.

A program should be instituted to develop new and innovative intermediate technology relating to rural water supplies. The present method of well water removal by open containers subjects the well to contamination. The use of closed wells and a pump to transfer water to the surface would be desirable, however, the shortage of adequate equipment constrains the use of this type of installation.

Studies should be made to evaluate alternate energy sources such as wind and solar power. Wind power harnessed by wind mills has proven quite effective in pumping water in many of the undeveloped areas of the world. The

programs that are ongoing at the present time in relation to improved rural water supply should be expanded. These programs should involve education, technical assistance, and participation in self-help programs.

Detailed planning should be undertaken immediately in connection with water supply facilities for the resettlement areas where people displaced from the Manantali reservoir will be relocated. Water supply systems must be properly planned, designed, and constructed before actual relocation begins. These facilities must be in place at the time of the relocation activities or the people will migrate from the resettlement site to an area where adequate water is available. This migration will place additional stress on the water systems serving the area to where migration takes place. It is therefore very important that the exact sites of resettlement be selected and construction at the villages be started as the dams are being constructed.

Water treatment plants serving the cities of the River Basin have been found to be inadequate. This inadequacy relates to insufficient capacity of facilities to serve the needs of the population, ineffectiveness of treatment processes in producing water of acceptable quality, and the lack of redundant facilites that are necessary to assure uninterrupted water supply. These deficiencies have been indentified, based upon present demands and conditions. The seriousness of these deficiencies will be compounded because of increased system demands relating to normal population growth in response to the O.M.V.S. development program. It is essential that detailed studies be initiated for water supply systems from an engineering and economic perspective to identify water system facilities that should be provided. These studies should consider the development of short term programs that can be implemented quickly.

The cities of the Basin should be studied for the purpose of developing a master plan for collection and disposal of excreta and wastewater. The use of public comfort stations that are located in strategic points throughout these cities and the development of effective means for the removal of the collected wastes from the area is of particular importance. If wastewater treatment facilities will be needed, lagoons will probably be the most appropriate technology to utilize.

Future growth and development of cities will have significant environmental impacts on refuse collection and disposal. Studies leading towards the development of refuse plans for all of the major cities of the Basin are needed. The planning effort should deal with storage, collection, conveyance, and disposal of solid wastes.

The technology needed to mitigate or prevent adverse environmental impacts from industries is extremely variable and depends on many factors including: the product to be produced, the process to be used in production, and level of output. For the most part, the need for pollution control technology and the type of facilities to be used in the control of pollution must be decided on an industry by industry basis.

It is therefore recommended that Basin-wide regulatory provisions be considered as follows:

a) To require industries to submit facility design and operation plans for review together with their plans, if any, for handling and disposing of wastes.

b) To require that the storage and disposal of hazardous solid wastes be carried out in accordance with approved plans.

c) To require the use of diversion ditches and lagoons to handle stormwater runoff from manure piles at feed-lot operations.

d) To require burial or covering of solid waste if it is determined that such solid waste would provide harborage and breeding areas for insects and rodents.

e) To require that solid waste storage and disposal areas be sited so as not to pose a pollution threat to water supplies.

f) To regulate open burning such that burning activities would not threaten public health or jeopardize crops and vegetation.

g) To prohibit the discharge of wastewater that could threaten public water supplies or could cause fish contamination or fish kills; and to set industrial wastewater discharge limits.

h) To define toxic and hazardous wastes and to prescribe treatment and disposal standards and criteria for such wastes.

i) To require on-site or in-plant air pollution control facilities where it is determined that industrial air emissions could threaten public health or jeopardize crops and livestock; or, in lieu thereof, require that industrial facilities with problematic emissions be sited such that they are sufficiently buffered or separated from people, animals, and crops.

j) To require the use of erosion and sedimentation control measures where major earthmoving activities are involved including: construction sites, agricultural lands, and mining/quarrying sites.

Table C.7-2

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin - Municipal and Industrial Development

Component	Factor Creating Impact	Impact Description	Magnitude	Mitigating Measure
Modification of river regime	Saltwater may not be completely flushed from estuary during low floods	Lampsar and Djeuss marigots used as water supply for the City of Saint-Louis may not be able to be replenished with fresh water.	Light to moderate, adverse, long-term	A detailed engineering study should be performed to identify the most cost effective solution to supplying Saint-Louis with water.
Basin-wide development	Municipal growth and industrial development	Increased strains on community services such as water supply and excreta, waste water and refuse disposal.	Moderate, adverse, long-term	The cities of the basin should be studied for the purpose of developing master plans to help alleviate strains on community services.
Urban and industrial development	Increases in fecal and solid wastes and associated disposal problems	Degradation of land and water quality and possible increases in health problems.	Moderate, adverse, long-term	Same as above.
Agricultural and industrial development	Introduction of toxic wastes to the environment	Possible degradation of land and water quality and possible new health problems.	Light, adverse, long-term	A basin-wide regulatory agency be developed for pollution control.
Industrial development	Increased air pollution	Degradation of air quality and possible health problems.	Light, adverse, long-term	Same as above.

C.8. Socioeconomics

C.8.1. Existing Conditions

C.8.1.1. Immigration into and Emigration out of the Senegal River Basin

During the Middle Ages, rainfall in the central Mauritanian Plateau was twice its present average and settled agriculture was practiced. Pressures from moving Berbers and increasing desertification forced these sedentary agriculturists to migrate into the Senegal River Basin. While pressure from Moor expansion by political-military means has been foreclosed since the advent of French colonialism at the end of the 19th century, movement south from the desiccating northern zones has continued and various tribal communities have developed in the Basin. Tribal groups can be delineated moving up River from the mouth and include the Wolof, Tukulor, Soninkie, Khassonkie and Malinkie tribes. The Fulbe people are pastoralists whose communities lie scattered about the Basin.

Additional factors, such as the peanut economy, fostered by the French in Senegal, enticed the immigration of Moors into the Senegal River Valley to accept cash employment transporting peanuts and establishing small businesses. The people in the Moor communities have since developed into pastoralists, sedentary cultivators and, in the Delta, fishermen.

Initially, French colonialism and a cash economy slowed emigration out of the Basin. Some groups, such as Soninkie, were able to expand their area of influence within the Basin. By the 1940's, continuing encroachment of the sahelian zone and a failing economy hastened by a decline in French colonial influence began forcing tribual groups out of the River Basin. By the early 1960's, one-quarter of the world's Tukulor population lived outside of the Senegal River Basin, having migrated primarily to coastal urban centers, such as Dakar, where they presently comprise one-eighth of the city's population and make up the second largest ethnic group. Over 90 percent of the foreign labor in France that originates from sahelian Africa originates from the Senegal River Basin. Three-quarters of the sahelian Africans in France are

Soninkie, and one-quarter are Tukulor and Moors. Immigration of Tukulors south of Sine Saloum to cultivate peanuts continues to play an important role in draining the Upper Valley of its working-aged males. Villages visited during this Study were without close to one half of their able-bodied men who had left seeking salaried employment outside the River Basin.

With increasing desertification hastened by activities of man and his herds, a livelihood in the Senegal River Basin has become all the more precarious increasing the rate of emigration from the area. Assuming that each migrant supports 3.5 relatives, without the O.M.V.S. project 100,000 migrants will leave the Basin yearly by 1980 and 850,000 will leave yearly by 2028. Most of these migrants will be young productive males.

C.8.1.2. Herding and its Related Internal Migrational Patterns

Migration within the Senegal River Basin occurs amongst herders primarily in the Middle Valley and Delta. This internal migration is attributed to herds of cattle, goat and sheep that are moved about in search of food. The herders come primarily from the Fulbe and Moors groups. During the wet season, these groups leave the floodplain and head south into the Ferlo Desert of Senegal or north into the Mauritanian interior. As the dry season progresses, the grasses are depleted and the watering holes shrink, forcing a return migration to the River to profit from recession farming forage left behind after the harvesting of grain crops.

Upstream of Bakel in the Upper Valley of the Basin, abundant rainfall, cattle disease and attack by predators has limited pastoral farming and its associated migratory life style. Here, farming tends to be more sedentary.

C.8.1.3. Employment and Income

The primary economic activity in the Senegal River Basin is based upon subsistence food production. Only 20 percent of the population within the Basin is urban, living in centers of over 5000 people. Of the rural

population, over 70 percent are involved in farming, the remainder in fishing, herding and artisanal crafts. Many urban residents, likewise, participate in subsistence food production.

Half the wealth generated in the River Basin comes from agriculture. In the Delta, settled agriculture has been possible since the 1960's with intervention by SAED to resolve problems associated with salinity intrusion into the soil from the saltwater aquifer. A two-season cropping system exists in the Middle Valley. Rain-fed dieri farming takes place from July through September. From October through April, recession farming is the main agricultural activity. This involves farming the rich floodplains after the flood waters have receded. Rain-fed dieri farming predominates in the Upper Valley.

Pastoral herding of cattle, sheep and goats is a traditional agricultural activity in the River Valley. Twenty percent of the wealth in the River Valley comes from herding. In recent years, the number of cattle grazing in the Senegal River Basin has fallen precipitously as a direct result of environmental conditions.

Fishing in the Senegal River Basin is estimated to employ 10,000 full-time and 10,000 part-time fishermen. Fishing is an important seasonal activity practiced at the time of flood recession when fish trapped in depressions behind the high banks of the main channel can be easily harvested. In recent years, reduced inundation of the floodplains has resulted in reduced annual fish harvests.

Hunting is a traditional means of employment and source of protein throughout the Valley. Animal husbandry is oriented toward conservation rather than consumption of animals. Hunting is most important in the Upper Valley, where bountiful game still exists.

Crafts provide useful employment in the off-season agricultural economy. The most productive artisans are the smiths who, because of demand, often abandon agriculture. Other crafts include jewelry, woodworking, leather

crafts and the manufacturing of cloth. With its entrance into the world economy, trades that have arisen in the Basin include tailoring, masonry, mechanics, carpentry and baking.

Neither commerce nor industry is very developed in the Senegal River Basin. European based commercial chains almost completely abandoned their activities in the Basin shortly after independence. Each O.M.V.S. Member State, however, maintains branches of its national commercial house in towns along the River. The remainder of commercial activities are individually owned and deal in standard staples such as coffee, tea and sugar. A system of peddlers who travel from settlement to settlement has been established.

C.8.1.4. Existing Social and Cultural Conditions

Corporate Kinship Groups - Clan members tracing their lineage from a common male line form corporate groups within each village. Each group functions as a unit for political and economic purposes. In larger villages, several autonomous lineages represent a clan. Each lineage is headed by its oldest male member whose principal function is to distribute land. Within each lineage of a village there exist several compounds. A compound is constructed of several nuclear families headed by the senior male of the lineage. Each compound consists of sons and their families and, often, brothers and their families. Each compound works a common agricultural plot. These ties become abbreviated in the migratory pastoral societies.

Caste Organization - Besides common kinship ties, there exists a caste system whose social hierarchy is based upon control and access to cultivable land. The three social levels within the caste system in respective order of status include the freemen, artisans and captives. In the last two hundred years a clerical class has coalesced with the freemen. As a result of the caste system, relatively small groups control a large portion of the most productive recession land.

C.8.2. Impacts From Proposed Development

C.8.2.1. Impacts on Immigration into and Emigration out of the Senegal River Basin

Immigration into the Basin from Proposed Activities - Construction of the Manantali and Diama dams, as well as port and navigation facilities, is expected to attract people from outside the River Basin. A large percentage of the skilled laborers and professionals will be expatriate non-Africans who will depart from the region upon completion of their tasks. Over 90 percent of the unskilled labor is expected to be drawn from the rural population around the dam sites. The remainder will come from areas within the O.M.V.S. Member States but outside the Basin, or from Guinea. Since construction-related activities of navigational facilities will take place in or around urban centers, it is felt that the urban unemployed, who are expected to immigrate in ever increasing numbers, can be drawn upon for unskilled labor, decreasing the need for outsiders and leaving the rural population to concentrate on agricultural activities.

Since construction activities are short term in nature, many of the unskilled immigrants will return to their families upon completion of their tasks. It is not possible to predict the percentage of immigrants that will be absorbed into the society permanently residing within the Basin.

In the districts of Podor and Matam, Senegal and the fifth and sixth regions of Mauritania, employment needs, particularly in municipalities, will expand more rapidly than the local populations. Immigration will occur from outside these districts and probably from outside the Senegal River Basin.

Emigration out of the Basin from Proposed Activities - Overall development within the Senegal River Basin will decrease out-migration from the area by providing increased employment. The net result of the O.M.V.S. plans of development will be to provide sufficient but disproportionate work in the urban areas. Emigration out of the Basin will decrease with the exception of the Ololdou district in Senegal, and the fourth and tenth

districts of Maruitania, where underemployment or unemployment will force the continued emigration of the Soninkie males to search for work elsewhere within the Basin or, as is presently occurring, outside the Basin.

Changes in social patterns may increase emigration. Within the irrigated perimeters a hectare of land will be alloted to each family. Large families may pressure older children to emigrate in search of employment elsewhere. On the irrigated perimeters the role of the women will change from that of a primary cultivator to a marginal farmer. This role change will cause disruption of the established family structure and result in emigration of individuals whose marriages are affected by this occurrence.

In rural areas, by 2028, agricultural activities from the irrigated perimeters will support 1,453,500 people out of a rural population of 4,814,900. Thus, there will be no need for immigration into the Basin for agricultural activities associated with the planned development.

C.8.2.2. Internal Migration

Disruption of Migrational Movements Related to Herding Activities - Regulated flow and placement of land under irrigation will eliminate much dry season recession agriculture and pasturage. However, diminished grazing land will result in a loss of only 1.17% of the herds by 2028. A major impact of this development will be to affect the traditional movements of the herders. Irrigation perimeters, dikes and canals will be restricted from use by the herds and will act as barriers limiting access by livestock to the River as a source of water during the dry season. This will force livestock southeast to Lac de Guiers where overgrazing of lands is already feared to be intensifying desertification.

Migration of herds across the Senegal River will also become increasingly difficult. The River will remain deeper year round, limiting the areas suitable for crossing during the dry season. As development takes place, increasing political and economic measures will force the herders and farmers

to remain within their designated country of origin. Additionally, overall development is expected to further change the life style of the herders as increasing numbers elect to work the irrigated perimeters.

C.8.2.3. Internal Displacement of People

Inundation behind the Diama dam is expected to permanently displace 225 to 250 people around Rosso who reside in tents and thatched dwellings. An additional 3500 people will be permanently displaced by inundation of the well established villages of La Reau, Dieuk and Oualalan in Mauritania and Rong, Rhor, Diawar and Thigor in Senegal.

Inundation behind the Manantali dam will result in the permanent relocation of approximately 13,000 people, mostly Malinke, from 28 villages and satellite hamlets. Resettlement will take place on 39,000 hectares east of the impoundment and on 217,000 hectares northwest of the impoundment along the Bafing river. Unless these resettlements are supplied with adequate food and water, improved communication to the interior will result in out-migration from the area.

C.8.2.4. Impacts on Employment and Income

The integrated development program for the Senegal River Basin will change the existing subsistence economy to a cash economy. Long-term salaried jobs will develop in navigation, industry, agriculture, government, various trades and the professions. Employment in fishing, traditional herding, recession farming and dieri farming will be slowly reduced as the result of the development program. The net effect will be an overall increase in employment causing an inflow of workers to the Senegal River Basin rather than the present outflow.

Employment from Construction of the Diama Dam - Construction of the Diama dam will provide short-term employment commencing in mid-1979 and terminating in 5.5 years. After 1985, a small crew will be retained for maintenance and

operation of the dam. Construction will require 6715 man years of unskilled labor, 3435 man years of local skilled labor, and 1685 man years of expatriate skilled labor.

The average unskilled laborer will be drawn from the rural sector of the populace. As an example, the average rural Delta tenant family working SAED perimeters can equal its yearly earnings in one month by sending one male to work as an unskilled laborer at the Diama dam construction site. Because of this, working age males will be encouraged to abandon full time activities on the perimeters in favor of work as unskilled laborers.

Skilled national labor will be drawn from the urban sectors of the society earning an average of 1,175,000 CFA per year. Greater emphasis will be placed on the importance of the nuclear family which, unlike that of the unskilled laborer, will accompany the skilled employee to the job site. As a result, it is estimated that only 5 percent of the skilled laborer's salary will go to the extended family compared to 30 percent of the salary remitted by the average rural worker.

Employment from Construction of the Manantali Dam - Construction of the Manantali dam will provide intensive short term employment from 1980 until 1987 after which a few hundred employees will be kept for operation and maintenance of the dam and reservoir. Construction efforts will require 19,120 man years of unskilled labor, 9680 man years of local skilled labor and 6320 man years of skilled expatriate labor.

Most unskilled laborers will come from the Kayes region and will be close enough to their families to assure normal agricultural production by periodic trips to work or supervise the fields under cultivation. As necessary, they will be able to afford itinerant replacements in their absence. This is typically done by the emigrating Soninkie of the Upper Valley. Local skilled laborers will come from the urban sectors of the Member State. Remittances of 30 percent and 5 percent of the annual salary, respectively, will be paid to the extended family by unskilled and skilled laborers.

Effects of Irrigation Perimeters on Employment - Development of irrigated agriculture will result in losses of traditional employment such as fishing, herding, recession and dieri farming. However, the net effect of development will be to provide increased jobs, higher levels of agricultural production and, as a result, the development of a cash economy within the Senegal River Basin. Most of the workers on the new irrigated perimeters will be drawn from the local rural populations and will return to their extended families at the end of each working day. This form of agriculture is expected to quadruple the income of the average rural family who becomes involved in working these perimeters.

Effects of Navigation and Industry on Employment - Navigation and industry will provide an increase in employment in the Senegal River Basin. By 2028, work will exist directly and indirectly for approximately 72,000 wage earners at a combined income of 34 billion CFA yearly. For every job from the formal sector, there will be 1.15 additional jobs created, primarily service related. These will include merchants, masons, repairmen, barbers, butchers, taxi drivers, etc. Industrial jobs will primarily involve processing agricultural products derived from the agricultural perimeters. This will include employment in mills, vegetable canneries, cotton gins, spinning and weaving mills, sugar refineries, abbatoirs, tanneries, dairy plants and lime and processing plants.

C.8.2.5. Changes in Social Structure

Changes in the Traditional Social Structure from Construction of the Diama and Manantali Dams - The major changes in traditional social structure from construction of the two dams will come about by separation of the unskilled laborer from his traditional rural extended family. Salary levels will not permit the rural worker to transport or maintain his family at the job site, nor will he be able to visit home frequently. Continual conflicts may occur between the contruction company and the laborer who will require periodic return visits to the extended family, especially during peak periods of cultivation. Since the construction job will provide only short-term employment, the unskilled laborer will look to his rural resources and the extended family to maintain long-term economic security.

Short-term impacts from construction will involve the camp society that will become established at the construction site. The typical inhabitant will be a male, aged 20 to 30 and coming from a rural uneducated background. There will be no traditional social structure for material and emotional support. An increase in crime can be expected in the construction camps. Likewise, local residents may become the victims of such activities.

Changes in Social Structure from Relocation of Villages Inundated by Dam Construction - Relocation of the village communities will cause friction and disagreements over control for authority between various village heads as communities are amalgamated into centralized living environments. Loss of ancestral shrines as a result of inundation, especially in the Manantali area, will diminish the authority of the village chiefs who, in the past, relied on these sacred places as a means of supernatural reinforcement of their leadership. These synergistic events will ultimately reduce the elders' authority in the relocated communities and cause disintegration of the hierarchy in the village infrastructure. In addition, exposure of the younger people in the Manantali area to new social ideas from improved communications will further disrupt the village authority system.

Tension is also expected to mount between present inhabitants in the relocation sites and the newly resettled populations. Jealousy and/or a lack of understanding will arise among the older villagers, many of whom will fail to comprehend the attention and investment in water supplies, schools, dispensaries and roads given their new neighbors. Many of the people will be encouraged to abandon their older villages in favor of the more affluent resettled villages.

Allocation of land for farming will cause additional problems. Because of the concentration of people, villagers may be required to commute five kilometers daily to and from their fields. These villagers may relocate their housing from the centralized community, resulting in a scattered distribution of housing rather than the orderly planned community. Scattered housing will result in decreased administrative efficiency of the villages.

Within the family structure, friction will rise as younger men become increasingly independent of the extended family from exposure to the cash economy.

Cultural losses are expected to occur from relocation of communities and creation of new life styles in the cash economy such as the decreasing economic and ritual role of hunting as agriculture begins to play an increasingly important role in supplying food to the communities. Relocation of villages and the changing life styles will cause a general cultural impoverishment of the people.

Changes in Traditional Social Structure from Development of Irrigation Agriculture - Development of irrigation agriculture will result in a decrease in traditional employment such as herding, decrease in fishing, dieri and recession farming, and a decrease in corresponding cultural activities associated with these life styles. Although farmers will be drawn primarily from the rural sector, there will be some resettlement required. Resettlement will cause initial insecurity and uncertainty until the productivity of this innovative agricultural technology is proven successful. Many workers will be reluctant to resettle in certain sectors, especially the Delta where salty soils increase dependence on technology and preclude traditional agricultural practices outside of the perimeters.

Many settlers will be middle-aged, with few elders or men 20 to 30 years of age. Absence of elders will make it difficult to establish political authority. The perimeters will be worked by heterogeneous ethnic groups with different mores and cultures. This may cause further friction.

There will also be a change in the traditional allocation of agricultural lands associated with the caste system. Under the SAED program, one family, regardless of class, will be allotted one hectare of irrigated perimeter. Members of the clerical caste who currently hold most of the land feel that irrigation lands should be allotted in proportion to the amount of traditional

agricultural lands presently held. Additionally, if only one hectare is allotted per family, many extended families may become disrupted as young, able-bodied men will be forced to look for work elsewhere.

Under traditional agriculture, distribution of the land has been tied to inheritance. Parcelling out portions of an allotted hectare of irrigation land by inheritance can result in ineffective quantities of land to support a family and spottedly distributed parcels owned by one person. Such dividing of land is not felt to be conducive to optimum production. In the past, periodic redistribution of land in the irrigated perimeters has been practiced without regard to inheritance. As a result, the tenant farmer has failed to take pride in upkeep, management and production of his allocated plot. Under the long-term allocation of perimeters as planned by SAED, these problems will be alleviated. It has been recommended that an undivided inheritance system be used. Unassigned plots in newly created perimeters may then be allocated the uninherited portion of the family.

As a result of these control measures, farmers at the agricultural perimeters will lose a large degree of their independence that existed under their traditional life styles. They will farm under regulations set down by government authorities rather than by village elders or the extended family. They will be told what to produce and many may be required to limit traditional activities such as herding, fishing or other forms of agriculture.

Traditional artisan crafts may also be affected, especially by the double cropping expected from the irrigated perimeters. At present, most artisans work as cultivators during the rainy season and artisans at other times of the year. Artisans working the irrigated perimeters will be forced to pursue their craft in their spare time, hire others to work the land for them while pursuing craft activities, or give up working the irrigated perimeters altogether. It is expected there will be a decline in craft activities as a result of irrigation development.

Changes in the Traditional Social Structure from Navigation and Industrial Development - Industrial development and navigation will draw people into an urban setting. Under these conditions the autonomous nuclear family will be favored over the extended family. This will result in a number of political and social problems. Entrance at an early age into a cash economy will cause a decrease in authoritative control by family elders as youth become economically independent. The choice of a spouse will be more individualistic, whereas traditionally, wives have been chosen by a council of family elders. Ethnic and caste boundaries will tend to disappear as economic disparity decreases and intermarriage takes place. There will be a tendency towards cultural homogenization under the new urban settings in the Senegal River Basin.

Urban property is also predicted to increase as job hunters quickly surpass available jobs. This will place a heavy burden on housing, health facilities, markets, water supplies, waste disposal, schooling, public safety and food supplies. Because a high amount of urban unemployment will exist, activities will occur that are atypical of the immigrants' rural setting, such as prostitution, burglary, petty theft and crimes of violence.

A decrease in traditional crafts may result in cultural impoverishment of the area. As a cash economy develops and the standard of living rises, many salaried workers will prefer imported goods. Leather craft, woodwork and pottery imported into the Basin from abroad will be preferred over the local products. Imported cloth from Dakar or abroad will outsell local handmade fabrics at cheaper prices. Certain patterns of cloths will be retained for local use during ceremonies and festivals. Jewelers' handicrafts will rise in demand. The traditional troubadors will still be used in certain rituals but there will be less demand for them in the urban setting.

C.8.3. Proposed Mitigative Measures

Three sets of activities for enhancing and mitigating socio-economic impacts have been identified and include:

a) Measures to insure certain salary and housing standards at construction sites employing local labor. Also included are measures to insure that recruitment of workers does not excessively disrupt village and family social structures. These measures would be carried out by the specific units of O.M.V.S. charged with construction.

b) Measures to mitigate problems of resettlement of people displaced by the Diama and Manantali impoundments, those moving into the urban-industrial complexes, people colonizing the irrigated perimeters, herders, and populations displaced from areas no longer suitable for recession agriculture.

c) Measures to integrate the basic socio-economic needs of agricultural families into the development of plans for the irrigated perimeters.

An integrated land and water-use plan and specific urban and rural master land use plans are recommended to maximize land use benefits and improve the standard of living for future populations in the Basin. The O.M.V.S. Directorate for Planning and Coordination would be responsible for developing the Basin-wide water-allocation and land use studies. The suitability of lands for settlement will be assessed and guidelines will be proposed for environmentally and socially sound development of rural and urban areas for residential and economic activities. These guidelines will specify water supply, and solid and liquid waste disposal quality standards, health facilities and provide assistance in finding equitable solutions to questions of land tenure.

In terms of detailed planning for future population growth in rural and urban areas, the O.M.V.S. Directorate for Planning and Coordination would provide technical assistance to national groups for the regional and local development of specific master plans ranging from irrigation and drainage layouts, to urban infrastructure planning. One of the crucial roles for O.M.V.S. will be to detail the expected effects of Basin development on population movements, economic potentials, land availability and social infrastructure requirements to national, regional and local officials.

Table C.8 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Socioeconomics

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Construction Related	Competition for workers between construction activities and agriculture.	Drawing labor away from agriculture in favor of salaried job in construction of dams, navigation, and other development activities.	Moderate, adverse, short-term	Government regulation of wages of agricultural workers at levels high enough to competitively pay itinerent labor to work land. Draw construction workers living near construction site so can work agricultural plots in free time & cut loss of production to minimum. Hire nearby, urban unemployed, leaving agriculturalists to work land. Plan construction activities so that peak periods of labor coincide with periods of light agricultural activity. Develop quasi-permanent group of construction workers to reduce disruption from recruitment.
Construction	Search for salaried employment	Many individuals will be willing to travel long distances and break immediate family ties to obtain salary or high paying wage. This will place much stress on the traditional family structure.	Moderate, adverse, short-term	Recruitment in immediate vicinity of construction site. Provide transportation from certain key points to job site.
Construction	Bringing together young males into a situation where the authoritative structure of the village and extended family is absent	Increased crimes such as theft, crimes of violence and the social problems associated with an unstructured disrupted life style.	Moderate, adverse short-term	Hire workers principally from immediate area so they can return to families each evening. Encourage workers from outside the region to set up living quarters in nearby villages.

Table C.8-1 (Cont'd)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Socioeconomics

Component	Factor Creating Impact	Impact Description	Magnitude[1]	Enhancement or Mitigating Measure
Construction (continued)	See previous page			In isolated places, such as Manantali site, put up housing at the resettlement villages to be inhabited during construction by the labor force. Provide good meals, recreational areas, mosque, post office and other needs conducive to a civilized atmosphere.
Construction	Several thousand construction workers disrupting village and community atmospheres.	There will be a disruption of the serenity of many communities by influx of construction workers. Local residents may become victims of crimes associated with these activities.	Light, adverse, short-term	Dispersion of construction workers to a number of communities.
Irrigated Perimeters	Elimination of land from cultivation during the irrigated perimeter construction period.	Decrease in available food for local consumption during this interim period	Moderate, adverse, short-term	Stock piling of grains by the governments.
Road Construction	Displacement of Saint Louis - Nouakchott traffic to Diama	Loss of 300 to 500 jobs from traffic diversion in the village of Rosso, Senegal	Severe, adverse, short or long-term	Give Rosso priority for installation of industrial facilities.
Implacement of Proposed Dams	Inundation of villages and scattered homes that lie behind the Diama and Manantali Dams	The inundation of villages and scattered homes located behind the two dams displace large numbers of people from their settled life styles and result in a permanent loss of their homes.	Severe, adverse long-term	Relocation of villages, homes and people to higher grounds outside impoundments.
Creation of Reservoirs	Resettlement of people from inundated areas.	Decline in authority & social stability of relocated villagers whose homes will be lost from inundation.	Moderate, adverse, short or long-term.	Give villagers flexibility in making decisions. Immediate selection of chiefs of new consolidated villages is recommended.

Table C.8-1 (Cont'd)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Socioeconomics

Component	Factor Creating Impact	Impact Description	Magnitude[1]	Enhancement or Mitigating Measure
Creation of Reservoirs	Resettlement	Tension between relocated villagers and population already existing at resettlement zones.	Moderate, adverse, short-term	Build wells in old & new villages. Locate schools so as to benefit old & new villages. Provide older inhabitants with access to durable construction materials for homes.
Creation of Reservoirs	Resettlement	Cultural losses from resettlement	Moderate, adverse, long-term	Allow hunters and religious figures to be important voices in site selection of new villages, permitting transplantation of their functional roles to new villages.
Creation of Reservoirs	Resettlement	Migration of people away from resettled areas.	Moderate, adverse, short-term	Develop resettlement sites on schedule. Water & food and houses or materials for construction should be readily available. Economic expectations of new inhabitants must be met.
Irrigated Agriculture	Development of Irrigated Perimeters	Resettlement of people associated with the loss of recession lands that are planned for incorporation into agricultural perimeters	Severe, adverse, long-term	Locate irrigated perimeters to avoid unnecessary resettlement. In delta, postpone development of irrigated perimeters until technical problems solved by SAED to assure profitability of working perimeters before resettlement takes place.
Integrated Development In the Senegal River Basin	Integrated Development	Residential Instability	Moderate, adverse, long-term	Assure development occurs near population centers, when possible. Spread development proportional to needs of population among the 10 districts.

Table C.8-1 (Cont'd)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Socioeconomics

Component	Factor Creating Impact	Impact Description	Magnitude[1]	Enhancement or Mitigating Measure
Transportation	Roads near Diama development	Uncontrolled development of housing and other structures along road.	Light, adverse, long-term	Establish government agencies within Senegal and Mauritania to control roadside activities
Agriculture	Irrigated perimeters, industrialization, urbanization, decreased flooding	Loss of forage and grass lands for cattle, sheep, and goats from conversion to irrigation agriculture, affecting lives of herders.	Moderate, adverse, long-term	Placement of 14.5% of irrigated perimeters in forage production Use of by-products from other crops for forage. Allot herders working plots within perimeters.
Agriculture Urban and Industrial Development	Irrigated perimeters & villages	Physical blockage of traditional migratory herd routes to the Senegal River during dry seasons.	Moderate, adverse, long-term	Establishment of cattle corridors to allow access to the Senegal River. Pumping of water to specific sites where herds can obtain water.
Agriculture	Government control of agricultural perimeters	Increased dependency of tenant farmer on government.	Moderate, adverse, long-term	Place priority on small perimeter development. Permit tenant farmer his choice of crop in part or in whole on his plot during the off-season. Increase tenant farmers' responsibilities for construction and maintenance of irrigation works, inputs into cultivation and marketing outputs, and coordination of these activities with government. Provide government flexibility in social organization of production.
Agriculture	Urban development	Loss of rural farm labor on agricultural perimeters due to attraction to salaried jobs in the urban areas.	Moderate, adverse, long-term	Reduce wages of urban employees. Expand tenant farmer's share in benefits from irrigated perimeters.

Table C.8-1 (Cont'd)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Socioeconomics

Component	Factor Creating Impact	Impact Description	Magnitude[1]	Enhancement or Mitigating Measure
Agriculture	Irrigated agriculture	Loss of traditional agricultural roll of women due to development of intensive irrigation agriculture.	Moderate, adverse, long-term	Organization of collective group of women who will be allocated parcel of irrigated land for cultivation. Develop new occupations for women.
Agriculture	Irrigated agriculture	Increased disruption of extended family because of insufficient work on agricultural perimeter.	Moderate, adverse, long-term	Develop new occupations for the unemployed. Older unmarried sons involved in surveillance of cattle. Older sons given priority consideration for hiring as agricultural extension agents.
Basin-wide Development	Changing life styles	Overall decrease in crafts from: a) Change to cash flow economy; b) More employees working to create important goods; c) Less use of certain crafts and rituals in urban sectors than in rural areas; d) Replacement of traditional crafts by highly skilled jobs.	Moderate, adverse, long-term	Creation of centers for artisans to work, sell crafts and develop tourist trade.
Basin-wide Development	Urbanization	With industrialization and increased jobs in the urban areas the populations will expand, placing increased pressures on the government to provide planning and other municipal services.	Severe, adverse, long-term	Enact zoning regulation. Provide following municipal services: a) Water supply e) Fire protection b) School f) Street planning c) Public safety g) Waste disposal d) Health care Regulation in construction of public housing.

Table C.8-1 (Cont'd)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Socioeconomics

Component	Factor Creating Impact	Impact Description	Magnitude[1]	Enhancement or Mitigating Measure
Industrialization & Navigation	Development of better inland navigation, and industry	Creation of new jobs	Moderate, beneficial, long-term	Keep operations at a labor intensive level. Keep salaries high. Enact legislation to protect interests of workers in their jobs. Promote trade union organizations to provide job security.
Fisheries Production: Food and Jobs	Dam construction	Decrease in annual fish harvests.	Severe, adverse, long-term	Increase importation of marine fish into the basin from artisanal and industrial fishery. Fish culture coordinated with agriculture. Management of existing fishery. Better preservation and storage methods. Supplement losses of fish with increased agricultural products.
		Reduction in the number of jobs available to fisherman	Severe, adverse long-term	Allot fisherman agricultural plots.
Agriculture	Irrigated perimeter development, urbanization, and industrialization	Loss of access to river by herds from physical barriers such as dikes, agricultural plots, and villages	Moderate, adverse, long-term	Assure that open corridors are incorporated into development strategies so herds are allowed access to the river over traditional routes of travel.

[1] Magnitudes of impacts depend upon the extent that enhancement/mitigative measures are implemented.

C.9. Public Health

C.9.1. Existing Health Conditions

The health picture for Senegal River Basin communities is that of a population where the principal burden of disease resides on infants and young children. The diseases are almost exclusively infectious in nature. The infectious agents are mainly airborne and fecally related. These, together with malaria, represent the vast majority of infections. Malnutrition is prevalent in young children and undoubtedly plays an important role in increasing susceptibility to infection. It contributes, therefore, to the prevalence and virulence of infectious diseases and to the high morbidity and mortality rates of infants and young children. Older children and adults appear to be relatively healthy, with the exception of child-bearing females who show some degree of anemia although they are adequately nourished.

Malaria is an important health problem in the SRB. It is cyclic in nature, with transmission mainly limited to the rainy months. With the coming of the rains there is increased vector mosquito breeding and biting activity, favoring increased malaria transmission. With the return of the dry season, transmission virtually ceases. The magnitude of malaria in any given rainy season is directly related to the amount and duration of rainfall.

Malaria endemicity is lowest in the Delta and lower half of the Middle Valley, which receives the least rainfall. It is higher in the upper Middle Valley, which receives more rainfall, and highest in the Upper Valley, where the rainy season is longest and rainfall is most abundant. In the Delta and lower Middle Valley, it ranges from hypoendemic (0 to 9% infected) to mesoendemic (10% to 49% infected). In the Middle Valley from meso- to hyperendemic (50% to 74% infected) and, in the Upper Valley, it rarely drops below hyperendemic levels.

Where malaria is hyper- or holoendemic (+75% infected), adults and older children suffer relatively little from malaria infections. Children from 6

months to 5 years of age bear the brunt of this disease, with those 6 to 24 months of age suffering most of the deaths. It is estimated that 10-15% of these will die of malaria.

Where malaria is hypo- or mesoendemic, the morbidity rates in young children fall off markedly, and mortality rates may drop by two-thirds. At the same time, however, older children and adults become more susceptible to malaria, raising the morbidity rate in these age groups. The recurring cycle of drought in the SRB creates a fluctuating transmission pattern, which is termed "unstable malaria". Communities with unstable malaria benefit greatly during years of low rainfall as transmission is reduced. But the benefits may be offset by a loss of immunity; with the return of higher rainfall and more intense transmission, malaria will be more severe than if it had remained stable at a higher level of endemicity.

Urinary schistosomiasis, transmitted by Schistosoma haematobium, is endemic throughout the River Basin. Although widely distributed, prevalence of infection is generally low. It is more prevalent in the Upper Basin communities but, even there, infection rates suggest that intensity of infection is not high. While there are undoubtedly isolated foci situated away from the River with intense infection and evidence of serious disease, urinary schistosomiasis cannot be considered a major health problem in the SRB. There is no evidence that transmission of Schistosoma mansoni, which causes intestinal schistosomiasis, occurs anywhere in the SRB.

Onchocerciasis presents an important health problem for the riverine communities of the Upper Valley. Infections with trypanosomiasis are rare. Sleeping sickness, which occurs only in the Upper Valley, is of rare occurrence and does not pose an important health problem. Sporadic cases of cutaneous leishmaniasis occur, but must be considered of only minor health importance. The prevalence of intestinal parasites is unusually low and of no health significance. Guinea worm infections are reported in the Upper Valley and Selibabi area, and probably present a minor health problem.

The classical epidemic diseases: plague, yellow fever, meningococcal meningitis and cholera appear to have been quiescent in the Senegal River Basin in recent years. Trachoma occurs, but evidence suggests that it is not widely prevalent. Advanced stages of these diseases do not appear to be common in the SRB.

Several airborne diseases are major health problems in the Basin, especially among children. Measles, tuberculosis, and whooping cough (pertussis) are the most significant causes of diseases associated with the respiratory tract.

Nutritional disorders are prevalent in children under seven years of age, although severely affected children are uncommon. Fecally transmitted diseases, particularly intestinal infections, poliomyelitis, tetanus, and intestinal worms, are not a major cause of illness in infants and young children.

Tuberculosis is not as commonly seen as anticipated, but in view of the widespread malnutrition in children it must be considered an important disease. Leprosy occurs throughout the Basin, with infection being most prevalent in Mali. It must be considered a health problem of importance.

An interesting if somewhat ominous pattern appears to be emerging regarding treponematosis infections. As a contagious nonvenereal infection, endemic syphilis is a disease of children. The vast majority recover without treatment or serious sequelae. Once recovered, they are resistant to venereal syphilis. Endemic syphilis, once ubiquitous in the Basin, has been virtually eliminated in recent years because of WHO-sponsored treatment campaigns. This has resulted in a steadily increasing percentage of the population reaching the age of sexual activity without immunity to venereal syphilis. As a consequence, the more virulent venereal syphilis is replacing endemic syphilis. Neurologic and cardiac complications as well as congenital infections, which characterize venereal syphilis but do not occur with endemic syphilis, will probably become more prevalent in the Basin.

The health problems posed by zoonoses are not clearly defined. Diseases such as leptospirosis, salmonellosis and brucellosis do occur, but the probability that they constitute a major health problem does not appear to be high. Nor does it appear likely that the SRB development program will significantly influence the prevalence or importance of zoonotic diseases.

C.9.2. Impacts of Proposed Developments

Major development programs that are currently proposed for the Senegal River Basin will have significant beneficial and adverse impacts on the health of Basin residents. The programs will increase water and food availability, improve navigation and generate hydroelectric power, all of which are generally beneficial to health. On the other hand, the programs will alter population distributions and increase population densities, thereby increasing both the probability and the prevalence of communicable diseases. Development programs will modify but may not eliminate malnutrition. The need for direct health and environmental health activities will increase. Unless suitable mitigating measures are taken, adverse impacts resulting from these developments may cause serious long-term difficulties for the people of the Basin.

An increase in malaria can be anticipated, with the greatest impact on communities in the upper half of the Middle Valley. Vector mosquito breeding and subsequent malaria transmission is expected to increase as a result of constructing irrigated perimeters. The overall effect on the health-economy interaction will be negligible because of a changing pattern of immunity to malaria.

No upsurge in schistosome infections is anticipated. A significant increase in schistosome transmissions because of greatly expanded use of irrigated perimeters is by no means certain. Findings indicate that currently, in the irrigated canals of the SRB, transmission does not occur. This finding may very well apply to future irrigated perimeters. The only new focus of schistosomiasis that can be predicted with any reasonable certainty is the Manantali impoundment area. Even there, because of a relatively sparse

population, the adverse impact on health may not be great. Schistosomiasis transmission in the Delta, currently insignificant, is not expected to show much change with the construction of the Diama dam.

Onchocerciasis will disappear from that sector of the Bafing River to be flooded by the Manantali impoundment. Downstream of the dam, along the Bafing and Senegal River to the Kayes area, the disease will become more severe. The overall adverse impact on health by changes in onchocerciasis will be small. In addition, the WHO is planning a vector control program for the blackfly-infested portions of the Senegal River Basin. An effective control program could eliminate onchocerciasis if the program is maintained.

Arboviral diseases, trypanosomiasis and leishmaniasis, probably will not be significantly affected by proposed developments. It should be noted, however, that the available information for arboviruses is inadequate for unqualified predictions.

The Diama impoundment will provide an abundant, year-round supply of freshwater for many communities. This will positively affect the health of these communities. Resettlement, in-migration and urbanization could, on the other hand, result in increased transmission of both fecally related and airborne diseases, particularly during the construction phase of the program. However, development of properly constructed and maintained water supply systems could result in a net decrease in prevalence of fecally related disease.

The reduced availability of freshwater fish due to a drop in the estuarine fish populations and the loss of major fish breeding sites in the floodplain could have a negative impact on nutrition. This could be offset in the future by the increased productivity of irrigation agriculture. Increased fish harvests in the Manantali impoundment will have a positive impact on the nutrition of Upper Valley communities.

Family income of River Basin communities will rise as irrigation agriculture expands. This will make it possible for families to improve the quality of nutrition and housing, and at the same time provide the means for supporting better community health care systems.

C.9.3. Proposed Mitigating Measures

The plan of action to mitigate projected adverse changes in public health emphasizes prevention and local treatment of health problems rather than large-scale treatment or disease control programs. A malaria eradication program, for instance, is considered to have unproven effectiveness and is too costly in view of the health benefits that would be gained. On the other hand, ways to inhibit disease transmission are available primarily by improving health education at the community level and providing the proper construction of dams, dikes, irrigated perimeters and related infrastructure.

Recommended measures to inhibit disease transmission that are not under the authority of health ministries and public health professionals are as follows:

a) Planning and providing water supply and waste disposal facilities to large population centers;

b) Encouraging resettlement of villages in Mali to be permanently inundated by the Manantali impoundment away from waters that may be infested with snail vectors;

c) Transporting marine fish into the Basin, proper management of the natural Basin fishery, and introduction of fish culture on irrigated perimeters in order to supplement the projected loss of riverine fish from the human diet;

d) Construction and maintenance of irrigation and drainage canals to discourage aquatic plant growth;

e) Judicious selection and use of pesticides.

Recommended actions that would be under the authority of health ministries and health professionals are:

a) Establishment of a community-level, primary health care system;

b) Development of a health monitoring program;

c) Implementation of an onchocerciasis control program by using pesticides to regulate blackfly vector populations;

d) Conducting medical examinations of dam construction workers prior to their employment;

e) A sociological study to adapt the primary health care program to local cultures and traditions;

f) A nutritional study to evaluate protein and caloric availability starting with an examination of potential agricultural production and comparing potential production to the needs of the people.

A community-level primary health care system is recommended so that curative and preventative health services can be provided to as many people in the Basin as possible. This system could be based on the "health hut" and "health post" concepts. Specific functions of a health hut will include:

a) Handling of common health problems that are easy to treat;

b) Providing health education to villagers to improve a person's understanding of diseases and to explain and encourage nutrition and sanitation practices that can prevent health problems from occurring;

c) Providing services, such as special care of children and child-bearing women, to prevent various health problems;

d) Providing public health agencies with disease surveillances and other health information needed to monitor public health in the Basin.

Primary health care recommendations also include the provision of health and sanitation facilities at the Diama and Manantali construction sites.

An effective health monitoring program in the Senegal River Basin could survey changes in disease patterns. Specifically, responsibilities that can be handled by a health monitoring program include:

a) Securing methods for detecting changes in disease patterns;

b) Monitoring of disease infection rates and transmission potentials by reviewing information from primary health care facilities and employing monitoring techniques;

c) Assisting in defining health protection requirements at construction sites, municipalities, health posts and health huts;

d) Evaluating the needs for special studies such as the need for a study to show effects of the construction of the Manantali impoundment on snail populations infected with schistosomes.

An onchocerciasis control program proposed for funding and implementation by the World Health Organization could help to control the spread of this disease.

Physical examination of construction workers is recommended prior to hiring workers for employment at dam sites in order to reduce the chances of spreading diseases.

Table C.9-1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Public Health

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Diama Dam	Creation of the Diama Impoundment	Drainage problems at several villages in the delta.	Adverse and year-round. Extent and duration of impact depend on implementing mitigating measures	Encourage resettlement if necessary.
		No increase in malaria prevalence in delta and lower valley.	None	None
		Increase in transmission of arboviral diseases due to increases in vector mosquito populations in the delta.	Slight, adverse, long-term and year-round	None
		Increase in population densities of schistosome-carrying snails.	Possibly moderate, adverse, long-term and year-round	Public Health monitoring
Diama Dam and Manantali Dam	Creation of salt-water barrier at Diama together with regulated dry season releases of water released at Manantali.	Provision of increased amounts of year-round fresh water supply upstream of Diama.	Moderate, beneficial, long-term and during the dry season	None
		Loss of amounts of fish in the delta and river valley.	Light to moderate depending on mitigating measure implementation, adverse, long-term and year-round	Transported marine fish into the basin to supplement sources of fish protein particularly during first few years after construction of the dams.
Manantali Dam	Resettlement of villages to be inundated by the reservoir.	Lack of water supply and waste disposal facilities in resettled areas.	Adverse and year-round, extent and duration depend on mitigating measure implementation	Provision of water supply and waste disposal facilities. Incorporation of villages into the primary health care system.

Table C.9-1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Public Health

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Manantali Dam Cont'd.	Creation of Manantali Impoundment.	Increased fish supply upstream of Manantali Dam.	Moderate in reservoir area beneficial, long-term and year-round	None
		Increase in numbers of snail vectors necessary for schistosomiasis transmission.	Light, to moderate,[1] adverse, long-term, and year-round	Reduce snail-to-human contact by resettling inundated villages away from impoundment. Public health monitoring.
		Reduction in onchocerciasis transmission upstream of Manantali dam.	Moderate, beneficial, long-term and year-round for communities near impoundment	Public health monitoring.
		Increase prevalence of trypanosomiasis vectors (tsetse fly) and arboviral diseases (certain mosquitoes).	None to light depending on environment, adverse, long-term and year-round	Public health monitoring.
	Releases of waters to the Bafing River downstream of the dam when reservoir is not filled.	Increase in blackfly populations that transmit onchocerciasis.	Moderate, adverse long-term and during the dry season from Manantali to the Kayes area.	Implement onchocerciasis control program as proposed by the W.H.O.

[1]Magnitude of impacts depends on unknown environmental factors and the extent recommended mitigating measure(s) will be employed.

Table C.9-1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Public Health

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Agricultural Development	Crop production	Increase in food supply in the river valley, reducing malnutrition, particularly in children.	Exceptional, beneficial, long-term and year-round	A nutritional study to evaluate present and future protein and caloric availabilities.
	Construction of additional irrigation and drainage canals and rice fields.	Increase in malaria transmission at larger and more numerous areas of standing water.	Light in the flood plain, particularly during dry season, adverse, long-term and year-round throughout the flood plain	Effective construction and maintenance of canals. Development of a primary health care system.
		Change in prevalence of snail vectors necessary for transmission of schistosomiasis.	None to moderate; uncertain due to unknown effects on snail populations, possibly adverse, long-term and year-round	Public health monitoring. Public health education via primary health care.
		Change in prevalence of mosquito vectors that transmit arboviral diseases.	None to light; uncertain due to unknown environment effects possibly adverse, long-term and year-round	None

Table C.9-1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Public Health

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Agricultural Development (cont'd.)	Use of Pesticides for agricultural purposes.	Long-term ingestion of pesticides from air, water and crops.	Light, adverse, long-term, and year-round	Avoidance of unnecessary use of pesticides.
Municipal Development	People living in larger communities particularly at existing populations centers and dam construction sites.	Increase in disease transmitted among humans.	Light to severe depending on local conditions and implementation of mitigating measures, adverse, long-term and year-round	Installation and maintenance of water supply and waste disposal systems; establishment of primary health care systems. Physical examinations of construction workers prior to employment in the basin. A sociological study to adapt the many health care programs to local cultures. Primary Health Care.

C.10. Fisheries

C.10.1. Existing Conditions

C.10.1.1. Riverine Fishery

With less than one percent of the Senegal River Basin presently under development, the fishery exists in a natural state regulated by two climatic extremes, the wet and the dry seasons. During the wet season, from August through December, the Middle Valley exhibits characteristics of a freshwater fishery relying upon inundation of floodplains to replenish the fish stock by providing habitat for breeding and as a nursery for various species.

During the dry season, the river gradually subsides, forcing the fish populations to leave the floodplains and to concentrate in the main channel of the river. All freshwater fishes caught are consumed, including zero-year class fishes (fish under one year of age). The more important families of freshwater fish consumed include Osteoglossidae, Mormyridae, Characinidae, Citharinidae, Cyprinidae, Clariidae, Schilbeidae, Bagridae, Mochocidae, Cichlidae and Centropomidae.

With the receding waters of the rainy season, a salt wedge develops, moving up river from the mouth as far as the Doue Marigot at Podor. The estuarine conditions that are created by this phenomena are critical to fishes whose life cycles are tied to the salinity regime. These fishes include important species such as Ethmalosa fimbriata (African shad), Tilapia quineesis, Sarotherodon melanotheron heudelotii, Mugil spp. and Liza spp. The African Shad is only a small contributor to the commercial marine fishery but is important in the artisanal fishery at the mouth of the Senegal River. Invertebrates whose life cycles are tied to estuarine conditions include the crab, Callinectes spp., and the shrimp, Penaeus duorarum.

To allow a comparison with projected changes in the fishery expected to result from Basin development, present, annual fish harvests have been

estimated for existing habitats and for sections of the Basin above and below proposed dam sites in which new aquatic habitats will be created. These areas include:

a) Lac de Guiers - Based upon an average surface area of 22,500 hectares and an annual harvest of 100 kilograms per hectare per year, this body of water provides 2250 metric tons of fish annually for consumption.

b) Lac R'Kiz - Under present conditions, little or no fish are harvested from this body of water. In December 1977 it contained no water.

c) Aftout es Sahel - When observed in 1977, two 25-hectare ponds existed, providing an estimated five metric tons of fish annually.

d) Upstream of the Proposed Diama Dam (Upper Delta) - Present fish harvests average 7500 metric tons per year.

e) Estuary (Lower Delta) - An average of 4000 metric tons of fish and shellfish are harvested yearly from this portion of the river.

f) Upstream of the Proposed Manantali Dam Site - At present a small unquantifiable but significant amount of fish is harvested in the Bafing River for consumption by the fishermen and their families.

g) Floodplains - Assuming an average inundation of 550,000 hectares of floodplains with an annual harvest of 60 kilograms per hectare per year, 33,000 metric tons of fish are harvested yearly.

The average annual per capita consumption of fish in kilograms (kg/c/yr) within the Senegal River Basin presently and projected for the year 2000 is respectively 58 and 67 kg/c/yr in Senegal, 15 and 22 kg/c/yr in Mauritania and 15 and 15 kg/c/yr in Mali. This study projects a total annual demand for fish of 48,000 metric tons presently, 110,930 metric tons by 2000, and 240,000 metric tons by 2028. This increased demand can be attributed to increased annual per capita consumption but more importantly to the rapidly expanding

Table C.10 - 1

Annual Fish Harvests in the Senegal River Basin Before and After Various Levels of Proposed Development, Assuming an Average Flood.

Year	Lac de Guiers	Lac R' Kiz	Aftout-es-Sahel	Diama Reservoir	Senegal River Estuary	Manantali Reservoir	Floodplain	Total
	Metric Tons of Fresh Fish Per Year							
1978[1]	2,250	---	5	7,500	4,000	---	33,000	46,755
1986[2]	2,750	1,200	5,000	4,500	(7)	---	31,800	45,250
1987[3]	2,750	1,200	5,000	4,500	(7)	4,000	20,400	37,850
2002[4]	2,750	1,200	5,000	4,500	(7)	3,000	19,200	35,650
2003[5]	2,750	1,200	5,000	4,500	(7)	3,000	13,800	30,250
2028[6]	2,750	1,200	5,000	4,500	(7)	3,000	11,400	27,850

1) Present Conditions.

2) Diama Dam complete. Estuary fishery is lost; increase in harvests occurs due to recharge of natural impoundments, some floodplain area is lost due to agricultural development.

3) Manantali complete. Significant loss in floodplain fishery due to artificial flood and continued agricultural development.

4) Same as in 1987 with continual loss of floodplains due to agricultural development.

5) Discontinuing artificial flood results in significant loss of floodplains area.

6) Same as 2003 with continued loss of floodplain area due to agricultural development.

(7) Estuary fishery as it presently exists will be destroyed.

population of the Basin which is projected to increase from its presently estimated size of 1.7 million to 2.9 million by 2000 and to 6.3 million inhabitants by 2028.

C.10.1.2. Distribution of Marine Fish to the Senegal River Basin

In addition to fish supplied from the sources mentioned above, fishes of marine origin are marketed in the Senegal River Basin primarily from the artisanal fishing centers of St.-Louis, Kayar, Yoff, Soumbedioune, Rufisque, Mbour, Joal and Djifere. The 1976 statistics, provided by the Direction de l'Oceanographie et des Peches Maritimes (D.O.P.M.) of Senegal, indicate an annual artisanal catch of 181,500 metric tons. F.A.O. statistics for 1977 indicate a catch of 120,000 metric tons, while D.O.P.M. records show 138,400 metric tons harvested from artisanal fishing. Of these annual harvests, D.O.P.M. indicates a sale of 28,100 metric tons in 1976 and 12,770 metric tons in 1977 to the Senegal River Basin. A small percentage of these annual sales originate from the industrial fishery but are not separable from the above statistical information, (Personal Communication with Dr. Bernard Dioh, Fishery Expert, D.O.P.M., April 1979). At present, marine fish distributed from Mauritania into the Senegal River Basin are of minor importance (Personal Communications, Traore 1977).

C.10.2. Impacts on the Fishery from Proposed Development

C.10.2.1. Impacts on the Senegal River Fishery

Proposed developments, particularly the construction of the Diama and Manantali dams, and initiation of intensive irrigation agriculture, will have the net effect of permanently altering the aquatic environment. It is estimated that a permanent deficit in annual riverine fish harvests will occur, with harvests progressively decreasing between 1979 and 2028 (Table C.10-2). This decrease will occur in steps paralleling various stages of development in the Senegal River Basin. The gains and losses in annual fish harvests have been compared for the various Basin areas. The following briefly states the assumptions made in deriving future fish harvests.

Table C.10 - 2

Net Gains and Losses of Fish in the Senegal River Basin Under Various Levels of Proposed Development, Assuming an Average Flood

Year	Metric Tons of Fresh Fish Per Year								% Loss of 1978 Fish harvest (52,755 m tons)
	Lac de Guiers	Lac R' Kiz	Aftout-es-Sahel	Diama Reservoir	Downstream of Diama Dam	Manantali Reservoir	Floodplain	Total	
1978	-	-	-	-	-	-	-	-	
1986	+500	+1,200	+5,000	-3,000	-4,000	-	-1,200	-1,500	3
1987	+500	+1,200	+5,000	-3,000	-4,000	+4,000	-12,600	-8,900	17
2002	+500	+1,200	+5,000	-3,000	-4,000	+3,000	-13,800	-11,100	21
2003	+500	+1,200	+5,000	-3,000	-4,000	+3,000	-19,200	-16,500	31
2028	+500	+1,200	+5,000	-3,000	-4,000	+3,000	-21,600	-18,900	36

a) Lac de Guiers - Increased recharge potential after construction of the Diama dam will enlarge the average surface area of the lake to 27,000 hectares. This will create additional aquatic habitat which will result in an increase of fish biomass, raising the potential annual harvest to 2750 metric tons. This will provide a net annual gain of 500 metric tons of fish for consumption.

b) Lac R'Kiz - An average inundated surface area of 16,000 hectares will result from improved recharge. It is projected that 1200 metric tons of fish could be harvested annually from this body of water.

c) Aftout es Sahel - With an average inundated surface area of 50,000 hectares from improved recharge, this area will create a stable aquatic environment with projected annual fish harvests of 5,000 metric tons of fish. This could result in a net annual gain of approximately 5000 metric tons of fish. High salinities could limit the development of a prolific fishery.

d) Upstream of the Diama Dam - Construction of the Diama dam will create a freshwater impoundment with an average surface area of 45,000 hectares. A maximum annual harvest of 4500 metric tons of fish is projected for this impoundment. Compared to present conditions, this area is analogous to the Upper Delta, which averages 7500 metric tons of harvested fish each year. Therefore, this area will be subject to a net annual loss of 3000 metric tons of harvestable fish.

e) Estuary - Construction of the Diama dam will result in a modified salinity regime. The length of the estuary and the salinity gradient per kilometer of estuary will be reduced, decreasing available estuarine habitat. During April, May and June, even with the Manantali dam in operation, salinity concentrations below the Diama dam may fail to drop below 10-15 parts per thousand. Reduced habitat will result in decreased fish biomass in the lower Delta. Additionally, estuarine and ocean fishes, whose life cycles require lowered salinities or freshwater, will disappear. Existing salt tolerant species will become predominant and new species presently not found in the estuary may take up residence in the newly formed habitats. It is expected

that the harvest of these fish will provide some employment and fish for local consumption. This study projects a net annual loss of 4000 metric tons of harvestable fish as a result of destruction of the estuarine fishery as it is presently known.

f) Manantali Dam - The proposed dam will create an impounded area of between 45,000 and 50,000 hectares. With an area of 50,000 hectares, and under the assumption that 80 kilograms per hectare per year of fish will be harvested in the newly formed impoundment, 4000 metric tons of fish will be caught annually. As nutrients become tied up in the bottom mud and the impoundment takes on mesotrophic characteristics, the annual harvest will fall to about 60 kilograms per hectare per year, providing 3000 metric tons of fish for consumption. It is expected that various cichlids, especially the genera of Tilapia and Sarotherodon, will become predominant in the newly developed commercial fishery.

g) Floodplains - By 1986, loss of 20,000 hectares of floodplain habitat from construction of the Diama dam and agricultural development will result in a yearly loss of 1200 metric tons of fish. With completion of the Manantali dam and artifical regulation of the flood crest in 1987, approximately 12,600 metric tons of harvestable fish will be lost from further elimination of floodplain habitat. By 2003, continued loss of floodplains from agricultural development and elimination of the artificial flood will destroy additional fish habitat, resulting in an annual loss of 19,200 metric tons of harvestable fish. Under maximum agricultural development, there will be an average loss of 360,000 hectares of floodplain habitat in 2028, resulting in a corresponding reduction of annual fish harvests that will average 11,400 metric tons, compared to the present annual harvest of 33,000 metric tons. This will result in a net annual loss of 21,600 metric tons of harvestable fish from the Senegal River by 2028.

C.10.2.2. Impacts on Future Fish Consumption

The need for consumable fish in the Senegal River Basin will increase as a result of rising per capita demands and as a result of increased population

densities throughout all zones of the Basin (Table C.10-3). Based upon riverine fish harvests in the Senegal River Basin, a deficit in fish available for consumption within the Basin is projected to occur in 1980 and may be occurring at present in the zones of Dagana and Rosso (Table C.10-4). This is not considered critical since it is assumed that a large part, if not all, of this deficit is accounted for with ocean fishes. Decreasing freshwater and estuarine fish harvests, as a result of habitat destruction from development, and continually rising demands for consumable fish will result in a net deficit of 75,280 metric tons of fish by the year 2000 and a deficit of 212,268 metric tons per year by 2028 (Table C.10-4). No attempt has been made to account for fish losses between harvesting and marketing due to poor preservation, storage and transportation. If this was accounted for, projected deficits could be even higher.

C.10.3. Proposed Mitigating Measures

C.10.3.1. Decrease in Annual Fish Harvests and Increasing Demands for Consumable Fish

A workable solution to alleviation of permanent decreases in the annual fish harvest is to develop an integrated program, combining exploitation of the marine fishery, improved preservation and storage techniques, an improved transportation network, an integrated agriculture/fish culture program, and employment of proper management techniques. The immediate short-term solution to the projected fish deficit is to increase off-shore exploitation of the marine fishery and to transport increasing quantities of these fish inland. A fishing pier, ice house and processing facility has been recently constructed at St.-Louis. Completion of the entry channel into the estuary will allow access of a commercial fishing fleet into the port. The expansion of the commercial marine fishery at the ports of St.-Louis, Dakar, Dijifer and Elinkin in Senegal is projected to produce 245,500 metric tons of marketable fish annually. Mauritania is also developing a commercial fishery, and has recently updated industrial fishing facilities at Nouadihbou. The developing industrial and artisanal fisheries should be able to supply increasing quantities of fish to inland markets, including the Senegal River Basin.

Table C.10 - 3

Present and Future Fish Demands with Implementation of the Proposed Development Program in the Senegal River Basin

Zone	Population[i] 1980	1980 Fish Consumption metric tons/year	Population[i] 2000	2000 Fish Demand Metric tons/year	Population[i] 2028	2028 Fish Demand[h] Metric tons/year
1 Dagana	230,000	13,800[a]	504,400	34,000[e]	1,130,900	76,200[e]
2 Podor	157,200	8,820[b]	277,000	18,700[e]	590,500	39,800
3 Matam	178,500	10,000[b]	305,300	20,600[e]	654,500	44,100
4 Bakel	30,400	390[c]	51,200	3,450[e]	104,300	7,030
5 Rosso	241,300	3,620[d]	384,700	8,460[f]	809,700	17,800
6 Boghe	167,700	2,520[d]	272,800	6,000[f]	568,300	12,500
7 Kaedi	179,500	2,690[d]	289,500	3,370[f]	564,600	12,400
8 Selibabi	104,900	1,570[d]	165,400	3,640[f]	384,400	7,670
9 Kayes	249,500	3,590[d]	446,500	6,700[g]	1,036,700	15,600
10 Bafoulabe	120,500	1,810[d]	204,300	3,060[g]	466,600	7,000
Total	1,649,500	48,800	2,901,100	110,900	6,274,500	240,100

a) 59.9 kg/capita/yr
b) 56.1 kg/capita/yr
c) 13 kg/capita/yr
d) 15 kg/capita/yr
e) 67.4 kg/capita/yr
f) 22 kg/capita/yr
g) 15 kg/capita/yr
h) Assume fish demand per capita in the year 2028 same as the year 2000.
i) Population figures garnered from the Socio-Economic Report by combining future urban population with the OMVS Program and DeSure Population Projections.

Table C.10 - 4

Fish Demand Versus Availability of Riverine Fish with Implementation of the Proposed Development Program in the Senegal River Basin in Metric Tons Per Year for an Average Flood

Year	Item	Lower Valley[a]	Middle Valley[b]	Upper Valley[c]	Total
1980	Fish Demand	17,400	29,600	1,080	48,080
	Predicted Fish Harvest	4,500[d]	42,750[e]	(f)	47,250
	Gain (+) or Deficit (-)	-12,900	+13,150	(f)	+250
2000	Fish Demand	42,460	65,410	3,060	110,930
	Predicted Fish Harvest	5,000[d]	27,650[e]	3,000[f]	35,650
	Gain (+) or Deficit (-)	-37,460	-37,760	-60	-75,280
2003	Fish Demand	94,040	139,080	7,000	240,120
	Predicted Fish Harvest	5,000[d]	19,850[e]	3,000[f]	27,850
	Gain (+) or Deficit (-)	-89,040	-119,230	-4,000	-212,270

a) Lower Valley includes the zones of Dagana and Rosso.

b) Middle Valley includes the zones of Podor, Matam, Bakel, Boghe, Kaedi, Selibabi, and Kayes.

c) Upper Valley includes the zone of Bafoulabe.

d) Includes Fish harvests from the estuary and Aftout-es-Sahel.

e) Includes fish harvests from Lac de Guiers, Lac R' Kiz, the Diama Reservoir and the floodplain.

f) Includes fish harvests from the Manantali Area; not enough information is available to predict harvests in 1980.

Thought should be given to developing a low cost nutrient source from the incidental catches of the industrial fishery. These catches consist of fish caught by the industrial fleets that are of little commercial value. It is possible that these fish could be processed into fish cakes, or meal, and sold at local markets.

The success of providing increased quantities of marine fish inland assumes that transportation systems will be improved. At present, an all-weather road is being constructed between Matam and Bakel. Continued improvements such as this, along with the institution of proper road maintenance procedures, should provide easy access to the ocean fishery as a source of protein.

In many developing countries a large source of potential protein is lost due to poor fish storage and preservation techniques. It has been estimated for other inland fisheries of Africa that 50 to 70 percent of the fish are lost between the time of harvesting and marketing, primarily from bacterial degradation and insect infestation with eggs and larvae. This is often the result of improper smoking, salting or other drying techniques. By assuring proper preservation, sanitary storage and proper transportation could prevent losses of harvested fish and greatly compensate for the expected deficit that will otherwise occur from development.

To assure the adoption of these techniques and construction of proper storage facilities and ice plants along the major fishery routes, an extension service should be established by the various Member States to act as a liaison between the fishing community and the latest available technology. This will require proper training and education of governmental personnel. Research efforts by such institutions as the Eaux et Forets of the Member States and Gaston Berger University should provide proper training and extension services to the fishermen (both marine and freshwater), the processors, distributors and merchandizers. It is only through integrated efforts between the governments, educational institutions, and the private sector, that an improved fishery can be achieved.

In addition to improving the fishery, the loss of fish harvests due to proposed development will be partially mitigated by the projected increase in agricultural products. This will offset the projected deficit in protein, fat and calories from the decreased availability of riverine fishes for consumption by Basin residents. This produce will be primarily in the form of rice, wheat, corn, sorghum, beans, livestock, and a variety of vegetables and fruits.

Integrated into this program of intensive irrigation agriculture, fish culture can provide an additional nutritional supplement. Agricultural by-products such as rice or wheat hulls (which often go to waste) can be formulated into a food supplement for pond-raised fish. Cattle and poultry manure can be introduced into fish ponds to increase planktonic biomass as a natural source of fish food. The success of such a program will require the support of a well financed organization. At present, a Senegalese Government/ U.S. Peace Corps/USAID fish culture program is being integrated into the existing agricultural program. Eaux et Forets in Senegal and the Peace Corps are developing a research station and raising breeding stocks of fish (probably Tilapia spp.) for commercial ponds that will be located on SAED-operated agricultural perimeters. Similar operations may be established in Mauritania, and possibly Mali where cage culture in the Manantali impoundment could prove successful.

Additionally, fishery habitat could be created by artificial recharge of waterways and depressions. As an example, in Senegal this would consist of recharging the Ndiaels (also recommended as a possible bird sanctuary), Mengueye and portions of the lower Ferlo Valley. It is recommended that a feasibility study be conducted throughout the Basin to investigate areas of potential recharge that could benefit aquatic life.

In conjunction with these activities and the expected increase in fish demand by the ever-growing populations, a management program of the existing freshwater fishery should be initiated. This will require trained scientists and economists to study fish catches, fish distributions and fishery demands throughout the Basin. Harmonization of existing laws between Member States

under O.M.V.S. coordination, and enforcement of these laws, should be immediately initiated in order to assure maximum sustained yields of fish. Attempts should be made to better understand the new fisheries expected to develop behind the Diama dam, Manantali dam, Lac R'Kiz and Aftout es Sahel. Proper management of these impoundments will provide a steady supply of fish in outlying areas of the River Basin.

C.10.3.2. Mitigating Loss of the Estuary

The destruction of the estuary in the Lower Delta and its related fishery could be mitigated by diverting freshwater from the Diama reservoir via a canal into the Tianbrank-Diaouling Lakes, creating a salinity gradient through which catadromous and anadromous fish and invertebrates could complete their life cycles. It has been estimated that it would cost 675 million CFA to construct a three kilometer canal from Debi on the Senegal River to the Tianbrank-Diaouling complex. From an environmental point of view, if successful, the artificial estuary would be considered beneficial regardless of costs, because it would prevent the irreversible destruction of aquatic life whose life cycles are tied to the estuarine environment. Its biological and engineering feasibilities must be further investigated. Although preliminary estimates indicate this measure to be economically feasible, more in-depth analyses should be undertaken before a final decision is made as to its cost efficiency.

Table C.10 - 5

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Fisheries

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Diama Dam	Recharge of Lac de Guiers	Increase in annual fish harvest by 500 metric tons	Moderate, beneficial, long-term, year-round	Improved preservation and storage techniques. Improved transportation. Proper management techniques.
	Recharge of Lac R' Kiz	Increase in fish harvested by 600-1200 metric tons yearly	Exceptional, beneficial, long-term, year-round.	Same as above.
	Recharge of Aftout-es-Sahel	Net gain of 5000 net metric tons of fish annually	Same as above.	Same as above.
	Impoundment upstream of dam	Net annual loss of 3000 metric tons of fish	Severe, adverse, long-term, year-round	Exploitation of marine fishery. Improved preservation and storage techniques. Improved transportation. Integrated agriculture/fish culture. Proper management techniques.
	Estuary	Permanent loss of 4000 metric tons of fish annually from loss of salinity regime and other estuarine conditions. Permanent loss of commercially valuable fish and invertebrate species	Severe, adverse, long-term, year-round	Same as above and establish an artificial estuary.
Manantali Dam	Upstream of Impoundment	Creation of new habitat initially providing 4000 metric tons of fish per year, later falling to 3000 metric tons per year as conditions stabilize	Severe, beneficial, long-term, year-round	Improved preservation and storage techniques. Improved transportation. culture. Proper management techniques.

Table C.10 - 5 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Fisheries

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Diama Dam and Irrigation Agriculture	Reduced inundation of flood plain habitat	Loss of 1200 metric tons of fish annually by 1986 during average flood from loss of 20,000 hectares of floodplain	Severe, adverse, long-term, year-round	Exploitation of marine fishery. Improved preservation and storage techniques. Improved transportation. Integrated agriculture/fish culture. Proper management techniques.
Diama and Manantali Dams and Artificial Flood Irrigation Agriculture	Increasing reduction in floodplain habitat	By 1987, loss of 12,600 metric tons of fish annually from loss of 210,000 hectares of floodplain habitat for average flood	Severe, adverse, long-term, year-round	Exploitation of marine fishery. Improved preservation and storage techniques. Improved transportation. Integrated agriculture/fish culture. Proper management techniques.
Diama Dam, Manantali Dam and elimination of artificial flood and maximum agriculture development	Maximum loss of flood-plain habitat	(Average flood) By 2028, loss of 360,000 hectares of flood-plain habitat resulting in an annual loss of 21,600 metric tons of harvestable fish	Severe, adverse, long-term, year-round	Exploitation of marine fishery. Improved preservation and storage techniques. Improved transportation. Integrated agriculture/fish culture. Proper management techniques.
Manantali Dam, Diama Dam & Agricultural Development	Decreased fish habitat, increasing populations and demands for fish as a nutritional source	By 1980, under ideal conditions a deficit of 7400 metric tons of fresh water and estuarine fish will occur in Dagana and Rosso zones. Demand for fish for consumption by the Basin population will increase throughout the Senegal River Basin to 75,000 metric tons by the year 2000 and 212,000 metric tons/yr. by 2028	Severe, adverse, long-term, year-round	Exploitation of marine fishery Improved preservation and storage techniques. Improved transportation. Integrated agriculture/fish culture. Proper management techniques.

C.11. Aquatic Vegetation

C.11.1. Existing Conditions

The Senegal River and Lac de Guiers support over 50 species of higher aquatic vegetation. In the Senegal River itself, water level fluctuations, flood water velocities, and high flood season turbidities limit aquatic plant growth. Plants thrive in Lac de Guiers, the marigots and floodplain depressions during the flood season. Higher aquatic plants are also abundant in canals within irrigated agricultural perimeters. Most of the aquatic vegetation found in the Senegal River are rooted plants. Thirty of these species of rooted aquatic plants can tolerate dry-season salinity concentrations found in the Delta. Nearly 20 species of rooted aquatic plants have been identified in Lac de Guiers. Floating aquatic plants are most abundant in Lac de Guiers and floodplain marigots, where the lack of strong currents encourages a moderate growth of these plants. The dominant floating plant species is Pistia. In Lac de Guiers, the highest Pistia population densities occur during and immediately following the recharge period.

Higher aquatic plants play an important role in the ecology of the Senegal River Basin. Emergent vegetation along the marshy edges of water bodies provides important habitat for a variety of bird life and semi-aquatic wildlife including mammals, reptiles and amphibians. Habitat is also provided by aquatic plants for fish breeding, as a nursery and for refuge, being especially important in the seasonally inundated floodplains of the Senegal River.

Floating and rooted aquatic plants provide habitat for a variety of invertebrates that act as important sources of food for fish. Certain species of aquatic plants as Ceratophyllum, Nymphea and Pistia provide habitat for the snail vector of schistosomiasis. These plants, along with epiphytic algae and phytoplankton also act directly as food for some species of fish. Plankton populations in the Senegal River Basin play an important role in the aquatic food chain, as evidenced by the important Tilapia fishery (planktiverous fish) in Lac de Guiers.

Observations

a) Higher aquatic plants in the Basin are restricted during much of the year to permanent quiescent bodies of water such as Lac de Guiers, Aftout es Sahel and Djoudj Park. Higher aquatic plants are most prolific during the rainy season, covering large areas of the inundated floodplains.

b) Water level fluctuations, wave action and turbidity limit higher aquatic plants to the edge of Lac de Guiers. At times, Pistia reach nuisance levels, affecting fishing and artisanal navigation activities.

c) Observations made during this study indicate that higher aquatic plants block flows in irrigation canals, and result in water losses from transpiration that might otherwise be used for irrigation.

d) Plankton, during the dry season, is abundant in quiescent water bodies such as Lac de Guiers, Aftout es Sahel and Djoudj Park and in the trapped pools of water of the main river channel.

e) During the wet season, high flows and increased turbidity reduce plankton populations in the main river channel. At this time, plankton populations play a major role in supplying oxygen and food to the floodplain fishery in the Basin.

C.11.2. Impacts of Proposed Developments

Beneficial Impacts

a) Phytoplankton will play an increasingly important role behind the Diama and Manantali dams in providing oxygen to the water column, and in acting as a source of fish food.

b) Wind and wave action will restrict development of nuisance levels of floating aquatic plants or mats of floating plants (Sudds) on the open waters of the Manantali.

c) Water level fluctuations along the shoreline of the Manantali reservoir will restrict the growth of rooted aquatic plants that could harbor the snail vectors of schistosomiasis.

d) Emergent vegetation along the increased shorelines of the Manantali and Diama dams, the Aftout es Sahel and Lac R'Kiz will provide important wildlife and bird habitat.

e) A major portion of the Diama reservoir (averaging less than 0.3 meters outside the main channel at the 1.5 meter IGN level) and the increased recharge of Lac de Guiers, Aftout es Sahel and Lac R'Kiz will provide excellent year-round habitat for the proliferation of higher aquatic plants and plankton.

Adverse Impacts

a) The increase in aquatic plant habitat discussed above can in no way compare to the total biomass of plants lost in the Middle Valley from a projected 2028 decrease of up to 359,000 hectares of floodplain habitat for an average flood as the result of Basin development. This in turn will have a major adverse impact on the annual fish biomass available for harvest in the Basin.

b) Floating aquatic plants may reach nuisance levels in the protected dendritic arms of the Manantali reservoir.

c) Increased nutrient levels downstream of agricultural, municipal and industrial activities could result in elevated levels of aquatic plant and plankton populations.

d) If uncontrolled, aquatic plants at irrigated perimeters will reach nuisance levels, decreasing the performance of irrigation canals as well as providing habitat for disease vectors, in turn affecting the health of agricultural workers.

An increase in the numbers of aquatic plants in certain areas can be considered beneficial or adverse to the environment. In addition to reoxygenating water, aquatic plant communities provide food and habitat to aquatic and terrestrial life forms that depend directly on aquatic plants for survival. Conversely, adverse impacts may result from aquatic plants if their densities become so large that they constrain movement of aquatic organisms, inhibit light penetration thereby decreasing primary production, adversely affect nutrient availability to other aquatic life forms, or reduce dissolved oxygen concentrations when their vegetational parts die and decay. Other adverse impacts that could result from such aquatic plant population increases are those that affect human use of the water. Although a general increase in the size of aquatic plant populations is predicted, there is no reason to believe that this increase will, apart from some isolated and localized nuisance problems, interfere with man's utilization of the Senegal River resources if proper mitigative actions are taken.

C.11.3. Proposed Mitigating Measures

In the near future, no mitigating measures are recommended, except for periodic monitoring of aquatic vegetational development throughout the Senegal River Basin. Monitoring serves the purpose of providing an early warning so that proper mitigative actions can be taken before nuisance problems develop. Details of the monitoring system for aquatic vegetation are presented in the overall plan of action.

Various mitigating measures that could be taken to alleviate nuisance problems before they occur include:

a) Intentional water level fluctuations in the Manantali and Diama reservoirs, Lac de Guiers, Lac R'Kiz, and the Aftout es Sahel to destroy rooted aquatic plant communities thriving on the shorelines of these water bodies. Such a measure should be only considered if other water uses are not impaired.

b) The diversion of agricultural return flows onto planned tree farms rather than into the Senegal River. This measure would reduce inputs of nutrients to the river that encourage growth of aquatic vegetation. At the same time, diversion of these waters to the floodplain could enhance the growth of trees within and adjacent to irrigated perimeters.

c) Elimination of aquatic plants from irrigation and drainage canals can be achieved by lining the canals.

d) Physical removal of aquatic plants. This measure is, of course, possible only on a limited scale, as for control of aquatic plants in irrigation ditches, but is environmentally safe.

e) Utilization of herbicides to kill aquatic plants. Application of chemicals to eliminate aquatic plants in itself can lead to environmental damages. Therefore, the use of herbicides for aquatic vegetation control should be considered only as a last resort to alleviate severe and localized problems.

Table C.11 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Aquatic Vegetation

Component	Factor Creating Impact	Impact Description	Magnitude	Mitigating Measure to discourage growth
Diama Dam	Creation or extension of Diama Reservoir, Lac R'Kiz, Aftout-es-Sahel, and Lac de Guiers.	Provision of extended environment for growth of aquatic plants	Moderate, encouraging growth, long-term	Intentional water level fluctuations to control shore growth, if necessary.
	Creation of a barrier against salt water intrusion.	Creation of fresh water condition upstream of Diama Dam leading to more favorable conditions for plant growth.	Light to severe, encouraging growth, long-term	*
		Change in aquatic plant species between Diama and Dagana.	Light, long-term	None
Manantali Dam	Creation of water impoundment.	Provisions of extended environment for growth of aquatic plants.	Moderate, encouraging growth, long-term	Intentional water level fluctuations to control growth, if necessary.
	Flow regulation.	Creation of a more steady water level in Senegal River leading to more favorable conditions for plant growth.	Light, encouraging growth, long-term	*
Manantali Dam and Agricultural Development	Flow regulation and perimeter development.	Loss of floodplain area immediately leading to unfavorable conditions for aquatic plants.	Moderate, discouraging growth, long-term	None
Agricultural Development	Return flows to the river from perimeters.	Increased supply of nutrients favorable for plant growth.	Light, encouraging growth, long-term	Direct return flows to floodplain.
	Existence of irrigation and drainage areas.	Extended environment for aquatic plants	Growth encouraging, light to moderate depending on mitigating measures, adverse for canal maintenance and long-term	Canal lining and/or periodic removal of accumulated plants.
Municipal and Industrial Development	Waste disposal into waterways.	Increased supply of nutrients favorable for plant growth.	Light, encouraging growth, long-term	*

*Only monitoring of aquatic vegetation development is recommended in the near future. Removal of aquatic vegetation should be considered, if nuisance problems arise.

C.12. Forestry

C.12.1 Existing Conditions

Three forest types are distinguishable in the Senegal River Basin's classified (managed) and unclassified forests. These forests are gonakie, dieri and upland savanna. The gonakie forests grow on river banks and in depressions innundated during annual floods. These forests cover approximately 50,000 hectares of land on both sides of the Senegal River or 0.17 percent of the surface area in the River Basin. They are well suited to prolonged flooding and to the soils within the floodplain. These gonakie forests are not found in Mali.

Dieri forests are multitypic, consisting of a variety of species. Dieri forests are much lower in productivity than gonakie forests. Approximately 15,000 hectares of nonclassified dieri forests exist in the study area. There are no classified dieri forests. The dieri forests require less water and grow in rainfed locations receiving less than 500 mm of rainfall per year, primarily areas located downstream of Bakel.

Upland forest savanna in the Senegal River Basin is found in the dry uplands of the Sudan vegetational zone of Mali. Due to the higher rain-fall (1200 mm) in these areas than in the River Valley or Delta, species composition is more varied than in the other two forest types, however these upland forests have little commercial value. Frequent and widespread burning of the tall annual grasses by herdsmen has had a detrimental effect on the survival of trees in upland areas.

In the Fleuve Region of Senegal, based on 1972 statistics, there are approximately 25,500 hectares of classified forests and 9100 hectares of nonclassified forests, of which 26,000 hectares are of the gonakie type. Based on 1972 statistics, in the Fleuve region of Mauritania there are approximately 20,200 hectares of classified forests and 6000 hectares of nonclassified forests, of which 24,000 hectares are of the gonakie type.

The gonakie forest, dominated by the Acacia tree, is the most valuable of the three forest types because of its commercial use as firewood or charcoal. The growth rate of the Acacia trees varies from two to four cubic meters/ha-yr, while growth rates in dieri forests total 0.2 cubic meters/ha-yr. Tree volumes measured in this study's field investigation included 3.5 cubic meters per hectare in the dieri forest at Diama, 10.3 cubic meters per hectare in the savanna at Manantali, and 130 cubic meters per hectare in older gonakie forests. Uses of forest lands include:

a) Commercial exploitation, primarily for fuel;

b) Source of habitat and food for various terrestrial life forms;

c) Animal grazing and browzing;

d) Use and exportation of raw materials such as gum arabic and certain seed pods;

e) Brush for constructing fences;

f) Obstacle to desert encroachment by enhancing moisture penetration, nutrient recycling and wind protection of soils.

While Senegal and Mali have other regions besides the Senegal River Basin that provide forests, Mauritania has no available forests outside the Basin.

Between 1-1.5 steres (0.4-0.6 tons) of firewood are required yearly per person in the Senegal River Basin. Because carefully managed classified gonakie forests cannot supply this need, dieri forests have been rapidly over-exploited. Recent increases in firewood and charcoal availability have been attributed to the increase in dead and dying trees on classified forests. Over-flights by the study team, indicate approximately 33 percent and 43 percent, respectively, of the classified gonakie forests in Senegal and Mauritania between Rosso and Matam have been killed by drought between 1972 and 1977. Fuelwood production in the river region of Senegal in 1977 was

one-sixth the 1976 production as availability of dying or dead trees declined following the drought. This lost timber is not being replaced, greatly reducing the productivity of these forests.

Next to drought, fire is the major enemy of forests in the Senegal River Basin. The annual burning of land for fertilizer generation often results in a fire invading forest areas and thus seriously hampering forest growth. Overbrowzing by livestock is another major destroyer of forests.

C.12.2. Impacts of Proposed Developments

The most significant forestry-related impacts will be due to flow regulation from the Manantali dam, agricultural development, and municipal and industrial development within the floodplain. These developments will have the greatest adverse impact on the commercially-valuable gonakie forests that predominate in the Valley. In the future, for an average-size flood, less floodplain surface area will be inundated and water levels will be lower. This means that, on the average, certain underdeveloped areas will not have as much water available for uptake by trees. This is projected to result in the loss of approximately 7600 hectares of the remaining 37,900 hectares of occasionally flooded gonakie forests which represents a volume loss of 1,817,000 steres of firewood. These losses are much less than losses due to drought and over-browzing by livestock. This impact, combined with the permanent loss of forests from inundation behind the impoundments, and conversion of forested areas into agricultural perimeters and population centers will tend to reduce the amount of land covered with forests in the Basin.

Approximately 1000 hectares (255,000 steres of firewood) of yearly flooded gonakie forest will be lost in the area to be inundated behind the Diama dam. Approximately 700 hectares of productive fringe forests along the Bafing River and 42,900 hectares of less productive, open forest are predicted to be permanently lost from inundation behind the Manantali dam. In addition, forests in the vicinity of the dams affected by construction activities will be lost for at least one growing cycle.

Two impacts of the proposed developmental activities are predicted to enhance growths of forests in areas adjacent to the Diama and Manantali impoundments and the River channel. The prevention of salt water intrusion upstream of Diama in combination with higher dry-season water levels behind the dam will allow more non-saline water to infiltrate the soil that will encircle the impoundment. Such an increased availability of non-saline water should enhance tree growth within three to five kilometers of the Diama impoundment. In the same manner, increased water levels both behind the Manantali dam, and along the River channel in the floodplain during the dry season are predicted to enhance tree growth adjacent to permanently inundated areas.

The net impact of proposed developments on forest resources, however, is predicted to be adverse. In addition to impacts of the proposed developments themselves, the demand for wood within the Basin is expected to intensify due to projected population increases within the Basin. Increased utilization of forest resources, especially in the lower reaches of the Senegal River Basin, if not properly managed, will lead to the eventual destruction of an already seriously depleted resource.

C.12.3. Proposed Mitigating Measures

The magnitudes of most impacts from proposed developments on forest resources depend on the type and extent of mitigating measures used to conserve and wisely exploit forest resources.

A plan of action designed to provide maximum usage of forests by man and other life forms should emphasize the following activities:

a) Harvesting and use of commercially-valuable forests behind the Diama and Manantali dams, and at irrigated perimeters before these areas are permanently unavailable for forestry exploitation;

b) Artificial generation of trees surrounding the two impoundments, along the river channel in the Valley and surrounding agricultural perimeters once individual developments are in place;

c) Land use planning that locates future perimeters and population centers around the Basin's forestry resources;

d) Harmonization and improved enforcement of existing forest protection laws;

e) Development of a forestry extension program together with the training of extension agents.

Table C.12 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Forestry

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Diama Dam	Creation of barrier to salt-water intrusion.	Improvement of water quality in aquifer, resulting in improved conditions for forest growth.	Light, beneficial, long-term	Better management and protection of forests. Proper land-use management practices.
	Construction activities.	Loss of trees in Diama Dam area.	Light, adverse, short-term, (one growing cycle)	Same as above.
	Inundation behind Diama Dam.	Permanent loss of approximately 1000 ha. of gonakie forest	Moderate, adverse, long-term	Harvesting of forests in areas to be inundated.
		Increased potential for forest growth in areas surrounding impoundment.	Beneficial, long-term, depending on mitigating measure	Afforestation of areas surrounding impoundment with fast-growing species. Proper forestry management.
Manantali Dam	Creation of impoundment	Permanent loss from inundation of approximately 700 hectares of "productive forest" and 47,000 ha. of "open forest"; simultaneous increase in size of forest area surrounding impoundment.	Moderate, net impact could be beneficial or adverse, long-term and year-round	Harvesting of productive forest prior to inundation. Implementation of forestry management and land-use practices. Setting aside additional forests as national parks.
	Construction activities	Loss of trees in vicinity of Manantali dam.	Light, adverse, short-term and year-round	Afforestation of area surrounding impoundment once the dam is in place if forest area is to be commercially exploited.
Manantali Dam Agricultural Development	Flow regulation in conjuction with construction of agricultural perimeters.	Permanent losses of gonakie forests occasionally flooded and dieri forests.	Long-term and year-round. Magnitude depends on implementation of mitigating measures	Land use planning. Afforestation of newly flooded areas with fast growing species. Use of nutrient rich agricultural drainage waters to irrigate tree farms.

Table C.12 - 1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Forestry

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Agricultural Development	Irrigation of 255,000 ha. of agricultural land by 2028.	Loss of forest at perimeters; gain in forest surrounding perimeters.	Adverse, long-term and year-round.	Planning of locations of future perimeters and population centers that considers forest resources. Development of tree farms, irrigation with nutrient rich agricultural drainage waters.
Municipal-industrial Development	Development of land for municipalities and industries.	Loss of forest in areas to be developed as municipalities.	Magnitude depends on implementation of mitigating measures.	Afforestation of areas surrounding.
Navigation	Dredge spoil disposal onto forest land.	Inhibited forest growth.	Moderate, adverse, short-term	Avoid dredge spoil disposal on forest lands.

C.13. Mammalogy and Herpetology

C.13.1. Existing Conditions

During the past several decades, a decline in wildlife populations throughout much of West Africa has been witnessed. Drought, habitat destruction by man and his livestock, and, to a lesser degree, hunting are the primary reasons for this decline.

Wildlife habitat in the Senegal River Basin is largely affected by variations in topography and rainfall, which influence the distribution and diversity of vegetational types.

Superimposed upon these geographical determinants are land use practices by man, especially in the Lower and Middle Valleys of the Basin, which have resulted in degraded wildlife habitat throughout much of the region. Dieri farming has resulted in removal of indigenous vegetational cover. Over-grazing of savanna vegetation by sheep, goats and cattle has reduced the habitat and forage available for native herbivorous mammals, such as the elephant, gazelle and monkey. Large cats and other predators relying on these animals for food have correspondingly been reduced in numbers. The lion has been eliminated by man from most if not all of the Lower and Middle Valleys because it is a menace to livestock. Lions do remain in areas upstream of Bakel. Harvesting of forest habitat for charcoal and firewood has resulted in reduced numbers of animals throughout most of the Basin. Some animals, for example warthogs and small rodents, have, however, found improved living conditions and thrive.

Some aquatic animals living in the Senegal River and its tributaries have had to surrender to the encroachment of man. Two of the most prominent aquatic animals, the threatened Senegal River Manatee and the endangered Nile Crocodile, survive in only very small populations. Both species are now included in the list of endangered species and are fully protected. However,

illegal hunting and continued habitat destruction make the survival of these species questionable. No manatees or crocodiles were observed during field investigations made during this environmental assessment.

C.13.2. Environmental Impacts

Proposed development in the Senegal River Basin will significantly affect the fate of wildlife in the study area. While some developments will further eliminate the already diminished wildlife resources, others hold the promise of improving habitat for some animals.

The construction of the Diama dam will increase the extent of inundated land throughout the Senegal River Delta area. Depending on the water level maintained behind the dam, this development will mean the loss of 130-310 sq. km of already degenerated habitat for terrestrial species such as warthogs, jackals, rodents and small carnivores (including gervals, civettes, and genets).

The year-round presence of freshwater in the Diama impoundment will, however, somewhat compensate for the loss of terrestrial habitat, as it will allow wildlife to colonize Delta areas formerly not available to them because of the lack of freshwater during the long dry season.

The size of the Diama reservoir will enlarge the habitat for aquatic animals. The Nile Crocodile can be expected to recover from its decline, if effectively protected against illegal hunting. To predict the fate of the Senegal River Manatee is more difficult, because very little is known about its reproductive and migratory requirements. If this specie can reproduce in a landlocked situation, the manatee should respond to improved habitat conditions by enlarging its population. Individual manatee living in the stretch of River below the Diama dam at the time of gate closure will be cut off from a vital part of their habitat and probably will not be able to survive unless they are allowed to pass through the navigation locks. The net effect of the Diama reservoir scheme on wildlife is judged to be beneficial, as the gain in improved living conditions for the Senegal River Manatee and the Nile Crocodile will exceed the minor losses in terrestrial habitat.

The Manantali impoundment will cover up to 500 sq. km (42,900 hectares) of terrestrial habitat, consisting primarily of savanna woodland and riparian fringe forest. In addition, similar habitat will be destroyed by the resettlement of people living in the area to be inundated. The area that will be lost to inundation and affected by resettlement presently harbors small game ungulates such as orim, bushbuck and red-flanked duiker. During the filling of the reservoir, most of these animals will drown. Small mammals and reptiles will suffer the greatest losses. Animals escaping by moving to higher grounds or away from the resettlement areas will find survival difficult in the new territory that may be at carrying capacity, its available niches being already filled by individuals of the species seeking new homes.

After the filling the Manantali reservoir, new wildlife habitats will develop. Marshes and swamps will form along the fringe of the impoundment, providing a suitable habitat particularly for the hippopotamus and the Nile Crocodile. Other animals attracted to the fringes of the impoundment may include roan antelopes, waterbucks and bahor reedbucks which prefer open woodland savanna located near water. Similar events have been observed after the construction of the Kariba Dam. This gain, however, cannot outweigh the inundation of 42,900 hectares of relatively undisturbed and productive wildlife habitat. The net effect of the Manantali reservoir on wildlife is therefore judged to be adverse.

Irrigated perimeter development and municipal growth will take place over the next 50 years on several thousand square kilometers of land in the Senegal River Valley downstream of Bakel. Most of the land designated for development at present is utilized for farming or grazing. Wildlife on these areas is now very sparse and often non-existent. Consequently, future land development will have little impact on the status quo, unless accompanied by a land use management program designed to upgrade the quality of land outside of agricultural and urban zones. If the quality of these lands could be improved by preventing overgrazing, limiting destructive farming techniques and by increasing forest protection and reforestation, a limited number of game animals such as gazelles or antelopes may once again find suitable habitat conditions in the River Valley.

Irrigated perimeters will provide habitat for different wildlife communities. Irrigation canals and drainage ditches will be ideal habitats for small mammals, reptiles and amphibians. The crops raised in irrigated perimeters will provide a plentiful food supply for many animal species, especially rodents that will thrive and become crop pests.

Navigation will only have a minor impact on wildlife in the Senegal River Basin. Dredging and dredge spoil disposal activities will disturb animals living on or near the river banks where excavated material is deposited. Dredge spoil disposal will destroy some existing habitat. However, due to the small area required for dredge spoil disposal and due to the fact that revegetation of these areas will take place within a few seasonal cycles, this impact is considered only minor.

C.13.3. Proposed Mitigating Measures

As stated in the previous section, the overall impact on wildlife, due to the proposed developments by O.M.V.S. in the Senegal River Basin, has the potential of being negative; the most adverse impacts being in the Manantali area resulting from land inundation and resettlement. A viable method for mitigating this loss of habitat would be through the establishment of a new national park. This park would provide an area of complete protection for animals and would permit habitat management, thus optimizing conditions for wildlife. The most desirable location for this new national park would be an area of 40,000 hectares along the banks of the Manantali impoundment. This park should have at least 45 kilometers of shoreline as it will be here that the largest congregation of wildlife will be found. Also, if this park is established before the completion of the dam, its officers could undertake an animal rescue program to save stranded wildlife during the filling of the reservoir. Such a rescue program would substantially reduce wildlife losses, which are expected to occur through drowning.

In the area of the Diama impoundment the overall impact on wildlife is expected to be adverse. Adding 5000 hectares to the existing Djoudj National Bird Park and the development of a new park (30,000 hectares) in Mauritania,

located across the River from Djoudj and extending to the Atlantic Ocean, are suggested mitigating measures. An alternative would be to develop the Ndiael area as a bird sanctuary. By expanding and developing new parks in the Diama area, wildlife populations should further increase in these protected environments.

The impact on the Senegal River Manatee is uncertain at this time. So little is known about the species that only general inference can be made about the social structure, reproductive requirements and movements. A research program designed to obtain fundamental information is therefore recommended. A life history study, lasting a minimum of two years and started at least two years before the completion of the Diama dam, should be undertaken. After construction of the Diama dam, manatee may become trapped below the dam. Whether or not they will die is again uncertain because so little is known about them. The development of an artificial estuary, as discussed in the Fisheries portion of this synthesis, would be a viable measure for allowing movements of manatees around the Diama dam. Another viable measure that should be studied is to allow the manatee to pass through control locks of the Diama dam. The fate of the manatee is of international concern. Planning assistance and partial or total funding for such a study may be available from international wildlife organizations working in cooperation with O.M.V.S. The alternative to such a study and implementation of its recommendations may be the extermination of the Senegal River Manatee.

Table C.13 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Mammalogy and Herpetology

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Diama Dam	Water Impoundment	Inundation of terrestrial habitat leading to reduction in wildlife populations.	Adverse, light, long-term	Improve and expand existing parks and establish new ones. Increase personnel and equipment in parks to effectively enforce game laws throughout the basin.
		Animal displacement from terrestrial habitat.	Adverse, light, short-term	Same as above.
		Increased volume and surface area of water. Recharge of Lac de Guiers, Lac R' Kiz and Aftout-es-sahel. Subsequent establishment of aquatic vegetation. Increased population of Nile crocodile* and Senegal River Manatee*.	Beneficial, moderate, long-term	Same as above to enhance benefits.
	Dam Construction	Some Manatees* may become trapped on the downstream side of the dam. These Manatees* could perish due to the high salinity concentrations.	Adverse, moderate, long-term	Capture and rescue plan. Could be carried out by park officer at Djoudj Park. Develop plan permitting manatee to pass through locks of Diama Dam.
Manantali Dam	Water Impoundment and flow regulation	Inundation of terrestrial habitat leading to reduction in populations of wildlife.	Adverse, moderate, long-term.	Improve and expand existing parks and establish new ones. Increase personnel and equipment in parks to effectively enforce game laws throughout the basin.
		Filling of reservoir may cause drowning of some animals.	Adverse, light, short-term	Animal rescue by park officials.
		Animals displaced from terrestrial habitat are likely to perish.	Adverse, moderate, long-term	Improve and expand existing parks and establish new areas. Increase personnel and equipment in parks to effectively enforce game laws throughout the basin.

*Endangered wildlife species

Table C.13 - 1 (Cont'd.)

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Mammalogy and Herpetology

Component	Factor Creating Impact	Impact Description	Magnitude	Enhancement or Mitigating Measure
Manantali Dam (cont'd.)		Increased flow downstream and creation of impoundment will benefit wildlife.	Beneficial, moderate, long-term	
		Development of new terrestrial habitat around impoundment will benefit wildlife.	Beneficial, moderate, long-term	
Agricultural Development	Perimeter Development	Loss of terrestrial habitat leading to reduction in wildlife population.	Adverse, moderate, long-term	
		Development of new terrestrial habitat will benefit wildlife (e.g. frogs, crop pests).	Beneficial, moderate, long-term	
Navigation	Disposal of dredge spoils	Loss of terrestrial habitat especially if deposited in forests.	Adverse, light, short-term	
	River traffic	Manatee* injuries & mortalities resulting from collisions with boats.	Adverse, light, long-term	Better understanding of life history of Manatee. Improve and expand existing parks and establish new ones. Increase personnel and equipment in parks to effectively enforce game laws throughout the basin.
Resettlement	Land clearing and habitation	Loss of terrestrial habitat and competition with domestic animals for food will lead to a reduction in wildlife.	Adverse, light, long-term	

*Endangered wildlife species

C.14. Ornithology

C.14.1. Existing Conditions

Four major categories of birds are of special interest in the development of the Senegal River Basin. These include waterbirds, savanna birds, granivorous birds and protected birds.

Waterbirds - Due to drought conditions, waterbird populations were far below normal levels at wetland sites in the Senegal River Delta during December 1977. Previous studies indicate that 90 percent of the waterfowl population in the valley consists of the following three species presented in order of abundance: Anas querquedula (garganey), Anas acuta (Pintail), and Dendrocyqna viduata (white-faced tree duck). Anas querquedula migrate from a vast area extending from Europe into Siberia. Djoudj Park, the national bird sanctuary of Senegal, along with the interior Niger delta in Mali, represents an important wintering ground for this widely distributed but uncommon european duck.

In field surveys conducted by the ornithological team during this study, 78 species of waterbirds, both wintering and indigenous species, were recorded. This included six kinds of pelicaniforms (anhings, cormorants and pelicans), 21 kinds of ciconuforms (herons, storks and ibises), ten kinds of waterfowl, 24 kinds of shorebirds (polvers and sandpipers) and eight kinds of gulls and terns. The largest populations were observed in the Delta. These species were well represented up river, except in the Manantali area of the Bafing River where they were scarce during the May, 1977 survey. It should be acknowledged that the dry season of May was not the ideal time for observing waterbirds in this area.

The Djoudj Park and other wetlands of the Senegal River Basin complement each other as areas of waterbird habitat. Birds begin arriving in September, utilizing the flooded Middle Valley as a wetland habitat. At this time the Djoudj depression in the Delta is still dry. Later, beginning in October, the Djoudj Park is inundated and becomes the important migratory fowl habitat

within the Valley. In addition, Lac de Guiers, Lac R'Kiz and the Aftout es Sahel contribute to the reported 7,000 square kilometers of wetland habitat in the basin under maximum flooding conditions. This habitat normally shrinks to 1,100 square kilometers by midwinter.

Savanna Birds - Observations made during this Study showed the savanna bird populations in the Senegal River Valley greatly exceeded the density of 230 birds per 40 hectares reported in the nearby Ferlo region. This high concentration of birds is thought to be related to the availability of water and seed. During the height of the drought, many bird species have been reportedly forced out of the Ferlo country to the savanna habitat near the Senegal River where water is readily accessible.

Granivorous Birds - Because the Senegal River lies in the savanna vegetational zone, which is rich in seed producing plants, the region is characterized by a preponderance of granivorous birds. Quelea quelea (black-faced dioch) is one such species which is a notorious pest of grain crops in Africa. In recent years, the Quelea quelea populations have been on the decline in the Senegal River Basin as the result of reduced savanna habitat from drought, overgrazing by livestock and other agricultural activities. A number of other species of birds occurring in the Senegal River Basin also have been implicated in grain crop damage, but not to the same extent as has Quelea Quelea. These include several members of the genus Ploceus (weavers), the genera Euplectes (bishops), and Passer, especially Passer luteus (golden sparrow), a relative newcomer to the Senegal River area. Although Passer luteus has become very abundant in the Senegal River area in recent years, its food habitats consists mostly of insects and weed seeds.

Protected Birds - Game statutes exist for Senegal and Mauritania protecting avian species in the Senegal River Basin. Such statutes were not available for Mali. Ciconia ciconia (white stork), egrets, large bustards, cranes and flamingos are protected by the Convention Africaine pour la Conservation et l'Amenagement de la Faune et son Habitat (African Convention

for the Conservation and Development of the Fauna and its Habitat). This convention has been ratified by Mali. The position of Senegal and Mauritania regarding protection of these birds has not been ascertained. The Convention on International Trade in Endangered Species of Wild Fauna and Flora lists 7 protected genera from the Senegal River Basin including Balearica regulorum (crowned crane), eagles of the genera Aquila and Haliaetus, harrier hawks in the genus Circus, Pandion haliaetus (osprey), Otus scops (scops owl and Platalea leucorodia (European Spoonbill). None of the O.M.V.S. Member States has ratified the proclamations of this convention. Senegal has ratified the Ramsar Convention by setting aside Djoudj Park and an area near Ross-Benthio to protect and preserve waterfowl. No birds of species listed in the International List of Endangered and Threatened Wildlife and Plants under the United States Endangered Species Act have been observed within the River Basin.

C.14.2 Environmental Impacts

Diama Impoundment - Decreased fish productivity from modification of the estuary will result in a depletion of piscivorous birds such as herons, egrets and pelicans. Loss of gonakie forests and some savanna habitat will cause decreases in populations of savanna birds.

Increased frequency of recharge of Lac de Guiers, Lac R'Kiz and Aftout es Sahel, and construction of the Diama impoundment will create additional waterbird habitat throughout the year. Fluctuations in water levels behind the Diama dam will expose certain aquatic plants, and trap fish and amphibians in isolated pools. These fluctuations will provide readily accessible food for a variety of bird species. Additionally, more frequent recharge will provide resting areas for waterbirds on the open waters and breeding areas and food along their marshy edges. Emergent vegetation will supply increased food supplies and habitat for savanna and granivorous birds.

Manantali Impoundment - The overall effects from this impoundment will be beneficial. Creation of the impoundment will provide a significant increase in habitat for waterbirds, including protected species. Grassy areas are

expected to develop on the fluctuating edges of the impoundment and will provide excellent habitat for granivorous and savanna birds. Inundation will destroy the habitat of the crocodile bird (Pluvianas algyptius) and 47,000 hectares of habitat for savanna and granivorous bird species. This loss of habitat is considered minor when placed in perspective with the total available habitat in the River Basin. Therefore, these bird populations will be minimally impacted by proposed development

Agricultural Development - The net effect from development will be beneficial from an environmental standpoint although from the viewpoint of man, increases in bird populations associated with agricultural development will be considered a nuisance. Conversion of savanna lands into agricultural perimeters will result in a decrease in numbers of insectivorous birds and an increase in numbers of granivorous birds, which will become crop pests. Irrigation ditches will provide habitat for waterbirds. Piscivorous birds could become a nuisance if significant numbers attempt to use the proposed fish culture ponds as a food source.

Use of pesticides for crop protection could adversely affect granivorous, insectivorous and predacious birds. Fish-eating birds could be adversely impacted if insecticides contaminate natural waters and become concentrated in fish flesh.

River Navigation - Construction activities associated with the proposed entry channel, dredging, port development, and possible oil spills from boat traffic will adversely affect marine birds associated with the Langue de Barbarie National Park. Temporary adverse impacts on terrestrial birds will occur from habitat destruction by dredge spoils.

C.14.3. Proposed Measures to Mitigate Habitat Losses and Impacts on Djoudj

a. Prospective lands for addition to existing parks and for creation of new national parks should be designated around Djoudj, in Mauritania and in Mali as soon as possible. A committee of national park service members from the O.M.V.S. countries should be included in the planning stages.

b. Following land acquisition, new park conservation officers should be trained and the organization of staff members in the new parks should begin.

c. The Government of Senegal, with assistance from the O.M.V.S. would be responsible for implementing dike and gate repair in Djoudj, monitoring potential problems in the breeding colony at the Langue de Barbarie National Park, and maintaining a dike maintenance program for the park and research programs on existing birds in the park by park personnel.

d. The wetlands ecology program proposed for Djoudj should be initiated as soon as possible to assess water level impacts before construction of the Diama Dam begins. This program compliments the proposed manatee research program and should proceed in conjunction with it.

e. A research program to assess savanna ecology and bird population numbers should be initiated, but is not as critical to the initiation of the project as the preceding proposed measures. After consultation with appropriate agencies (such as O.R.S.T.O.M.), the plan could be implemented depending on present research activities.

C.14.4. Proposed Measures to Control Bird Pests

The control of granivorous birds is a problem in all of Africa that requires international cooperation. Because many species are wide-ranging, control in one area may not remedy the problem and more birds may invade the area from other regions. This pest problem is analogous to locust outbreaks that are still uncontrolled over much of Africa.

The first part of any action, therefore, is to obtain international assistance to deal with the problem on a regional scale. Studies in association with appropriate organizations would lead to a program to be administered by O.M.V.S. It is felt that such a program should only be initiated when appropriate control methods can be utilized to deal with specific problems. For example, the Quelea quelea impact may be minimized by

synchronized harvesting of rice during September while the Quelea quelea are breeding in remote savanna areas. Ruff and tree-duck predation on sprouting rice may be controlled by application of Methiocarb, a bird repellent. Programs to remove nesting colonies of weavers near rice fields may be used to control some local problems. Additional studies should be undertaken to analyze the potential impacts of Passer luteus on grain crops in the agricultural perimeters.

Table C.14 - 1

Environmental Impacts and Proposed Mitigating Measures Associated with Proposed Developments in the Senegal River Basin

Ornithology

Component	Factor Creating Impact	Impact Description	Magnitude	Mitigating Measure
Diama Dam & Manatanli Dam	Construction of Diama Dam and provision of dry season flows from Manantali Reservoir	Loss of estuarine fish as food supplies for certain birds. Increase in habitat and food supplies for certain birds at Diama Impoundment and delta depressions	Severe,[1] adverse to some birds and beneficial to others, long term	Repair and maintenance of dikes and water gates to enhance Djoudj Park as a bird refuge. Establish a Wetlands Ecology Research and Management Program. Establish new parks as habitat alternative.
Overall Basin Development	Inundation behind Manantali Dam; Destruction of habitat from agricultural and municipal-industrial development.	Loss of savanna and granivorous bird habitat from basin development Increase of waterbird habitat	Moderate,[1] adverse to some birds and beneficial to others, long term	Set aside parks equivalent to areas lost. At Manantali this will require setting aside 123 km. of fringe forest habitat as a preserve. Expand existing parks. Provide funding for wildlife specialists to survey areas affected by development and areas being considered as preserves. Establish reforestation and rangeland management programs.
Agriculture	Increased Crop Production	Increased crop production will increase food supplies of nuisance granivorous birds	Moderate,[1] adverse to farmers, long term	Systematic destruction of nesting colonies and birds on night-time roosts near crops. Use of seed dressing or crop dressing repellents. Harvest crops when potential migratory pests are absent. Alternate grain with non-grain crops.

[1]Assuming no mitigating measures are implemented.

CHAPTER D

INTEGRATED ASSESSMENT OF IMPACTS ON THE ENVIRONMENT RESULTING FROM PROPOSED O.M.V.S. DEVELOPMENTS IN THE SENEGAL RIVER BASIN

The purpose of this chapter is to integrate and summarize the impacts identified in the previous chapter into an overall assessment of the environmental effects resulting from proposed development in the Senegal River Basin. Environmental impacts will be created by all levels of future O.M.V.S. development in the Senegal River Basin. The same impacts can be judged detrimental or beneficial, depending on the point of reference from which they are appraised and the special interest of the appraiser. For an integrated assessment, the following two central questions must be answered:

a) What are the effects of the proposed development on environmental and natural resources in the Senegal River Basin?

b) What are the effects of the proposed developments on the social and economic well-being of individuals living in the Senegal River Basin?

D.1 Environmental and Natural Resources

The level of social and economic well-being in the Senegal River Basin will depend on the manner and effectiveness by which resources are managed. Development within the Basin should be balanced against deterioration of natural resources so that it can be accomplished in a manner that best serves both long-term and short-term interests of the people from the Basin and from the Member States. The environmental and natural resources of the Senegal River Basin that will be affected by the O.M.V.S. development plan are land, water, and wildlife.

D.1.1 Land Resources

Land and the associated vegetation, among the most threatened resources in the Senegal River Basin, will be affected by the proposed River Basin development. Impacts from agricultural, municipal and industrial development on land resources will affect the Senegal River Valley, primarily between Bakel and St.-Louis. Less significant concerns include the projected loss of land and resettlement associated with the Manantali Reservoir, and coastal erosion south of the proposed entry channel through the Langue de Barbarie.

D.1.1.1 Desertification in the Senegal River Valley Downstream of Bakel

As in many areas of Sahelian Africa, parts of the Senegal River Valley downstream of Bakel have experienced a gradual depletion of vegetation during the past few decades from overgrazing by livestock and from forest destruction by man for fuel. These conditions, combined with climatic factors, such as the Harmattan winds and rains, have removed the rich top soils throughout a large portion of the Basin. The remaining soils are organically poor and nutrient-deficient, which is not conducive to reestablishment of protective vegetational cover. This situation was aggravated during the drought years of the 1970's when the scant vegetation was further depleted by sparse rainfall and starving livestock. Unless proper range management practices are instituted, additional large scale desertification of dieri land will be inevitable in the Senegal River Valley. With proper management of the 255,000 hectares of irrigated perimeters planned for the Senegal River Valley and Delta by the year 2028, these lands will be saved from further desertification.

The proposed O.M.V.S. agricultural development program has the potential to become either a nucleus for a general rehabilitation of the land and vegetational resources in the Senegal River Valley or a source of further range deterioration. The fate of these lands will depend on future policies concerning agricultural, herding, forestry and range management.

The development of irrigated perimeters will decrease the area available for future pastoral activity. To decrease the pressures on already overgrazed

rangelands, herders will be integrated into the agricultural development scheme by setting aside approximately 14 percent of the irrigated perimeters for fodder production. At the same time, use of the remaining natural grazing land should be limited to the carrying capacity of the land.

The projected population in the Senegal River Basin is expected to exceed 6 million by 2028. This factor, along with the globally increasing prices of petroleum fuels, will place presently degenerated forests under increasing pressure as a local fuel source. Protection and management of existing forests and the seeding of new forest areas are necessary if the people are to have an adequate source of wood. Irrigated perimeter development can contribute to this end in several ways. Integration of herding activities into irrigated perimeter operation will ease the pressure on forests and grazing lands by providing forage for livestock. Decreases in traditional slash/burn agriculture will result in less forest destruction. Irrigated perimeters themselves can provide an ideal nucleus for reforestation. New forests could be placed around or in the vicinity of irrigated perimeters. In some cases, it may be possible to irrigate forest tracts with drainage water from the perimeters. These forests could have two beneficial functions. They could serve as a source of firewood for the cultivators living near a perimeter and they could serve as windbreaks that inhibit soil erosion.

Desertification and environmental deterioration will remain a serious threat to the lands of the Senegal River Valley unless planned perimeter development is accompanied by a comprehensive program of land use planning and management. The program must also have as its central objective the achievement of a balance between use and the natural carrying capacity of the land. Only through such a program can the progression of desertification be decreased in the Senegal River Valley. Major elements of a proposed land use management plan should include:

a) The reorganization of livestock activities to give herders an opportunity to grow crops in agricultural perimeters;

b) Regulated use of dry season and wet season pastures outside perimeters. Implementation of a pastoral code designed to stabilize and improve the productivity of range areas;

c) The propagation of forest resources by protecting and enlarging existing forest resources and by encouraging reforestation efforts in areas where irrigated perimeters are constructed;

d) The regulation and improvement of farming practices. Clearing and development of marginal lands should be controlled or prohibited.

D.1.1.2 Loss of Land Around the Manantali Reservoir

The proposed operating methodology for the Manantali reservoir indicates that water levels in the impoundment will vary between 187 and 208 meters IGN. These water level fluctuations will cause the surface area of the reservoir to vary between 272 and 477 square kilometers. The 477 square kilometer area will be irreversibly lost for permanent use by humans and wildlife. Resettlement of people from areas to be inundated by the reservoir will occur. Fortunately the number of people to be resettled is not large. Large tracts of essentially unused land in the Bafing River watershed are available as resettlement sites. The use of these areas will not create major adverse effects on land resources in the Manantali reservoir area.

D.1.1.3 Developments in the Southern Portion of the Senegal River Estuary

The entry channel planned to cross the Langue de Barbarie south of St.-Louis will adversely impact the estuary and the portion of the Langue de Barbarie located south of the entry channel. The portion of the estuary south of the entry channel will be transformed into a lagoon that will eventually be filled by sedimentation. The sedimentation process is predicted to occur very slowly and will not be complete for several hundred years.

The Langue de Barbarie will be subject to severe beach erosion immediately following completion of the breakwaters protecting the proposed entry channel. The rate of erosion is not known at this time, but all preliminary investigations suggest that beach erosion will be severe.

Erosion will lessen the value of the Langue de Barbarie as a resource for potential future development, although no plans exist for its development. At present the section of shore line that will be subjected to erosion is uninhabited. Erosion on the Langue de Barbarie will therefore have no immediate economic consequences although it will cause the ultimate destruction of an important bird sanctuary. Whether or not expensive measures should be taken today to protect this endangered stretch of beach is a question government leaders should answer.

D.1.2 Water Resources

Both surface water and groundwater resources will be affected by the proposed developments.

D.1.2.1 Surface Water

One of the major goals of the proposed O.M.V.S. development program is to change the natural flow regime of the Senegal River, thereby improving the utility of its water resources. At present, effective use of the Senegal River as a water resource is severely hampered by the River's wide variations in flow throughout the year. The Diama and Manantali reservoirs will provide a more even distribution of flows and allow the more frequent and more efficient recharge of Lac de Guiers, Lac R'Kiz, and the Aftout es Sahel. Peak flows will be tempered somewhat and low flows will be augmented to a level sufficient to support river development objectives. The impact of water resources of the Senegal River on opportunities for development is of significant benefit as the availability of larger amounts of water during the annual dry seasons enhances agricultural development. This is essential if the food requirements of the people are to be met. Without flow regulation, the proposed agricultural development will not be possible.

The only significant water quality problems that exist in the Senegal River Basin at present are associated with saltwater intrusion. The intrusion of saltwater into the Basin during periods of low river flow render the water in the estuary unsuitable for irrigation, water supply, and recharge

of exploitable groundwater resources. Pollutant discharges into the River do not cause water quality problems at present and none are expected in the near future if the anticipated development occurs. Mathematical modeling of the river to determine its response to waste loads indicates the augmented flow that will occur in the River during the dry season will prevent the deterioration of water quality to harmful levels during the planning horizon (1979-2028). A potential for the development of dissolved oxygen deficits is projected for the estuary downstream from St.-Louis. These deficits, however, are projected to occur towards the end of the planning horizon and then only if all of the wastewaters from St.-Louis are discharged into the Senegal River without treatment. If water quality problems are observed downstream from sewered municipalities or industries, these problems can be mitigated by installation of wastewater treatment facilities. Considering the climatic conditions, treatment requirements and desirability for implementing a labor intensive solution, facultative lagoons appear to provide the most appropriate wastewater treatment technology at present.

An environmental monitoring program is recommended as a means for detecting pollution and establishing the level of pollutant loadings that can be discharged into the River without causing degradation of water quality below desirable levels.

An additional source of pollution in the Senegal River Basin is the potential spillage of oil and discharge of bilge water or ballast from boats and other vessels. The extent of this pollution will largely depend on the care taken in handling and storage of oil and ballast, and in the prevention of accidents. To minimize the amount of oil discharged into the Senegal River and its estuary, adoption and strict enforcement of an oil pollution control code is essential.

The construction of the two dams, port facilities, the river navigation channel and the proposed estuarine facilities will result in some localized sediment pollution of the Senegal River. Environmental impacts from sediment will be minor, especially if effective control measures are employed during the period of construction.

A major change in surface water quality will result from the prevention of saltwater intrusion by the Diama dam. The significant beneficial effect of this measure will be that freshwater will be available for irrigation and as a water supply on a year-round basis. The prevention of saltwater intrusion into the Senegal River upstream of Diama will be beneficial and enhance the value of the Senegal River as a water resource.

D.1.2.2 Groundwater

At present, groundwater is a relatively untapped resource in the Senegal River Basin. Long-term changes in groundwater quality are expected as a result of construction of the Diama Reservoir. Prevention of saltwater intrusion into the Senegal River upstream of Diama may prevent additional saline contamination of shallow groundwater strata adjacent to the River. The flushing of saline waters from the groundwater table may occur in some areas, depending on local conditions.

Decreased floodplain inundation in the Senegal River Valley due to flow regulation and agricultural development will reduce the recharge of shallow aquifers adjacent to the Senegal River. Wells in rural areas will be most affected. Reduced recharge may decrease the potential of future large scale exploitation of groundwater resources whose major recharge is from infiltration during the period of floodplain inundation, but this type of exploitation is not foreseen.

Agricultural development and municipal and industrial growth will, as everywhere in the world, constitute a threat to the quality of groundwater. Conscientious planning of waste disposal locations and practices with respect to groundwater location will be necessary to prevent groundwater contamination.

D.1.3 Wildlife Resources

Wildlife inhabiting the Senegal River Basin will be impacted by the proposed O.M.V.S. development plan. For the purpose of identifying impacts on wildlife, the River Basin has been divided in three zones, the Diama and

Manantali reservoir areas and the River Valley of the Senegal River between the two reservoirs. Physical changes brought about by River Basin development will have a distinct effect on future wildlife habitat and propagation for each of these three zones:

a) Diama Reservoir Area: A gain in aquatic habitat will occur accompanied by a loss in terrestrial habitat due to inundation and recharge of depressions. The disappearance of a salinity gradient in the Senegal River upstream of Diama and alterations of salinity gradients downstream of Diama will particularly affect wildlife that use this Senegal River habitat.

b) Manantali Reservoir Area: A gain in aquatic habitat will occur accompanied by a loss in terrestrial habitat due to inundation and resettlement.

c) Senegal River Valley: A decrease in aquatic habitat will result due to a decrease in floodplain inundation resulting from flow regulation and agricultural development, loss of terrestrial habitat due to agricultural, urban and industrial development will also be evident.

Other areas within the Basin will not be affected by proposed developments to a degree that will significantly impact terrestrial and aquatic habitats.

D.1.3.1 Diama Reservoir Area

Wildlife in the Senegal River Delta over the last two centuries has been decimated. The main reasons for this occurrence were destruction of wildlife habitats by man and his livestock and, to a lesser degree, hunting. Larger mammals such as gazelles, antelopes, monkeys, and cats have almost completely disappeared from the Delta. Smaller animals such as jackals, rodents and some small cats have managed to adapt to these modified conditions.

Inundation behind the Diama reservoir and more frequent recharge of depressions in the Delta will result in loss of terrestrial habitat but a gain

in aquatic habitat. The loss of this wildlife habitat is relatively minor when placed in perspective within the total land area of the Basin. Additionally, much of the land, as a wildlife habitat, is presently in a degraded state.

The increase in an aquatic habitat in the Senegal River Delta upstream of the Diama dam, particularly during the dry season, is expected to benefit both the Senegal River Manatee and the Nile Crocodile. Small populations of the Senegal River Manatee and the Nile Crocodile are still present in the Delta area, with most of the remaining individuals living in Djoudj National Park. Both the manatee and the Nile Crocodile are threatened with extinction in the Senegal River Delta. Accompanied by strict protection measures, the year-round freshwater habitat will give both of those species a chance to survive in the River Basin. Evidence from the Senegal River Manatee in the Lake Chad Basin and the American Manatee supports the hypothesis that manatee can complete their life cycle entirely in freshwater. Still, inadequate scientific evidence is available to unequivocally support this belief. Additionally, the little understood life history of the manatee makes it difficult to predict the outcome of manatee trapped in the highly saline waters downstream of the Diama dam.

The wetlands will also create additional habitat for water birds. Emergent vegetation along the increased shorelines of the impoundment will provide habitat for granivorous and insectivorous bird life.

The Diama dam will have a dramatic effect on the existing fish diversity and population dynamics within the Senegal River Delta. The creation or expansion of permanent freshwater impoundments (Diama reservoir, Lac de Guiers, Lac R'Kiz and the Aftout es Sahel) will favor the development of a freshwater fish population adapted to lacustrine conditions.

The Diama dam will destroy estuarine conditions in the Upper Delta, upstream of the dam. Loss of this portion of the estuary will completely eliminate the estuarine fishery from this stretch of the river. Downstream of the Diama dam, changes in salinity gradients will result in a reduction of estuarine habitat. During the rainy season, freshwater conditions, on the

average, will prevail downstream of the dam as they have in the past. During the dry season, salinities will tend to be higher than present salinities. This will be accentuated by construction of the entry channel. At certain times of the year, particularly April, May and June, salinity levels below the dam may not fall below 10 to 15 parts per thousand. This could result in the disappearance of fish and invertebrates that must spend a portion of their life cycles under low salinity or freshwater conditions. Most notably, the African shad (Ethmalosa sp.), the crab (Calinectes spp.) and the shrimp, (Penaeus duorarum) may be lost to the commercial fishery. Species of fish adaptable to the increased salinities and changing salinity gradients during the dry season will become predominant below the Diama dam.

From an ecological point of view, changes in fish species composition in the Senegal River is certainly undesirable. From an economical and sociological point of view, the disappearance of the African shad and other fishes, whose life cycles depend on the annual salt tongue development, is of significant importance as most of the artisanal fishing is related to these fish species. Estimates made in this Study indicate that the yearly estuarine fish harvest potential could decrease by as much as 4000 metric tons in the Lower Delta and 7500 metric tons in the Upper Delta. The annual harvest of 4500 metric tons from the freshwater fishery projected to develop upstream of the Diama dam will partially mitigate these losses. However, a net loss of 7000 metric tons of harvestible fish annually from this region is projected.

D.1.3.2 Manantali Reservoir Area

The Manantali reservoir and the area designated for the resettlement of people presently living in the area to be inundated will result in the destruction of 42,900 hectares of natural habitat. In contrast to the Delta area, which harbors little wildlife, the habitat that will be lost in the Manantali area supports one of the most diversified and productive wildlife populations in the Senegal River Basin. Most of the animals displaced by the waters of the Manantali reservoir have only a small chance for survival, as they will face increased predation and starvation in the surrounding habitat, which is assumed to be at carrying capacity under existing conditions. The

fringes of the future Manantali reservoir will create new habitat for some animal species. The hippopotamus, Nile Crocodile, roan antelopes, and water bucks are among the species that could be sustained by this new habitat. Their survival will be governed by the extent to which they are protected from human exploitation. This gain in habitat, however, cannot make up for the loss of relatively undisturbed and productive terrestrial wildlife habitat that will be inundated or used for resettlement villages. The net effect of the Manantali reservoir on wildlife is therefore judged to be adverse.

The newly created aquatic habitat within the Manantali reservoir, on the other hand, has the potential to support a prolific freshwater fishery and enhance conditions that are supportive of other forms of aquatic life. Among the fish species projected to colonize the reservoir, Tilapia and Sarotherodon should be of commercial value. From a fisheries point of view, the Manantali reservoir constitutes a very beneficial development.

D.1.3.3 Senegal River Valley

Agricultural development in the River Valley downstream of Bakel will reduce available wildlife habitat. Much of this land is presently in a degraded condition from over-grazing and farming, and as a result, supports little wildlife. Therefore, future development activities will have little impact on existing wildlife populations. In the assessment of land resources in this report, the recommendation is made to make the planning of irrigated perimeter development the nucleus for a wide-ranging land use plan. A land use planning program is proposed to curtail desertification and to improve land resources of the Senegal River Valley by the preservation of existing resources, by the creation of new forestry resources and by the control of destructive grazing and farming activities. If this program could be enacted and general improvement of range and forest habitats could be achieved, wildlife may have a chance to return and proliferate in the Senegal River Valley. A limited number of gazelles, antelopes, monkeys and elephants could find a future home in the Senegal River Valley between Bakel and Dagana in spite of agricultural, urban and industrial growth. If these wildlife are to survive, aggressive conservation programs will be required.

Annual floodplain inundation is extremely important for the reproduction and nursing of many fish species in the Senegal River Valley. Decreases in annual inundations of floodplain depressions as a result of flow regulation and irrigated perimeter development will lead to a decrease of fish habitat and, correspondingly, to a decrease in fish productivity in the Senegal River Valley. Estimates made as part of this study indicate that annual harvestible fish resources will decrease by approximately 20,000 metric tons by 2028. This reduction is due to the destruction of floodplain habitat.

D.2 Social and Economic Well-Being

A major objective of the O.M.V.S. development plan is to improve the social well-being of the people affected by the developments. Therefore, the final criterion for judging the value of the Senegal River Basin development plan centers around the following question: will the people of the Senegal River Basin and of the three O.M.V.S. Member States benefit from the O.M.V.S. plans?

The social and economic well-being of people living in the Senegal River Basin depends on a great number of parameters that are interrelated and sometimes difficult to define. The following aspects of well-being have been selected to judge the effect of the O.M.V.S. development program on people in the Senegal River Basin.

a) Food and nutrition;
b) Public health;
c) Migration;
d) Employment;
e) Social structure and culture.

D.2.1 Food and Nutrition

One of the major goals of O.M.V.S. is to maximize agricultural production in order to increase the gross national product, promote development of agro-industries and improve the quality of life in the Senegal River Basin by providing better nutrition. The prinicipal nutritional disorders presently existing in the basin are protein-caloric deficiencies, nutritional anemia and endemic goiter. Mauritania ranks malnutrition as the number two cause of death in children. Mali attributes at least 30 percent of childhood deaths, aged 1-4, to malnutrition. In recent years, inadequate rainfall in the Basin has severely curtailed food production and aggravated the problem of malnutrition. Past experience has proven that the solution of alleviating malnutrition is through improved agricultural production, storage and distribution of foods, rather than short-term relief from famine levels. Proper development of the Senegal River Basin will provide an improved level

of nutrition through the integrated approach of combining traditional agricultural practices with modern agricultural technology.

Traditional agriculture that will continue to play an important role in the diet of Basin residents includes:

a) Recession Farming;
b) Dieri Farming;
c) Herding;
d) Freshwater Fisheries.

Newly initiated food-related activities, which are expected to play an increasingly more important role over the next 50 years, include the development of 255,000 hectares in irrigation agriculture and, to a lesser extent, fish culture and the increased availability of marine fishes. Existing agriculture is dependent from year to year and from season to season on the ever-fluctuating rainfall, typical of the Sahelian climate. On the other hand, irrigation agriculture, following the construction of the dams, will provide year-round yields of crops on a much greater scale than previously possible.

While the marine fishery has been heavily fished by foreign nations, the Senegalese and Mauritanian Governments are only now realizing the potential value of this resource as an exportable commodity and as a local food supply. The richness of the fishery is a result of the annual upwelling phenomena off the coasts of Senegal and Mauritania, which brings deep nutrient-laden waters to the surface. This results in a rich near-shore fishery from December to May. Other deep water fisheries may also be available for exploitation.

The following discussions relate the various facets of agricultural production to the nutritional intakes of the population within the Senegal River Basin. Table D.2-1 contains predictions of amounts of nutrients potentially available from the various levels of agricultural production. Table D.2-2 projects total numbers of calories and amounts of protein available for per-capita consumption. Based upon FAO statistics provided by the Friends of the Sahel, desirable levels of nutrient intake that O.M.V.S.

Table D.2-1

Summary of Projected, Available Amounts of Nutrition from Agricultural Products on an Annual Basis with Implementation of the Proposed Plans of Development
Senegal River Basin

Sources	Year 1980				Year 2000				Year 2028			
	Calories x10^7	% of total[1]	Protein Grams	% of total[1]	Calories x 10^7	% of total[1]	Protein Grams x 10^7	% of total[1]	Calories x 10^7	% of total[1]	Protein Grams x 10^7	% of total[1]
Recession Farming	15,354	16	440	7	14,458	6	433	4	6,958	1	203	1
Dieri Farming	13,600	14	400	7	6,800	3	200	2	-	-	-	-
OMVS Irrigated Perimeters	23,000	24	450	8	182,590	72	4,576	43	395,700	85	9,837	57
Livestock[2]	40,084	41	3,718	64	43,166	17	4,032	38	47,250	10	4,469	26
Riverine Fisheries	3,300	3	550	10	2,500	1	430	4	2,000	0	330	2
Salt Water Fisheries	1,400	1	240	4	5,320	2	912	13	14,000	3	2,400	14
TOTAL	96,738	100	5,808	100	254,834	100	10,583	100	465,908	100	17,239	100

1) Because of rounding-off of numbers, percentages do not always add up to 100.
2) Includes cattle, sheep, goats and to a lesser degree, pigs and fowl. It should be understood that, under the present subsistence economy, livestock is not consumed to the degree that may be possible under a cash economy.

Table D.2-2

Summary of Projected, Available Caloric and Protein Intakes for the Population of the Senegal River Basin on an Annual Basis With Implementation of the Proposed Plans of Development

	Year 1980	Year 2000	Year 2028
Population	1,649,500	2,901,100	6,274,500
Calories			
Total available (x 10^7)	96,738	254,834	465,908
Total desirable[1] (x 10^7)	138,476	243,547	526,744
Deficit/gain (x 10^7)	- 41,738	+ 11,287	- 60,836
Daily per capita availability	1,607	$\geq$ 2,300	2,034
Protein (Grams)			
Total available (x 10^7)	5,808	10,583	17,239
Total desirable[2] (x 10^7)	3,974	6,989	15,115
Deficit/gain (x 10^7)	+1,834	+3,594	+2,124
Daily per capita availability	$\geq$ 66	$\geq$ 66	$\geq$ 66

1) Assume average value of 2,300 calories per capita per day for projected Basin populations.

2) Assume average value of 66 grams per capita per day for projected Basin populations.

should strive to attain for the residents of the Basin are 2300 calories/capita/day and 66 grams of protein/capita/day.

Although no analysis was conducted of mineral and vitamin levels in the diet, it is normally assumed that these nutrients will become increasingly available as the quality of the diet, as measured by protein intake, improves. If the overall nutritional status of the inhabitants in the Senegal River Basin can be improved, there will be a decline in malnutrition and a decreased susceptability of the people to disease. Better nutrition will enhance the social well-being of the Basin by improving public health, which, in turn, will increase the inhabitants' vitality and efficiency in performing various activities. An increase in the economic status of the area may also result if a more productive worker is provided to the job market.

In 1980, livestock production, irrigated agriculture, recession farming and dieri farming will supply the most important sources of potential caloric intake, providing an estimated 41 percent, 24 percent, 16 percent and 14 percent respectively of the total caloric intake available to the inhabitants. This will leave a deficit of 417,380,000,000 calories providing 1607 calories/capita/day. This deficit can only be made up by importation of food products into the Basin.

It is estimated for 1980, that 61 percent of the available protein intake will be from livestock production. The remainder of the available amounts of protein will be equally distributed among the other sources of protein. A surplus of 18,340,000,000 grams of protein is projected which should allow the projected population to meet the minimum intake requirement of 66 grams/ capita/day. Realistically, although livestock provide an important potential dietary source of protein, fat and calories, their consumption for cultural reasons (i.e. sign of wealth and means of barter) is not anywhere near its potential. Livestock consumption patterns are expected to change under the future cash economy where currency rather than livestock will become the primary indicator of wealth in the Basin.

By the year 2000, agricultural production from the O.M.V.S. project will become the dominant source of available calories, superseding livestock

production and providing 72 and 17 percent respectively of the total available calories. Sorghum and rice will be the two most important sources of calories from the irrigated perimeters. The gross production from all levels of agriculture will result in a surplus of 112,870,000,000 calories allowing the possibility of attainment by the Basin residents of the minimum daily intake requirement of 2300 calories per person.

It is estimated that Basin development will provide a surplus of 35,940,000,000 grams of protein per year by 2000. This should allow inhabitants to meet minimum daily per capita protein intake requirements. The production of protein will be distributed between irrigation agriculture, livestock production and the fresh/saltwater fishery, yielding 43, 38 and 17 percent respectively of the available protein in the Basin.

By 2028, production from the irrigated perimeters will become the pre-dominant source of both caloric intake and protein, providing 85 and 57 percent respectively of these available nutrients. Because of the ever-increasing population, expanding at a rate of 2.3 percent per annum, a deficit of 608,360,000,000 calories per year is expected to exist. An estimated 2034 calories/capita/day will be available. Protein requirements will still be met, but the surplus will drop to about 21,240,000,000 grams of yearly available protein. Unless increased land is placed into irrigated agriculture, foods such as marine fish (accounted for in this nutritional analysis), rice and wheat will have to be imported into the Basin to supplement the diet of the projected 6.3 million inhabitants of the Senegal River Basin.

This analysis of nutrition is based on a number of assumptions that should be qualified. It was assumed that programmed levels of agricultural development will proceed at the scheduled rate of implementation. The expected annual crop yields assume proper management of irrigated perimeters using extension services. It has also been assumed that the dietary needs of the people will be met before any food is marketed for export. Realistically speaking, certain products may exist that will provide cost-effective returns from exportation. This in turn will provide the consumer with increased funds

with which to fulfill dietary requirements and other material needs from imported products. No attempt has been made to stratify nutritional intake by income levels nor to predict effects of a cash flow economy on the quality and quantity of food.

It should be pointed out that if population projections for the year 2028 of over 6 million people are reasonably accurate and agricultural production remains at approximately the same level as 1980, the daily per capita caloric intake could fall to as low as 424 calories/person/day while protein intake could fall to 26 grams/person/day. This would mean severe malnutrition of the inhabitants of the Basin, and under these conditions, an increased susceptibility of the people to disease.

The outcome of this integrated assessment indicates that the exponential increase in population within the Senegal River Basin and the resulting food demands will, from 2000 to 2028, exceed the linear growth of agricultural production. While it appears that the quality of the diet as measured by protein intake will remain adequate, deficiencies in the quantity of food consumed as measured by calorie intake will be a problem during this period. This caloric deficiency is evident even if it is assumed that all agricultural products produced within the Basin will be available for consumption by local inhabitants. Additionally, this deficiency is evident without having stratified the populace by age even though caloric deficiencies are more common in the younger age groups.

Caloric deficiencies may ultimately result in protein malnourishment even though adequate supplies of protein are consumed. This results from proteins being used as an energy source in place of much needed calories. Proteins are then lost as building blocks for growth, repair and preservation of the body and bodily functions.

The caloric deficiency which is projected to occur during the period from 2000 to 2028 will be in part attributable to the decrease in the yearly rate at which land is projected to be converted to irrigated perimeters during the period from 2021 to 2028. Based upon this Study's realistic adjustment of the Groupement Manantali rate of development, the average annual increase in

irrigated perimeters from 2011 to 2020 is projected to be 5540 hectares as compared to 4360 hectares for the period 2021 to 2028. The population in the same periods is projected to increase at a constant annual rate of 2.5%. The inevitable conclusion, assuming the projections for population growth and agricultural development are valid, is that, if caloric deficiencies are to be avoided during the latter stages of the program, provision must be made to increase the production or importation of foodstuffs within the Basin.

D.2.2 Public Health

Proposed developments will have a beneficial impact on health in the Senegal River Basin if measures to mitigate adverse impacts are effectively implemented. Changes in the prevalence of diseases, changes in food and water availability and changes in human populations will arise that impact on public health.

The enhancement of public health within the Basin will decrease physical suffering among its inhabitants and will increase the available time for family and employment activities as well as the securing of basic survival needs such as food and clothing.

Diseases - Future changes in disease prevalence are not quantifiable with any degree of accuracy because of variable factors concerning disease-carrying organisms and variations in disease resistance among Basin inhabitants. It is projected that vector mosquito breeding and subsequent malaria transmission is expected to increase as a result of year-round habitat from the construction of irrigated perimeters in the upper portion of the Middle Basin. The Manantali impoundment will have favorable vector snail breeding conditions, resulting in a significant increase in schistosome infections in that vicinity. Neither presently nor in the future will these diseases be considered a serious health threat to inhabitants of the Delta. With flow regulation after implacement of the Manantali dam, onchocerciasis could become a serious health threat downstream of the dam because of the year round availability of highly oxygenated, free flowing waters necessary for the successful breeding of the blackfly vector of this potentially blinding

disease. The high prevalence of endemic goiter in the Upper Basin is caused by an iodine deficiency. The diseases discussed above are controllable and do not pose a serious health threat to Basin inhabitants if health care programs and health education are instituted by appropriate governmental agencies of the Member States.

D.2.2.1 Availability of Food and Water

Proposed agricultural development in the Senegal River Basin is planned to enhance the nutritional well-being of the Basin inhabitants. The extent of this enhancement will depend on the types of crops grown and the availability of these crops to people in the Basin.

This study found malnutrition to reach a peak in March and April of each year just before the crop harvest, when food supplies were running low. On a long-term basis, the proposed irrigation agriculture program should provide readily available food supplies on a year round basis, eliminating the seasonally adverse nutritional status of Basin inhabitants. On a short-term basis, the elimination of cultivable land during the irrigated perimeter construction period will require stockpiling food grains to replace the lack of grain harvested during the conversion period. By maintaining or improving the nutrition of Basin residents, there will be an increased ability to resist disease and other health disorders.

Flows from the Manantali dam will be beneficial to public health by eliminating the often unsanitary pools that develop during the dry season in the Bafing and Senegal Rivers. Free-flowing water will be available year round for bathing, drinking and washing. Increased dilution and assimilation of pollutants reduce concentrations of contaminants. This beneficial effect of flow regulation will become increasingly important as developmental goals are attained, populations expand, and more contaminants enter the River.

Population - Changes in human populations will include increases in the numbers and densities of people within the Basin. Population resettlements will also occur. The proposed development program will create jobs and

encourage people to live where these jobs are available. Projected increases in the numbers and densities of population, especially in urban areas, will promote the transmission of health disorders among humans, unless proper planning is instituted in the form of health care and preventive programs, health education, proper water and waste disposal, and development controls. The conclusion that public health is enhanced by proposed developments is dependent on strengthening health facilities and providing sanitary conditions at population centers.

D.2.3 Migratory Patterns

Emigration from the Senegal River Basin, especially of working-age males in search of employment, has been increasing since the 1940's primarily because of encroaching desertification and a failing economy. This emigration reached critical levels after the drought of the early 1970's. Development of the Senegal River Basin will result in a net immigration into the Basin over the next 50 years because of increased employment.

Within the Basin, internal migration will occur from resettlement of villages that will be inundated by flooding behind the Manantali and Diama dams. Migration is also expected to take place from areas where people will outnumber jobs to regions, such as the Delta, where there is expected to be a rapid increase in employment opportunities.

A trend of migration is expected from the rural sectors of the Basin into the urban areas where a majority of the new jobs will be created. The migratory life style of herders will become more sedentary over the next 50 years as pastoral land diminishes and as the herders become increasingly involved in working the irrigated perimeters.

D.2.4 Employment

Over the next 50 years, development within the Senegal River Basin will bring about a gradual shift from traditional subsistence food production to a cash flow economy. There will be a major shift from traditional employment associated with fishing, herding and subsistence farming to intensive modern

irrigation agriculture in the rural areas, and to agro-industrial activities and supporting services in the urban areas. Improved navigation and the creation of ports along the River will provide additional opportunities for employment. Job opportunities are expected to expand more rapidly in urban areas rather than in the rural sectors of the Basin. Intensive, high paying employment opportunities will exist for five to six years in the early 1980's due to construction of the dams and navigational facilities.

D.2.5 Changes in Traditional Social Structures and Cultural Resources

Development of the Senegal River Basin will result in a major evolution of life styles and widespread cultural changes. One of the most significant changes that will take place in the Senegal River Basin is expected in the inter-relationships within the extended family. With the development of a cash flow economy and the increasing availability of jobs for youthful males, there will be a decline in the authority of the traditional family and village elders. This change will be compounded as better communications bring various conflicting social and religious thoughts into the area.

As rural families migrate into urban centers for employment, more importance will be placed on the nuclear family as social mores change. Ethnic and cast boundaries will disappear as economic disparity decreases and intermarriages take place.

In the rural areas, cultural activities, associated with traditional fishing, herding and farming will diminish as these subsistence life styles become obsolete under the cash flow economy. Many of the individuals associated with these activities will become involved in government-related irrigation agriculture. This change away from traditional activities will bring about a loss of independence previously associated with the subsistence life styles and a shift of authority from the village level to the regional and national level. Government regulation and distribution of land will jeopardize the existing caste system and affect the traditional system of land inheritance.

A decrease of indigenous crafts may occur in both the rural and urban sectors. As the result of an elevated economic status of the populace and improved transportation, there will be an increased preference for goods imported into the Basin. In rural areas, increasing pressures will be placed on the craftsman to abandon his trade in favor of working the more lucrative irrigated perimeters. In urban areas, there will be a decreasing need for traditional crafts as life styles become more sophisticated.