628 050300 820 628-0503

AGENCY FOR INTERNATIONAL DEVELOPMENT

PROJECT REVIEW PAPER FACESHEET

PD-AA6-083

1. TRANSACTION CODE: A (A = ADD, C = CHANGE, D = DELETE)

PRP

2. DOCUMENT CODE: 2

3. COUNTRY/ENTITY: OMVS

4. DOCUMENT REVISION NUMBER:

5. PROJECT NUMBER (7 digits): 628-0503

6. BUREAU/OFFICE: A. SYMBOL: AFR; B. CODE: 1

7. PROJECT TITLE (Maximum 40 characters): Water Data Collection

8. PROPOSED NEXT DOCUMENT: A. 3 PP; B. DATE: MM 0 9, YY 7 7

9. ESTIMATED FY OF AUTHORIZATION/OBLIGATION: A. INITIAL FY 7 8; B. FINAL FY 8 2

10. ESTIMATED COSTS ($000 OR EQUIVALENT $1)

A. FUNDING SOURCE	FIRST FY B. FX	FIRST FY C. L/C	FIRST FY D. TOTAL	LIFE OF PROJECT E. FX	LIFE OF PROJECT F. L/C	LIFE OF PROJECT G. TOTAL
AID APPROPRIATED TOTAL	1790		1790	[illegible]		[illegible]
GRANT	(1790)	( )	(1790)	([illegible])	( )	([illegible])
LOAN	( )	( )	( )	( )	( )	( )
OTHER U.S. 1.						
OTHER U.S. 2.						
HOST COUNTRY						
OTHER DONORS		300	300		1500	[illegible]
TOTALS	1790	300	2090	[illegible]	1500	[illegible]

11. PROPOSED FUNDING ARRANGEMENTS

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	PRIMARY TECH. CODE C. GRANT	PRIMARY TECH. CODE D. LOAN	E. FIRST FY ___ E. GRANT	E. FIRST FY ___ F. LOAN	LIFE OF PROJECT G. GRANT	LIFE OF PROJECT H. LOAN
(1) FX	163	[illegible]		1790		[illegible]	
(2)							
(3)							
(4)							
			TOTAL	1790		[illegible]	

12. PROJECT PURPOSE (Maximum 240 characters) ☐ PID COMPLETED

To strengthen the technical planning competence of the Secretariat of the OMVS by undertaking investigation to identify the location, quantity, and quality of sub-surface water and its relationship to surface water flows in the Senegal River Basin.

13. DATA CHANGE IN PID? WERE CHANGES MADE IN PID FACESHEET DATA, BLOCKS 12, 13, 14, OR 15? IF YES, ATTACH CHANGED PID FACESHEET.

1 (1 = NO, 2 = YES)

14. PLANNING RESOURCE REQUIREMENTS (Staff Funds)

15. ORIGINATING OFFICE CLEARANCE

SIGNATURE: Edward C. Fancy Jr.

TITLE: OMVS Coordinator

DATE SIGNED: MM 1 2, DD 1 0, YY 7 6

16. DATE DOCUMENT RECEIVED IN AID/W, OR FOR AID/W DOCUMENTS, DATE OF DISTRIBUTION: MM 1 2, DD 1 0, YY 7 6

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PROJECT REVIEW PAPER
TITLE: OMVS/SENEGAL RIVER BASIN HYDROMETEOROLOGICAL SYSTEM AND HYDROGEOLOGIC INVESTIGATIONS AND EVALUATION

1. Priority and Relevance

The strategy statement of the Development Assistance Program (DAP) for 1976-80 for the Central-West African region, of which the Senegal River basin is a part, concludes by stating that the United States must (1) continue to assist in increasing food production from drylands and present irrigated areas and (2) embark on assisting in the expansion of the productive resource base through river basin planning and development. Without comprehensive river basin planning to provide the mechanism for the more effective and efficient use of surface water and ground water, the agricultural productive resource base is condemned to oscillate from maximum to minimum depending on the magnitude and intensity of the rainfall and the flooding of the river, thus perpetuating the existing subsistence-level agricultural production. This situation can be changed, and the area could be developed to provide nearly all the agriculturally related requirements of the region and to export considerable quantities of livestock and produce to other Sahelian countries, other parts of Africa, or world markets. The organization, acquisition, and interpretation of vital water-resources data and the

training and development of the human resources of the area are required to accomplish these goals. The sector goal is to develop and utilize the human and natural resources of the Senegal River basin for increased food production. The most important response to this goal is river basin development—that is, the development of the surface-water and ground-water resources of the area, to be used separately or conjunctively, depending on availability, time-frame requirement for development, economic factors, etc. The purpose of the project is to strengthen the technical planning competence of the Secretariat of the Organization pour la Mise en Valeur du Fleuve Senegal (OMVS) by establishing within OMVS a hydrometeorological system to provide a continuous record of riverflow and rainfall, by time units, for key stations on the main stream and major tributaries. The system should provide the basic data essential for basin planning, flood warning, and water-resource project design and for the timing of agricultural activities related to flood and low riverflows. Another purpose of the project is to identify the location, quantity, and quality of ground water and its relation to surface water in the Senegal River basin.

One of the largest deficiencies in the initiation of development of the Senegal River basin is the lack of critical data on volume of discharge, peak-flow rates, and flood stages of the Senegal River and (or) its major tributaries at specific points along the river system.

Meaningful precipitation intensity data are needed at key stations in the headwaters area of the river system. The existing records contain few measured flood peaks, and the rating curves showing the stage-discharge relation at the streamflow-gaging stations are not well defined at peak stages. In fact, most of the curves are extrapolated or estimated from slope-area determinations. The riverflow in the lower basin below Bakel is not known because of unmeasured overbank flow and the difficulty in rating gage heights because of tidal influence.

Precipitation intensity data are available for only a few stations that are relevant to the prediction of runoff rates into the river system. Before effective river basin planning can be implemented, the following additional information is required: (1) precipitation-intensity data, (2) accurate determination of peak discharges, and (3) a continuous record of riverflows during flood periods. This is especially true for the determination of the probable maximum flood for the design of diversion and storage dams. Both types of dams are required if the river system is to be regulated to provide maximum utilization of the water resources in a multi-objective approach to development.

Another critical deficiency is the lack of data pertaining to the relation between different water stages and area flooded when the river overflows its banks. More detailed accurate topographic maps are required to delineate the flood-prone areas. The paucity of this

information and the seeming inability to get flood-warning information to the people cause loss of life to inhabitants and livestock and damage to crops and property. Conversely, if flood-recession information was available on a real-time basis, earlier or more timely planting could be done in the recession farming areas, which would enhance the probability of a successful harvest. An improved, expanded, and properly operated and maintained stream-gaging system and precipitation network and a rapid communication system are needed. An effective organization is also required to operate these systems.

The common shortcoming among developing nations is that government organizations tend to downgrade the importance of data acquisition and fail to realize that the success or failure of an entire development program is dependent on accurate and meaningful data. Deficiencies in facilities and equipment are the easiest problems to resolve when funding is available. The largest constraint facing a developing society is the lack of trained and experienced personnel who are properly motivated and adequately paid. The only way to overcome this deficiency is to develop an effective all-inclusive training program for all echelons of the project-development organization.

The program proposed in this project review paper is essential to accomplish the sector goal, which is the optimum utilization of the water resources of the Senegal River basin as determined through the media of river basin planning and development. The United States has an opportunity to play a critical role in helping these countries achieve this goal. The United States has expertise and interest in the following:

1. Organization and management.
2. Training.
3. Technical assistance.
4. Capital assistance.

2. Project Description

The project consists of the establishment of an improved hydrometeorologic and hydrogeologic system for the Senegal River basin. This multifaceted program would be granted funds over a 5-year period. The project would include (1) technical assistance, (2) provision and installation of equipment, (3) training of OMVS and member-country personnel, (4) analysis and evaluation of hydrometeorologic and hydrogeologic data, (5) establishment of a flood-warning and precipitation-reporting network, and (6) operating costs for the initial 5 years. It is essential that the project be very closely

coordinated with the programs now in operation by ASECNA and the CILSS [illegible]

coordination eliminates duplication and results in a supportive effort that will enhance the capability of all programs to attain their goals.

A. Technical Assistance

The technical assistance part of the proposed project would be conducted by a team - U.S. Bureau of Reclamation, U.S. Geological Survey, NOAA, or individual contract—composed of 1 senior hydrometeorologist for 5 years, 2 hydrologists for 3 years, 1 hydrogeologist for 3 years, and 1 communications technician for 2 years. The technical assistance team would function in an advisory capacity and would work with a counterpart team from the OMVS organization. OMVS would implement the project and would work with representatives from the different water-resources organizations of the member countries.

B. Provision and Installation of Equipment

The equipment required for the operation and maintenance of the hydrometeorological and communications networks would include the following:

1. Hydrometric equipment.
2. Meteorological equipment.
3. Surveying equipment.
4. Radio transmission and receiving equipment.

5. Land and water-transport equipment.

6. Access to computer equipment (terminal).

7. Office equipment and supplies

The equipment should be compatible with that being procured for the communications system of the CILSS Agromet-Hydromet system to facilitate in integration or intertie, if desired, and in the capability of being integrated into the different national communications systems maintenance and servicing programs. Streamflow-recording and measuring equipment and precipitation measurement equipment should be standardized to insure ease of operation and maintenance in the national or OMVS areas of responsibility.

C. Training of OMVS and Member-Country Personnel

Only a few trained personnel are available to man the proposed project. Training of personnel should be on a high level and should include one participant from OMVS and each of the three member countries in the fields of hydrometeorology and hydrogeology — a total of eight participants. The participants should be trained in the United States for 18 to 24 months and should aim possibly toward an M. S. degree. The candidates should be college graduates in the fields of civil engineering or geology as applicable. One equipment specialist from Mali, Mauritania, and Senegal should be trained in the United States for 8 to 10 months. Formal instruction and on-the-job train-

ing at suitable locations and institutions in the member countries should be included for the following technicians from the member countries and OMVS:

1. Four (4) engineering technicians (hydrogeology).

2. Twenty-five to thirty (25 to 30) hydrology and meteorology technicians.

3. Eight communications technicians.

D. Analysis and Evaluation of Hydrometeorological and Hydrogeological Data

The technical assistance team, working in conjunction with the OMVS and member-country counterpart personnel, would evaluate the existing data and the data-collection systems and design an improved hydrometeorological and hydrogeological system. The team also would design the required communications network and would order all equipment and supplies required to install, operate, and maintain the systems. The team would assist in the formulation of a system of compilation, analysis, storage, retrieval, publication, and dissemination of water-resources data for use by the OMVS and member countries.

E. Establishment of a Flood-Warning and Precipitation-Reporting Network

Using the above assembled data, the combined team would develop a hydrologic model to predict flood peaks and low water levels at different points along the river system. The information

would be disseminated to the inhabitants of the river basin through the [illegible]

F. Operating Costs for the Initial 5 Years

The major problem with the existing hydrometeorological stations is the lack of funds and trained personnel to properly operate and maintain them. Records for several stations having automatic recorders are not being obtained because of inoperable recorders due to the lack of maintenance and equipment servicing. Some staff gages are not being read because of the lack of funds to hire and retain qualified observers. Many gaging stations lack rating curves at high flows because of the insufficient personnel and equipment required for stream gaging.

An improved data-collection system with the accompanying operation and maintenance costs could not be financed based on the present inability to properly finance, operate, and maintain existing system. This inability may result from higher priority expenditures in other fields of the limited funds available. Under these circumstances such costs will have to be part of the grant-in-aid program.

OUTPUTS

The proposed A. I. D. project will result in the development of a system of hydrometeorological stations complete with equipment

and competent operators and observes to collect meaningful real-time precipitation and streamflow data in the Senegal River basin. These data will provide the basis for effective river basin planning of the water-resources development in the basin. Data collection would include water-quality and sediment data at selected sites. The project will clarify and substantiate the available ground-water data and will recommend expansions of data collection where needed to facilitate ground-water development. Special attention will be given ground water could be developed for irrigation. A telecommunications network will be established for the transmission of streamflow and precipitation data to a central headquarters for analysis and evaluation. Pertinent information will be relayed to the residents in the basin who are adversely affected by floods and who would benefit by timely flood-recession information.

An important and long-range output will be the training of about 50 people from countries in the Senegal River basin and OMVS in a variety of skills. The training will consist of a minimum amount of long-term training in the United States and a maximum amount of short-term formal and on-the-job training in hydrology, meteorology, hydrogeology, communications, planning, evaluation, and operation and maintenance of equipment. It is expected that the trainees will return to work in the pursuit of the goals of this project.

The critical assumptions underlying the output include the following:

1. There will be continued interest and cooperation on the part of OMVS; the governments of Mali, Mauritania, and Senegal; U. S. A. I. D.; and other organizations.

2. There will be improved coordination between OMVS and member-country agencies and interdepartmental coordination within each member country. There also will be close coordination between OMVS, ASECNA, and CILSS.

3. There will be sufficient qualified personnel assigned to the project from the United States, OMVS, and the member countries.

INPUTS

The success of this project will require specific inputs from U. S. A. I. D., OMVS, and its member countries. The U. S. A. I. D. input will consist of a technical assistance team, training, provision of equipment, and O and M funds for the initial 5-year period. The OMVS and member countries will provide professional counterparts, trainees, operational and installation personnel, sites for installation of equipment, duty-free entry of supplies and equipment, office space, and supportive services. The technical assistance team will consist of the following:

1. A senior hydrometeorologist or hydrologic engineer,

designated as team leader and program coordinator, having a tenure of five (5) years.

2. Two (2) hydrologists, working in conjunction with counterpart personnel, responsible for the operation of stream-gaging and precipitation-measuring stations, analysis of data, hydrologic-model development, and on-the-job training. The tenure of these individuals would be four (4) years.

3. A hydrogeologist to assist in the assembly and evaluation of available groundwater data, to supervise the ground-water monitoring program in conjunction with counterpart personnel, and to determine the need for and to direct additional ground-water studies and training. His tenure should be four (4) years with periodic returns to the area during the remainder of the program.

4. One communications technician for two (2) years with periodic returns during the remainder of the program. With the cooperation of counterpart personnel, he would design and install the communications system and conduct on-the-job training to establish an operational and maintenance capability among the indigenous personnel of OMVS and the three member countries.

5. One office manager, administration and supply, will be required for five (5) years, to take care of administrative details for the technical assistance team, order and administer commodity supplies, prepare or monitor local hire payrolls, prepare reports, perform on-the-job administrative and supply training with OMVS and member country personnel, thereby relieving technical personnel of these duties and enabling them to devote the maximum amount of time to their respective fields.

The use of consultants in the field of water resources should be planned over the 5-year program at the rate of 3 man-months per year.

Training has been covered in "Outputs" and is summarized as follows:

1. Eight (8) people for 18 to 24 months each for M. S. degree training in the United States.

2. Four (4) people for 8 to 10 months each for specialized training in the United States.

3. Thirty-seven (37) to forty-two (42) people for on-the-job and specialized training in the member countries.

The commodities will consist of equipment and supplies necessary to initiate, operate, and maintain the selected data-gathering stations. This equipment will consist of vehicles, boats, current meters, manual and recording-type rain gages, radio transmitters and receivers, generators and appertinent equipment, ground-water probes and measuring devices, and construction materials and supportive office materials, equipment, fuels, lubricants, various modes of travel, and local labor, etc.

The critical assumptions underlying the inputs include the following:

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1. The required technical experts for the advisory team can be recruited for the project.

2. Qualified candidates from member countries are available for training.

3. Member countries can financially support their parts of the project inputs (technical installation sites, office space, salaries for local professional personnel, etc.).

4. Project equipment and commodities can be cleared rapidly through customs on a duty-free basis.

5. The local markets can provide the basic requirements of labor and materials, on a timely basis, including resident observers at measuring stations.

Purpose

The purpose of this project, as previously stated, is to strengthen the technical planning competence of the Secretariat of the Organization pour la Mise en Valeur du Fleuve Senegal (OMVS). This can be accomplished in the member countries of OMVS by establishing a hydrometeorological system to provide a continuous reliable record of riverflow and rainfall, by time units, for key stations. The project is required to provide basic data essential for basin planning and water-resources project design. The project includes the establishment of a real-time river stage-precipitation reporting system that can be used

in the development of a flood-warning and a flood-recession forecasting system for the benefit of residents who are affected by the flooding or who are dependent on recession-type farming. A part of the purpose is to investigate the location, quantity, and quality of ground water and to identify areas having a ground-water irrigation potential. Critical assumptions underlying the purpose include the following:

A. The improved hydrometeorological network can be established and operated effectively.

B. Local physical and human resources are available to establish and operate the different systems on a cooperative basis.

Goal

The sector goal is to develop and utilize the human and natural resources of the Senegal River basin for increased food production. Some indicators of progress would include the following:

A. An increase in trained personnel in the water-resources development field.

B. Increased yields and cropping success on recession-type agricultural lands and a decrease in human, livestock, and property losses owing to floods.

C. The establishment of an effective system for the collection and dissemination of hydrometeorological data.

D. The establishment of a real-time flood-warning system.

E. The [illegible] for irrigation development.

Some critical assumptions include the following:

A. Availability of trainees and their extended tenure on the project after receipt of training.

B. Residents will use the information generated by this project to advantageously modify their farming practices.

C. The program will continue to be operated by OMVS and River. At first, the Union Hydroelectrique Africaine (UHEA) and, above all, the MAS (Mission d'Amenagement du Fleuve Senegal) made some experiments forecasting floods; after Independence, the National Services of River States gradually took over this task. Flood gages were installed and observed at several sites including Bakel, Kayes, Ambidedi, Mahina, etc. Both the Senegalese and Malian governments have on-going bilateral programs with the Office de Recherche Scientifiques et Techniques, Outre-Mer (Paris) (ORSTOM) to upgrade and equip selected river gaging stations in the Senegal River basin.

According to the Senegal-Consult Study, although gage-height records and stream-gaging measurements have been made at many stations, only 13 stations have adequate records that can be used as a reliable basis for hydrologic studies.

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Ground-water surveys and development programs are currently undertaken by the Hydrologic Services Agencies of the three member countries. In addition, numerous ground-water surveys have been made and reports prepared by the Bureau de Recherches Geologiques et Minieres (BRGM) as a consulting service to agencies of the three member countries.

The Agence pour la Securite de la Navigation Aerienne-Dakar (ASECNA) performs a weather-forecasting service for aircraft, using meteorological data from the three member countries. The existing the member countries after the termination of the 5-year project.

D. Water-resources development plans will be implemented using the data generated by this project.

3. A.I.D. and Other Relevant Experience

How much experience A.I.D. has had in projects that are exactly as proposed in this report is not known. It is known that A.I.D. and its cooperators, under PASA agreements, have had considerable experience in the individual facets of this project—i.e., stream gaging programs, ground water investigation and development programs, river basin and project planning programs, training and communications systems, and precipitation data-gathering systems. The U.S. Bureau of Reclamation has had vast experience in water-resources development projects from basic-data gathering programs, investigations, planning,

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design, and construction on large and small scales in the United States and in many foreign countries. The U.S. Geological Survey is [illegible] in the field of surface-water and ground-water resources investigations and development programs. The Corps of Engineers and NOAA have established flood-warning systems in the United States. This project is intended to further develop and utilize existing and prior programs, improving and augmenting them to provide accurate and usable data.

From the beginning of this century, different organizations have worked to obtain a better knowledge of the behavior of the Senegal climatological network in the upper Senegal River basin consists of:

1. Eleven (11) synoptic stations.
2. Sixteen (16) climatological stations (auxilliary stations).
3. Fifty-one (51) precipitation stations.

In general, most of the synoptic stations have radio real-time reporting facilities.

An extensive Agromet-Hydromet system is being established under the auspices of the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS) throughout the Sahelian area. This system includes several river gaging and precipitation stations in the Senegal River basin.

One of the objectives of the A.I.D. project is to assist OMVS in coordinating the water-resources activities of these different organizations.

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4. Beneficiary

The project has a trifold purpose that can have some almost immediate and some long-term benefits. An immediate benefit from the project would be the receipt of real-time data on river water surface elevations—dates and times when critical flow elevations will occur along different reaches of the Senegal River and its tributaries. Notification of the time when the threat of flooding is past and planting can begin will allow more effective use of the available soil moisture in the land that had been previously inundated.

An intermediate and long-range purpose of the project is to develop the technical capability of the human resources of the area through short-term and medium-term training of personnel. The training will enable local people to become more proficient in the location, installation, and operation of water-resources data collecting facilities and in the interpretation and utilization of the data collected for planning and operation of water-resources projects, using surface-water and ground-water supplies.

Although this is not a water-resources development project, it will provide the essential data base and trained personnel required to assist in the planning and implementation of such projects. The benefits derived from multipurpose projects would be very extensive. These would include, but not be limited to, the following:

1. Increased food production through irrigation.

2. Flood control and stabilized river conditions.

3. Improved navigation (transportation).

4. Hydroelectric power generation.

5. Control of ocean salinity intrusion.

Secondary benefits under such development would be mining and industrial development, which would permit a better balanced economy.

The principal social impact this project would have on the people of the region would be the potential reduction in flood damages and related hardships. Increased agricultural production from improved management of recession farming would also have a positive social effect. Future water-resources development projects would have a major social impact. This evaluation would have to be made in conjunction with these development plans.

5. Feasibility Issues

A. Economic Issues

Economic issues, as normally defined, are not applicable to this project, which is primarily of an infrastructive building and training nature. The basic data generated by this project are necessary to plan and implement water-resources development projects, estimated to cost in excess of $3,000,000,000. The cost of this program, which is in the magnitude of $5,527,000 is a minor fraction of this total

investment; therefore, economic issues are pertinent to subsequent development rather than this project.

B. Technical Issues

The facilities proposed in this project are not necessarily the most sophisticated available but have been selected to be compatible with facilities existing and currently proposed by other organizations. It is believed that this type of equipment can be operated and maintained effectively under local conditions. At the time when water-resources development projects are implemented, conditions may be such that upgrading these facilities may be warranted. There is well-drilling expertise and equipment available in the basin in both the governmental and private sectors. This capability should be sufficient to take care of any ground-water investigations envisioned under this project.

C. Financial Issues

The project will require A.I.D. support for the 5-year tenure of the project. There is a possibility that the OMVS and the member countries will not be able to finance the operation and maintenance of the system after this contractual period and may require at least partial support to keep the system operable.

6. Other Donor Coordination

There are no other donors directly involved in this project. The project agreement will be signed by the OMVS, who will coordinate the activities and inputs of the member countries.

7. Financial Plan

A. A.I.D. inputs are expected to total $5,527,000 for the 5-year tenure of the project. (See next page for details)

B. OMVS inputs will consist of land for the equipment sites, candidates for training counterparts, required office and supportive services, and duty-free entry of project commodities. A value of $1,500,000 has been given to the OMVS inputs.

8. Implementation Plan

The OMVS will be the Grantee Agency. It is expected that technical services will be contracted for through the U. S. Bureau of Reclamation. The OMVS through a Project Director will be responsible for the implementation of the program with the concurrence of the technical assistance team leader. It is anticipated that the technical assistance team will be functioning in an advisory and consultative capacity to enhance the potential for the development of indigenous technical personnel within the OMVS and the member countries.

Contact with member-country governments at the policy level will be through OMVS, which will also coordinate the various activities with member government agencies. Working relationships are expected to develop between the technical assistance team and the OMVS and member-country personnel.

With A. I. D. /W approval of the PP, final project details can be worked out with OMVS in fiscal year 1977, at which time a project

FINANCIAL PLAN FOR AID INPUTS: IN OBLIGATIONS
($000)

A. Technical Services	FY 78	FY 79	FY 80	FY 81	FY 82	Total
1 Team Leader, Hydrometeorologist $65,000/yr. x 5	80	65	75	65	80	365
1 Office Manager, Admin and Supply $53,000/yr. x 5	68	53	68	53	68	310
2 Hydrologists, $58,000/yr x 4 + 2 person/m/yr x 1 @ $6000	146	116	136	146	12	556
1 Hydrogeologist, $58,000/yr x 4 + 2 person/m/yr x 1 @ $6000	73	58	68	73	12	284
1 Communications Specialist $58,000/yr x 2 + 2 person/yr x 3 x $6000	73	73	12	12	12	182
Consultants - 3 person/m/yr @ $6000	18	18	18	18	18	90
Sub-Total	458	383	377	367	202	1,787

B. Training	FY 78	FY 79	FY 80	FY 81	FY 82	Total
8 Participant Training - 2 yrs 18 mo. Acad - 6 mo. OJT (4 Hydrologists & 4 Hydrogeologists) @ $13,600/yr.	109	109				218
4 Short-Term Spec-TMG-Communications 10 mo. @ $1250/mo.	50					50
40 In-Country Training - 2 mo. ea. @ $600/mo.	24	24				48
Sub-Total	183	133				316

FINANCIAL PLAN FOR AID INPUTS: IN OBLIGATIONS
($000)

C. Commodities	FY 78	FY 79	FY 80	FY 81	FY 82	Total
Hydrogeological equipment	5	3	1	1		10
Hydrometric equipment	140	10	5			155
Meterological equipment	75	10	2			87
Surveying equipment	32					32
Radio communications equipment	250	22	6	3	4	285
Land transport	193					193
Water transport	50					50
Local construction materials	20	30	15	5	5	75
Office equipment	13	3				16
Sub-Total	778	78	29	9	9	903
D. Other Costs; Construction, Drilling and Operation						
Vehicles, Operation & Maintenance	30	50	60	60	40	240
Utilities, Miscellaneous	8	10	10	10	7	45
Access to computer facility (Dakar)	5	20	20	20	20	85
Well drilling contract (40 wells)		360	600			960
Office supplies	10	8	8	8	6	40
Observers and local labor	20	75	45	45	45	230
Grand Sub-Total	1,492	1,117	1,149	519	329	4,606
E. Contingency and Inflation - 20%	298	223	230	104	66	921
GRAND TOTAL	1,790	1,340	1,379	623	395	5,527

PRP
Summary Cost Estimate and Financial Plan
(US $000)

	AID		Host Agency (OMVS)		Other		
	Fx	LC	Fx	LC	Fx	LC	Total
Technical Services	1,787	--	--	--	--	--	1,787
Training	316	--	--	--	--	--	316
Commodities	903	--	--	--	--	--	903
Other Costs	1,600	--	--	1,500	--	--	3,100
Inflation Factor	460	--	--	--	--	--	460
Contingency	461	--	--	--	--	--	461
TOTAL	5,527	--	--	1,500	--	--	7,027

Incrementally Funded Projects
Project Summary - AID Appropriated Funds
(In $000 or EQ)

Country OMVS PRP New X Rev.#

Project #628-0503 & 628-507 Title OMVS Hydrometerological System and Hydrogeologic Investigations

Cost Components	Budget Year Direct AID	Contract Other Agency	Total
U.S. Technicians	--	549	549
Participants	--	220	220
Commodities	--	933	933
Other Costs	--	88	88
TOTAL	--	1,790	1,790

agreement can be drafted in order to obtain signatures in early fiscal year 1978. Preliminary contract discussions with the U. S. Bureau of Reclamation can also begin in fiscal year 1977 so that a contract can be signed shortly after the project agreement is approved.

A. Technical Assistance Team (Combined)

1st Year

The sequence of activities involving the full membership of the team is listed below:

1. Formation of the team.

2. Order office and supportive supplies and equipment.

3. Arrival in country—set up office facilities, etc.

4. Integration of technical assistance team with staffs of OMVS and member countries.

5. Develop a final list of trainees for United States training and initial group for in-country training.

6. Make final arrangements with training institutions and initiate training program.

7. Begin the inventory, compilation, and analysis of existing hydrometeorological and hydrogeological data and installations.

8. Complete list of trainees for in-country training.

B. Technical Assistance Team (Hydrometeorologic Section)

The sequence of activities involving the hydrometeorological phase of the project is listed below:

1st Year

1. Selection of tentative project data-collection sites, field reconnaissance, and finalization of actual location.

2. Design improved data-collection and communications systems.

3. Order technical equipment and commodities.

4. Organize installation and operational personnel to upgrade existing facilities, acquire new sites, and initiate measurements at these sites.

5. Accelerate efforts to obtain measurements and data at all sites during the wet season.

2nd Year

6. Receive and install newly acquired equipment and initiate operation of this equipment.

7. Detailed compilation and analysis of existing data.

8. Utilizing new topographic maps, start to analyze the water stage elevation-area of inundation relationship in flood-prone areas.

3rd Year

9. Start formulation of hydrologic model to facilitate flood forecasting.

10. Organize mechanism to disseminate hydrometeorological data pertaining to flood peaks and flood recession to the general populace.

11. Continue on-the-job training.

4th and 5th Year

12. Continue operation and maintenance of data-collection and flood-warning systems.

C. Technical Assistance Team (Hydrogeologic Section)

The sequence of activities for the hydrogeologic phase of the project would be as follows:

1. The first year will be required to collect and review exising ground-water data and interpretive reports in conjunction with counterpart staff.

2. During the second year, the evaluation of existing data will continue, and a preliminary report--complete with maps, etc.--will be prepared delineating areas of potential irrigation from ground water. Sites for approximately fifteen (15) test wells will be selected and drilling operations initiated.

3. During the third year, the drilling and testing of the initial fifteen (15) wells will be completed, and an additional twenty-five (25) test wells will be located, drilled, and tested.

4. During the fourth year, final interpretive reports will be prepared complete with maps, etc.

9. Project Development Schedule

A. The following actions will be required in order to complete all preauthorization work on this project.

This PRP should be reviewed by AID/W before December 31, 1976.

The Project Paper (PR) can probably be completed by about April 1, 1977. It is believed that only a minimal amount of additional effort will be required and that one or two people for two weeks in the field can gather the additional details, particularly to evaluate progress on, on-going hydrometerologic projects, by other agencies or organizations. The progress on these projects could materially affect the amount of facilities required at the various installation sites, both the technical and communications equipage and probable personnel requirements for this AID project.

There should be a renewed effort by OMVS to locate and assemble all available hydrometerological and hydrogeologic data to be used by this project to expedite this phase of the program.

The flood effect portion of this project is also predicated upon the completion of the proposed topographic mapping program. These maps would be required to complete the flood evaluation-flood warning activities of the project.

Increased coordination among the various involved departments within the member government of OMVS; between the member governments, OMVS and other organizations and agencies doing work in the hydrometeorological or hydrogeologic field would be highly advantageous and should be encouraged.

Finally, the watershed area of the Senegal River situated in Guinea is the key to the Senegal River System. It contains only about fifteen (15) percent of the drainage area but generates over fifty (50) percent of the runoff. Every effort should be exerted to establish or improve communications and the transfer of hydrometeorological data between Guinea and OMVS and its member countries.

Members of this Project Review Paper team were:

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Personnel contacted during the tour of duty in West Africa were as follows:

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Mr. Joseph C. Guardiano, OMVS Program Coordinator
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OMVS

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APPENDIX A

ASSESSMENT OF SURFACE WATER INFORMATION IN THE SENEGAL RIVER BASIN

Basin Description. The Senegal River is the second largest river in West Africa (the largest being the Niger). The Senegal River is over 1,800 kilometers (1,100 miles) long and drains a watershed of about 290,000 square kilometers (113,000 square miles) and produces an average annual flow of over 20 billion cubic meters (16 million acre-feet). The drainage basin is located in the countries of Senegal, Maurtama, Mali and Guinea. The watershed area in Guinea comprises only about 11 percent of the total basin but about 50 percent of the streamflow originates there. No significant flows are added to the Senegal below its junction with the Faleme at the head of the river flood plain, some 825 kilometers upstream from the ocean.

Over 80 percent of the runoff occurs in the three months of August, September, and October. The average monthly flows vary from about 10 m ^{3}/s (350 ft^3/s) in May to about 3,400 M^3/s (120,000 ft^3/s) in September. An important indicator for the practice of flood recession agriculture is the average flow for the peak month. This maximum month flow has varied from the average of 3,400 m^3/s to a high of 5,891 m^3/s (208,000 ft^3/s) and to a low of 918 m^3/s (32,500 ft^3/s). During the period of flooding the rate of flow of the river may reach up to 10,000 m^3/s (354,000 ft^3/s) at Bakel.

Climatologically, the basin goes from semi-arid in the north to tropical in the south. Average annual rainfall varies from 250 millimeters (10 inches) in the north to 2,000 millimeters (86 inches)

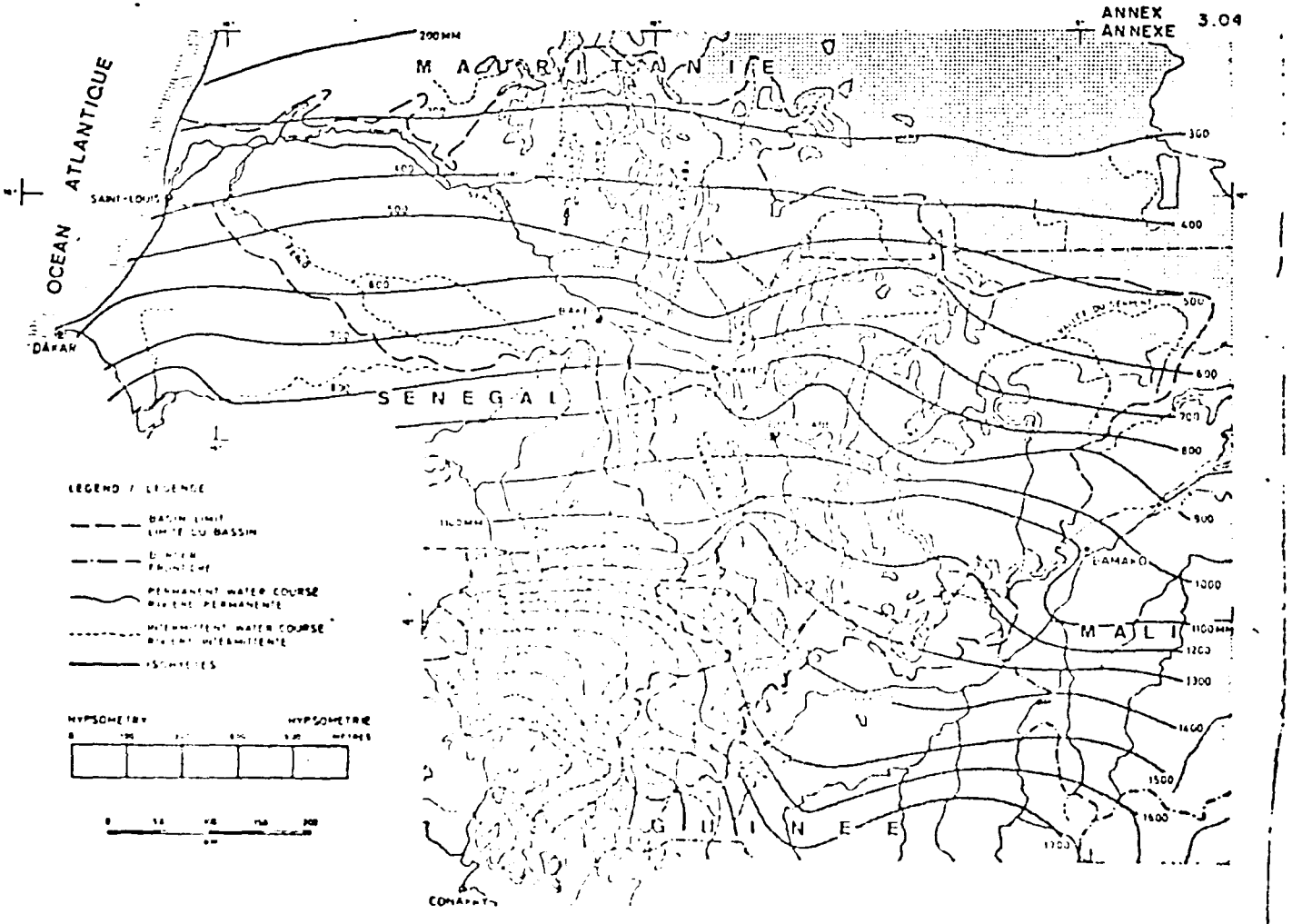
in the south as shown on the map on the following page. In the north, the rainy season lasts only 3 months, July-September, while in the south it occurs in the April-November period.

During the rainy season, the monsoon winds from the south and southwest bring warm, moist air into the basin. During the rest of the year, the dry harmattan winds from the east and northeast prevail. These result in daily maximum temperatures, averaging about 43°C (109°F) in May. Daily minimum temperatures occur in January averaging about 17°C (63°F). Average annual values of relative humidity are generally from 50 to 60 percent, but monthly values range between 10 and 90 percent. Annual potential evaporation varies from 1,500 millimeters (59") in the Guinean area to 3,400 millimeters (134") in the north of the basin.

As the rainfall decreases northward - so does its reliability, so that for the river flood plain downstream below Bakel in most years, the rainfall is not adequate for growing crops.

Flood Hazard. The annual flooding of the Senegal River provides the source of moisture for the subsistence (flood recession) agriculture practiced by the riparian population. At the same time excess flooding endangers the lives and property of the people.

Over one-half million people live within the Senegal River Basin, most within the river flood plain downstream of Bakel Senegal. Historically the river has meandered over the lower valley, which averages about 15 to 20 km wide, leaving many oxbows



UNITED NATIONS	NATIONS UNIES
SENEGAL RIVER PROJECT	PROJET D'AMENAGEMENT DU FLEUVE SENEGAL

SENEGAL RIVER BASIN
PLUVIOMETRIC MAP

BASSIN DU FLEUVE SENEGAL
CARTE PLUVIOMETRIQUE

SENEGAL — CONSULT SCALES DATE 15 12

and old channels locally called "marigots". The river has built up natural levees along its main channel so that the land slopes away from the river bank to the chain of lakes and low swampy areas. Tributaries or other connecting channels punctuate the main river bank at intervals providing access for floods from the river to flow into this system of marigots. Most of the villages are located at the higher places on the river bank where the flooding is less frequent.

However, most of the river flood plain and the villages along the river bank are inundated when the higher peak flows occur with loss of life and property of the villagers.

The travel time for the peak flood flows is as follows:

KP	Station	River	Travel Time Days
	Dokka-Saidou	Bafing)	2
	Bafoulabe	Jct. W)	
		Bakoye	1
	Keyes	Senegal	
794	Bakel	Senegal	2
169	Dagana	Senegal	45

An adequate flood warning system would permit the valley population to move their possessions to higher ground and to know the practical extent of dike reinforcement.

In addition to the more primitive "flood recession" agriculture traditionally practiced by the river valley population, an agency of the Senegal Government "SAED" 1/ has been constructing

1/ SAED - Societe d'Amenagement et d'Exploitation des terres de Delta et de la Vallee du Fleuve Senegal

modern irrigation projects along the river. About 11,000 hectares of land has been developed with additional projects planned. These are expensive developments often involving more than a thousand hectares each, complete with pumping plants, irrigation systems and flood protection dikes. The dikes are usually designed for about a 1 in 10-year frequency flood. Therefore an adequate flood warning system is essential for protection of facilities when floods might overtop the dikes.

Agriculture. A detailed knowledge of the flows of the Senegal River is important for three sectors of the valley agriculture. The sectors include the traditional flood recession agriculture, the modern irrigation projects and ocean salinity intrusion in the Delta area.

An adequate determination of arable land in the Senegal River Basin is not available; however the Senegal - Consult report 1/ lists the following areas:

	Hectares
Total valley land Bakel to San Luis	1,050,000
Total arable area (61 percent)	640,000
Arable land middle valley; Bakel-Dagana	510,000
Arable land in Delta below Dagana	130,000

In years of average or small floods, about 100,000 hectares of dry land are cultivated which are dependent only on the rainfall. Seeding of these crops is started shortly after the beginning of the rainy season and they are grown from June through October.

1/ Feasibility Survey for the regulation of the Senegal River - Senegal Consult, Switzerland 1970

these crops are at harvest stage when the floods are receding. Depending on their quality, they are frequently abandoned in favor of cultivation of the lands that has been inundated. Inundated dry farmed lands may also be reseeded to recession crops.

The area cultivated after the recession of the floods varies as a function of the height of the flood and the date and rate of receding.

The frequency and the area of inundation and cultivation are estimated as follows:

	Years out of 100	Hectares Inundated	Hectares Cultivated
Large flood	5	230,000	180,000
Medium flood	50	130,000	130,000
Small flood	95	80,000	80,000

In addition to the amount of available soil moisture, crop yields depend upon the date of the flood recession which affects the possible date of seeding and thereby affects the stage of the plant at the beginning of the harmattan. Recession crops are generally planted in November and harvested in February. The harmattan occurs during February and March.

The location and pattern of the flooded lands and dry cropped land is lacking. The following seems to be the generalization for 230,000 hectares of cultivated land:

Size of flood	Area Inundated	Recession Agriculture	Dryland Agriculture	Total Planted	Idle	Total Cultivated Land
Large	230,000	180,000	0	180,000	50,000	230,000
Medium	130,000	130,000	100,000	230,000	0	230,000
Small	80,000	80,000	100,000	180,000	50,000	230,000

In drought years, there are periods of no flow at Bakel in June.

Downstream of Bogha (about 380 km from the mouth) the streambed of the river is below sea level. During the dry season, ocean salinity can intrude up the river to this point. The following tabulation lists the extent of intrusion for various rates of streamflow as reported by the Beyrard study.[1/]

Flow (m^3/s)	Distance of Intrusion (km)
300	60
200	75
150	90
100	115
50	140

As the saline water moves upstream, the irrigation projects relying on the river for their water supply must curtail their operation. The operation of these irrigation projects could be much improved through adequate predictions of the rate and extent of the salinity intrusion.

Planned Water Resource Development. The Senegal River Basin Development Authority (L'Organisation pour la Mise en Valour du Fleuve Sénégal - OMVS) includes the Republic of Mauritania, Mali, and the Republic of Senegal, three countries of the Sahel which have agreed to concert their efforts to develop the Senegalese River Basin.

1/ Program Integre de Development du Bassin du Senegal -- P.N.V.D., OMVS - Norbert Beyrard, France - 1974

Therefore, they created an organization, the OMVS and adopted a joint program which will aim, among other goals, to stabilize the incomes of a maximum number of the population (farmers, livestock breeders, fishermen, etc.) and to establish a more stable equilibrium between man and his environment by making him less vulnerable to climatic fluctuation and the irregularity of flooding. This equilibrium can be established through the control of the river flow and the introduction of irrigated cultivation.

All of these objectives may be accomplished through inter-state cooperation resulting in the integrated economic development of the three States.

In the medium term, this means:

1. On the regional level, establishing a basic infrastructure which would include:

- A hydroelectric dam reservoir at Manantali on the Bafing 80 km from Bafoulabé. Its functions would be to regularize the river flow to 300m3/s at Bakel, thus permitting year-round navigation between Saint-Louis and Kayes the irrigation of some 400,000 ha of land in the valley and the generation of 800,000 kilowatt hours of energy destined for the production and processing of the Basin's mining resources.

- A Hydro-agricultural dam at Diama in the delta, 20 km upstream from Saint-Louis. Its functions would not only be to irrigate 30,000 ha (double crop) and to supply water to R'Kiz lakes at Guiers and to the Artout Es Sahel, but also to prevent seawater intrusion.

- A river-seaport at Saint-Louis, a river port at Kayes and 9 ports of call. These works will be indispensable once the river is regularized and opened to perennial navigation.

2. On the national level, a combination of national programs which would result in better profits for the joint infrastructure.

- Development of more than 400,000 ha in double crop irrigation.
- Exploitation of the Basin's Mining Resources and Development of Industry etc.

One should note that important studies have been carried out in this area with the assistance of UNDP. In the beginning, these studies permitted determination of the Basin's potentials and later the setting of priority objectives for certain projects.

These projects include:

- A study for a system of control of the river flow in the Senegal River Basin (Regularization project).
- Study of the navigability of ports on the Senegal River.
- Irrigation studies.
- Agronomic research, etc.
- Integrated development programs for the Senegal River Basin (Norbert Beyrard) etc.

Now that the OMVS is preparing to enter the final phase of its integrated development program for the Senegal River Basin, further knowledge, indeed forecasts of the floods and low water levels of the river is a necessity of an increasingly urgent nature.

Existing Data Since the beginning of this century, knowledge of the Senegal River's behaviour has been of interest to river dwellers. Flood gauges were installed and observed in various characteristics sites such as Bakel, Kayes, Ambidedi, Mahina, etc..

Various organisms have worked to establish and use a hydrologic system. Until 1960, the most important work in this area was accomplished by the Union Hydroélectrique Africaine (UHEA) and above all, by the Mission d'Amenagement du Fleuve Sénégal (MAS). Since then, competent technical services from the River States have gradually taken over this work.

The Climatological Network of the Basin. Considering that the river is essentially supplied by flows from the Upper-Basin, only the stations upstream from Bakel will be taken into account. There are:

- 11 synoptic stations (Main climatological stations)
- 16 climatological stations (auxiliary stations)
- 51 precipitation stations.

The geographical location of these stations and their installation dates are specified in the Report of SENEGAL-CONSULT V.3A annex 3.0.7.

All data relating to these stations are available at national meteorological services in the States.

Hydrometric network. The current network is comprised of the following principal stations:

a) In the Upper-Basin

- on the Baoulé: Parc Baoulé, Missira and Siramakana
- on the Bafing: Dakka-Saidou, Bafing Makana, Soukoutali, Dibia and Mahina
- on the Falémé: Moussala, Gourbassi, Fadougou, and Kidira
- on the Kolombiné: Kobaté
- on the Karokoro: Bokediambi
- on the principal River: Bafoulabe, Galougo, Gouina, Felou, Kayos, Ambidedi, Segala, Koungani and Bakel.

b) In the valley

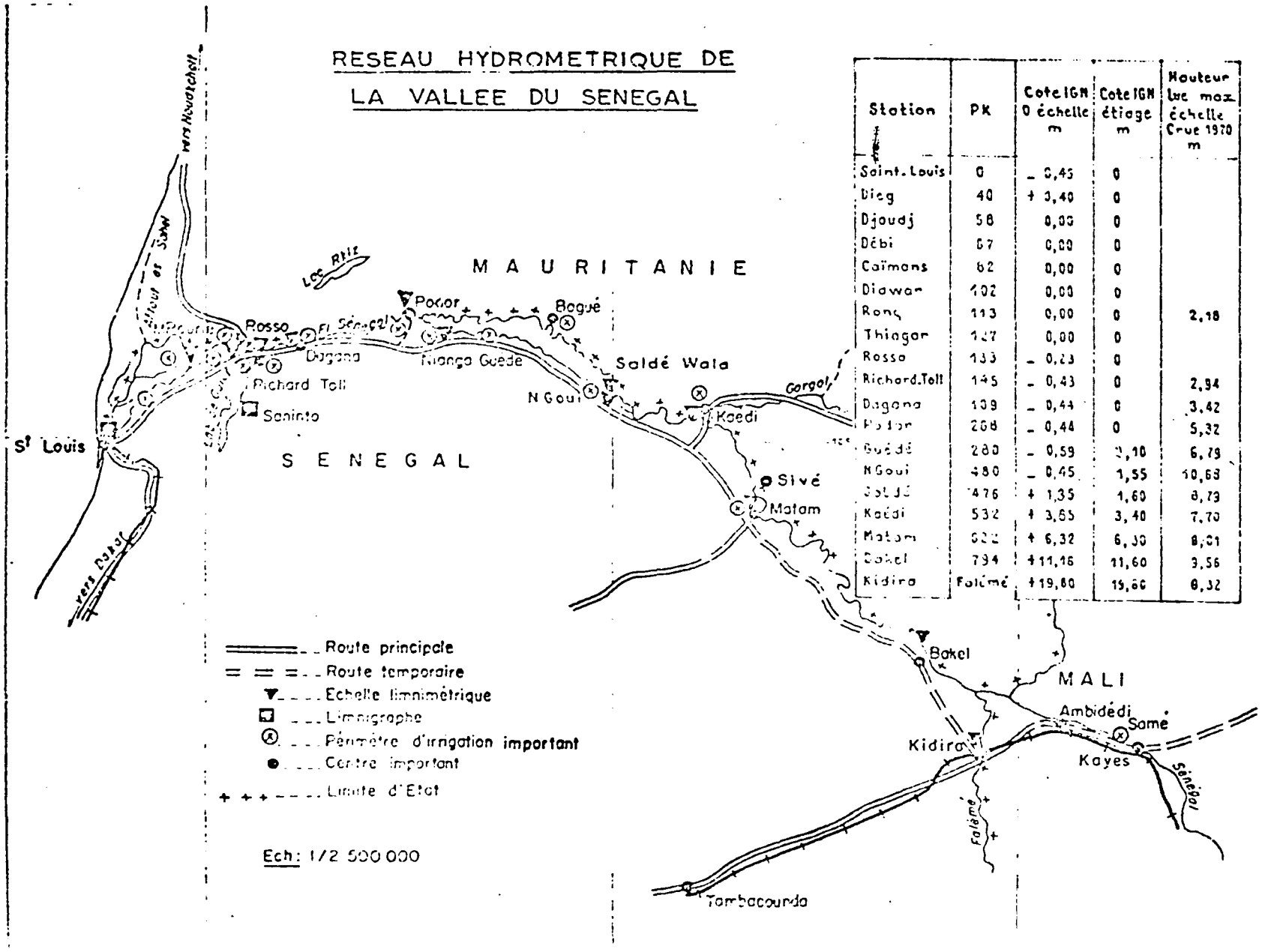
Ouasandé, Matam, Kaédi, Saldé, Diouldé Diabé, Boghé, Podor, Dagana, Richard-Toll, Rosso and Saint-Louis.

Naturally, the data received from these stations are not of equal value. Certain stations such as Bakel, Kayes, Ambidédi, Mahina are fairly old, while others are more recent. But the majority of the gauges were installed after 1950.

A preliminary gathering, treating and reevaluation of data were made by ORSTOM from 1765 to 1968. The results obtained appear in a voluminous monograph. For some years, the hydrological service in Mali has also published hydrological annuaries.

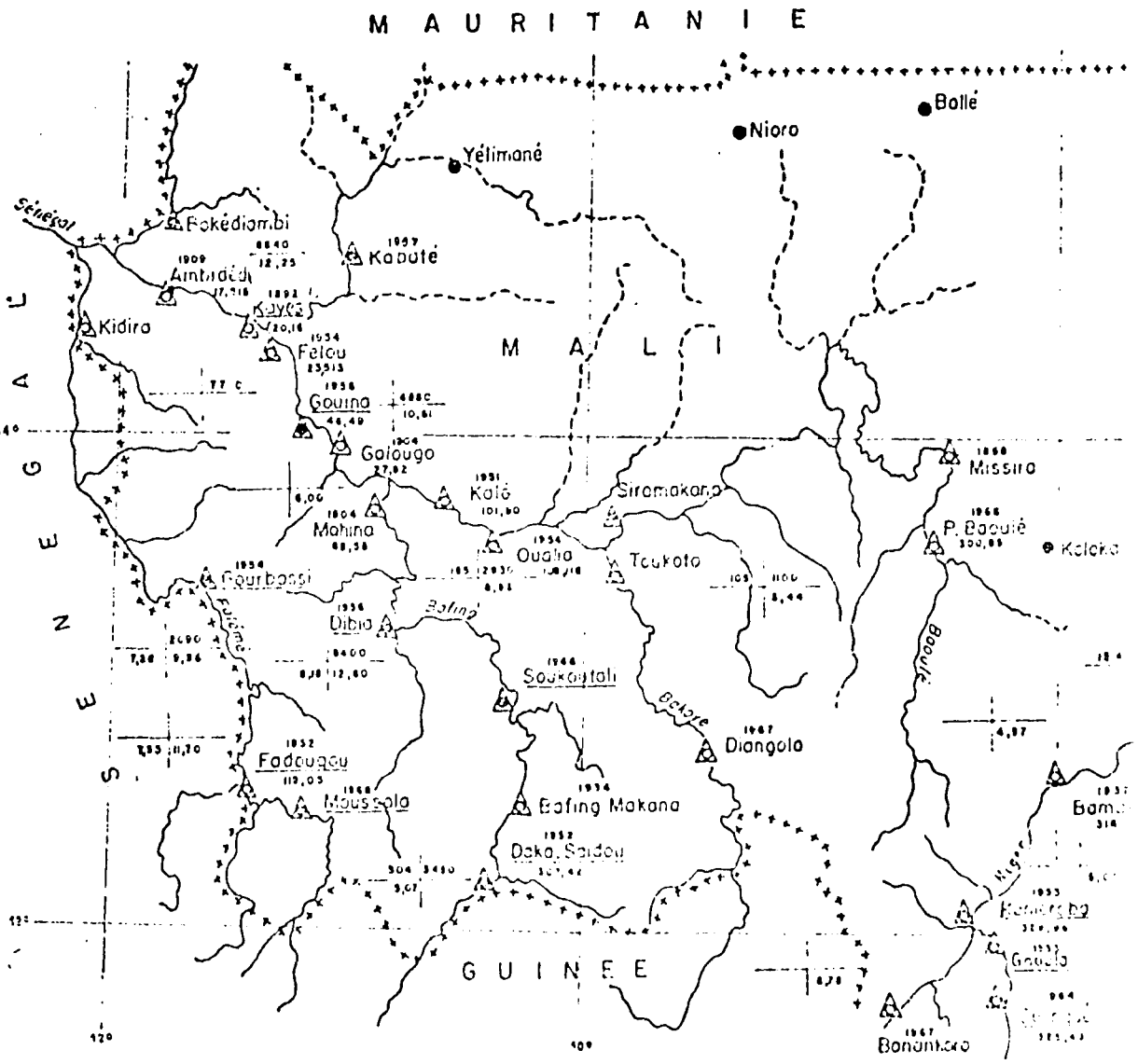
The location of the present gaging stations are shown on the following two plates (one for the upper basin and one for the lower basin).

RESEAU HYDROMETRIQUE DE LA VALLEE DU SENEGAL



Station	PK	Cote IGN 0 échelle m	Cote IGN étiage m	Hauteur lue max échelle Crue 1970 m
Saint-Louis	0	- 0,45	0	
Diag	40	+ 3,40	0	
Djoudj	58	0,00	0	
Débi	67	0,00	0	
Caïmans	82	0,00	0	
Diawar	102	0,00	0	
Rong	113	0,00	0	2,18
Thiagar	127	0,00	0	
Rosso	133	- 0,23	0	
Richard-Toll	145	- 0,43	0	2,94
Dagana	159	- 0,44	0	3,42
Podor	208	- 0,44	0	5,32
Guédé	280	- 0,59	0,10	6,79
N'Goui	480	- 0,45	1,55	10,63
Saldé	476	+ 1,35	1,60	8,79
Kaédi	532	+ 3,65	3,40	7,70
Matam	622	+ 6,32	6,30	8,01
Bakel	734	+ 11,16	11,60	3,56
Kidira	Falémé	+ 19,60	19,60	0,32

RESEAU HYDROMETRIQUE DU HAUT-BASSIN DU SENEGAL AU MALI



Echelle limnimétrique

Echelle limnimétrique + limnigraphe

Diaïla Station de jaugeages

1952 Date d'installation de l'echelle

267,00 Kara Cote I.G.N. du zéro de l'echelle en m

1	2
4	3

1. Module interannuel en m³/s
2. Débit maximum observé en m³/s
3. Hauteur maximale observée en m
4. Hauteur moyenne en m

Source: Carte hydrologique du Mali 1971 _ Ing. A. DEMBELE

Ech : 1/2 500 000

D. PETER - HIOVE - [illegible]

The origin and History of all stations installed before 1968 appears in publications by Mm. Rocho, Rochette and Jaccon.

The data were updated in 1969 and 1970 respectively in the OERS-UNDP projects: "Study of the Navigability of the Senegal River" and "Preinvestment Studies for the Regularization of the Senegal River."

According to the Senegal-Consult Study, although gage-height records and stream gaging measurements have been made at many stations, only 13 stations have adequate records which can be used as a reliable basis for hydrologic studies.

The following tabulation lists the locations with usable records; the station locations are shown on the location map and can be found in the Senegal-Consult Report:

Location Map Reference Number	Station	River or Tributary	Catchment Area (in km^2)	Date Installed	Mean Annual Discharge m^3/s
1	Siramakana	Baoule	59,500	(1954 (1967	71
2	Toukoto	Bakoye	16,500	(1904 (1951	81
3	Qualia	Bakoye	84,700	1954	167
4	Dakka-Saidou	Bafing	15,700	1952	287
5	Soukoutali	Bafing	27,800	1966	367
6	Dibia	Bafing	33,500	1956	419
7	Galougo	Senegal	128,400	1904	616
8	Gouina	Senegal	128,600	1926	-
9	Kayes	Senegal	157,400	1892	627
10	Fadougou	Faleme	9,300	1953	120
11	Gourbassi	Faleme	17,100	1954	165
12	Kidira	Faleme	28,900	(1930 (1951	195

The stations at Baken and Kayes, for which long-term records are available, were used to extrapolate the records for other stations. The water year is assumed to start May 1 and end April 30.

Although the present hydrometric network is generally considered sufficient for completing projects now underway, the network needs to be reinforced: observations on the different water level measuring stations need to be followed through, certain rating curves need to be specified, others retaken. This is particularly important for forecasting phenomena. One should also note that the forecasts of flooding, from 1952 to 1958 by MAS, were made by experienced men who knew the river and used the facilities then available.

A modern service to forecast and announce floods requires a much more complex means to inform, treat, and transmit data. Such a service goes far beyond the present capabilities of the system.

Present System Deficiencies. There are four main areas where the present hydrometric network is deficient:

1. No information from Guinea
2. Limited real time reporting of information
3. Lack of maintenance of stations
4. Limitations in data recorded.

Guinea Data. Although over half of the runoff of the Senegal River originates from Guinea, OMVS does not receive any rainfall or runoff information from Guinea, because of political differences. It is therefore difficult to justify too sofisticated a network for the rest of the Basin for predicting floods and low flows when information on the most important portion of the basic will be missing. The highest priority should be given to obtaining rainfall

and runoff data from Guinea. This information is especially important to determine the relationship between intensity of rainfall and runoff for spillway design floods for proposed reservoirs.

Immediate Data Reporting. With the exception of the Guinea area, the present hydrometric stations within the Senegal Basin are generally sufficient. It is recommended that two discontinued stations (Koungani and Ouaoundé) be re-established and that a new station be installed at the proposed Diama damsite. However, in order to make use of the present system for forecasting floods and low flows, a system of immediate "real time" reporting is required. Under the present system it often requires 2 to 3 months for the records from the remote stations in the upper basin in Mali to reach the central office of the Mali Hydrologic Service. At present there is no regular communication system between the Hydrologic Service of Mali and Senegal whereby the population along the river valley (mostly in Senegal) can be warned of floods rising in the upper basin.

The situation is somewhat better with the climatological network with four stations in Mali reporting every three hours by radio or telephone. The principal need is not only for additional radio reporting rainfall stations, but also for stations recording rainfall intensity. Also there are many areas not adequately covered by rainfall stations because of lack of available observers.

Station Maintenance. A major problem with the existing hydrometric stations is the lack of funds and personnel to properly service or maintain them. Records for several stations with automatic recorders are not being obtained because of lack of maintenance in servicing the recorders. Other staff gages not being read because of lack of funds to hire qualified observers. Many hydrometric stations lack rating-curves at high flows because of insufficient personnel for stream gaging.

Limited Data Collection. There is a need for more of the hydrometric stations to have automatic recorders in order to register instantaneous flood peaks. Additional rainfall stations are needed for recording rainfall intensities. Additional climatological stations are required to determine humidity, temperatures, evaporation and evapo-transpiration over the basin.

Data as to sedimentation and water quality needs to be collected at several of the key stations on the Senegal River.

In the lower river valley most of the gaging stations only measure the flow in the main channel. In order to evaluate the availability of water in the lower basin, the impact of constructing dikes and irrigated perimeters, and the construction of the salt water barrier (Diama Dam) it will be necessary to measure the flow through the main gate and the river flood plain. To determine the flow regime of the lower valley, detail mapping of the valley topography is essential.

APPENDIX B

ASSESSMENT OF GROUND-WATER INFORMATION IN THE SENEGAL RIVER BASIN

Introduction

In compliance with a request from the Division of Foreign Activities, U.S. Bureau of Reclamation, Washington, D.C., who are under a special contractual agreement with the U.S. Department of State, the U.S. Geological Survey assigned a hydrologist—Mr. H. M. Babcock—as a part of a team to assess the need for and the design of a meteorological-hydrological measuring network and to assess the present knowledge of the ground-water resources in the Senegal River basin. This report deals with the ground-water part of the assessment.

Data Available

Adequate geologic and ground-water information is available for the basin. Good records have been kept of well-drilling and development activities, and a large number of interpretative ground-water studies have been made.

From a review of the data made available by the governments of Mali, Mauritania, and Senegal and by the Bureau de Recherches Geologiques et Minieres Services Geologique National (B.R.G.M.), it is apparent that ground water of suitable quality and sufficient quantity for

irrigation can be obtained in large areas in the western part and extending north and south of the drainage basin. In the area from about 60 km west of Bakel eastward, the lithology of the formations that underlie the basin is such that large well yields are unlikely.

Base maps of different scales—including those at 1:250,000 prepared by the U.S. Army Map Service—are available for the entire Senegal River basin. Several small-scale geologic and hydrologic maps prepared by the hydrologic departments of the three countries and by B.R.G.M. are available; in addition, numerous large-scale maps showing ground-water information in parts of Senegal and Mauritania are available.

The most recent comprehensive study of the ground-water resources of the basin was prepared by B.R.G.M. in 1975 under the sponsorship of "Le Fond d' aid et de Cooperation de la Republique Francaise." The results of the study are presented in the report entitled "Notices Explicatives et Cartes de planification pour l' Exploitation des eaux southerraines de l' Afrique Sahelienne." The report includes the text that describes the ground-water conditions and three sets of maps showing (1) productivity of the aquifers, (2) cost of producing ground water, and (3) chemical quality of the ground water. A map is being prepared that will show the quantities

of usable ground water in storage. In conjunction with this study, an annotated bibliography that contains several hundred references on all ground-water studies in Senegal has been prepared. A similar bibliography is in preparation for Mauritania.

A report prepared by B.R.G.M. entitled "Cart Hydrogeologique Du Bassin Sudouest Mauritania" is typical of some of the other larger-scale interpretative reports. The report contains a table of pertinent well data (about 500 wells) and a map showing the geology, location of wells, depth to water, type of aquifer material, total dissolved solids, stiff diagrams showing water type, contours of the water levels, and contours of total dissolved solids. Similar information is available for Senegal and to a lesser extent for Mali.

Occurrence of Ground Water

The following is a summary of the occurrence of ground water in the Senegal River basin. The detailed information is available in the many reports listed in the bibliographies.

In the area from about 60 km west of Bakel eastward, the basin is underlain by granite, gneiss, and consolidated sedimentary rocks that can be expected to yield only small quantities of water. A map prepared by the Direction Generale De Hydraulique, Republic

of Mali, shows that many wells—especially those drilled in the granite and gneiss—are nonproductive.

Westward from near Bakel, most of the basin is underlain by the Continental Terminal Formation, which in turn is underlain by the Maestrichtien Formation. These units contain ground water. The Continental Terminal Formation consists of sand, gravel, and clay that generally yield at least small quantities of ground water under water-table conditions; however, it is doubtful that a sufficient saturated thickness of the formation is present in most of the area to yield the quantities of water needed for irrigation.

The underlying Maestrichtien Formation consists of limestone, clay, and sand beds. The sand beds are quite extensive and generally are sufficiently thick and permeable to yield moderate to large quantities of water to wells. The water is under artesian pressure and generally rises to a level above that of the shallow water-table aquifer. Well records in the files of the Director of Urban and Rural Hydrology show that specific capacities of 20-30 gpm (gallons per minute) per foot of drawdown are not uncommon, which indicates that wells yielding from 500-1,000 gpm can be developed. The Maestrichtien and the Continental Terminal Formations extend for great distances north and south of the Senegal River drainage

basin. The formations are regional aquifer systems and probably are little affected by the Senegal River except in areas adjacent to the river.

Recharge from the river to the Maestrichtien Formation probably is limited to areas where the sand beds in the formation may be in contact with the overlying Continental Terminal Formation or flood-plain deposits. Near Matam tests run by the Bechtel Engineering Co. indicate that there is little if any hydraulic connection between the upper saturated flood-plain deposits or Continental Terminal Formation and the underlying Maestrichtien Formation. Ground water in the flood-plain alluvium and the underlying Continental Terminal Formation is hydraulically connected with the river. The Continental Terminal Formation is saturated under the river flood plain and to some extent away from the river flood plain. The saturated section would be expected to decrease progressively with increasing distance from the river. As this material is capable of moderate to large yields where sufficiently saturated, it should be considered as a potential source of irrigation water under the flood plain and in areas adjacent to the flood plain. In these areas, the aquifer could be developed rather extensively because water withdrawn would be recharged continuously from the river. In the areas under and adjacent to the river flood plain, an opportunity would exist to

develop irrigation water from both the Continental Terminal and flood-plain deposits water-table system and the underlying Maestrichtien artesian system.

Use of Ground Water

Ground water is used extensively for stock and village water supplies in Mauritania and Senegal and to a much lesser extent in Mali. A few irrigation wells have been drilled in Senegal in an area east of Dakar; apparently, only a few of these irrigation wells are in use. Although there is a good possibility of obtaining sufficient ground water for irrigation in parts of Senegal and Mauritania, the high cost of power has been a deterrent to well development.

Each of the three countries has a governmental organization with a small technical staff that is responsible for the development of ground water. The organizational structure is similar in each country and has a Director of Hydrology as the head. In Senegal the work is divided between three divisions.

1. The Division of Urban and Rural Hydrology is responsible for selecting well locations, drilling wells, monitoring wells, and monitoring changes in water levels. One hydrologist and a government-owned drilling company, SONARFOR, is assigned to this division. Presently, SONARFOR has six drilling rigs.

2. The Division of Studies and Programs performs as a study and research group that is responsible for investigative work on soils and hydrology. The group does ground-water studies for the Division of Urban and Rural Hydrology as needed. The group is made up of 2 hydrologists and 2 technicians.

3. The Division of Rural Equipment maintains all equipment and is responsible for directing irrigation development.

The Hydrology Department also makes extensive use of the consultant services of B.R.G.M. for regional and specialized ground-water studies. For example, B.R.G.M. recently has completed mathematical models of the ground-water system in two heavily developed areas in Senegal.

In addition to the government-owned drilling company, three small private drilling companies—COFOR, SASIF, and SATON—drill wells in the Senegal River basin. The companies are headquartered in Dakar.

Ground-Water Potential for Irrigation

The possibility of obtaining sufficient quantities of ground water for irrigation appears to be quite good in the Senegal River basin

and adjacent areas in Mauritania and Senegal. In the area from about 60 km west of Bakel eastward the basin is underlain mainly by the Maestrichtien Formation that contains fairly thick sand beds in many places. Irrigation wells can be developed in places where the beds are sufficiently thick. Adequate geologic and hydrologic mapping has been done to delineate the general areas most favorable for the development of irrigation wells.

It is suggested that a comprehensive review be made of all available ground-water data, maps, and interpretive reports. A report would then be prepared identifying areas where ground water of sufficient quantity and suitable quality for irrigation can be obtained. This information should be shown by patterns on a map or maps in such a manner as to show relative yield potentials. In consultation with the appropriate governmental departments of Senegal and Mauritania, at least one area in each country could be selected for more detailed study so that an irrigation feasibility study could be made similar to the one being made by the Bechtel Engineering Co. near Matam. These studies would require some additional test drilling to more precisely evaluate the aquifer potentials.

Deficiencies

The three countries are very dependent on expatriates for technical expertise and consulting services, although they have a few trained hydrogeologists and competent consulting help to advise them on ground-water development. A program for the training of additional personnel in hydrogeology is recommended to lessen the dependency on expatriates for technical help. In addition, if ground-water irrigation proves to be economically feasible, the present staffs would not be capable of taking on the additional work of directing irrigation development.

One hydrogeology trainee from each country and one from OMVS should be sent to the United States for training. Although the potential for ground-water development for irrigation in Mali is not promising, trained hydrogeologists are needed there to assist in the location and development of domestic and stock water supplies. The trainees should have a bachelor's degree in geology as a prerequisite and should be given 2 years of courses in hydrology in the United States.

Supporting Information for Ground-Water Program

Test Well Drilling

Test wells will be 6" in diameter to an average depth of 150 meters. Cost of drilling casing and testing will be approximately $24,000 per well, based on information obtained from Mr. Henri Moussa (BRGM Dakar). This compares with a cost of about $17,000 for the same work in the U.S.

Test drilling can be done by contract with SONAFOR, COFOR, SASIF, or SATON. All headquarters in Dakar.

Drilling will be scheduled as follows: 15 wells during the second year and 25 wells during the third year.

APPENDIX C

Travel Report of the U.S. Bureau of Reclamation Team to the Senegal River Basin, West Africa

The Foreign Activities Division, U.S. Bureau of Reclamation, Washington, D. C., received a request from USAID/Washington to field a team to prepare a Project Review Paper (PRP) covering the combined projects identified by the Project Identification Documents (PID) calling for the establishment of a hydrometeorological system and a hydrogeologic investigation in the Senegal River Basin. The team consisted of Adrian K. Long, Water Resources Advisor and Team Leader, U.S. Bureau of Reclamation, Salt Lake City, Utah, Earll D. Dudley, Hydrologist, U.S. Bureau of Reclamation, Sacramento, California, and Horace M. Babcock, Hydrogeologist, U.S. Geological Survey, Tucson, Arizona.

The Team Leader departed from Salt Lake City, Utah, on October 20, 1976, and was briefed in Bureau of Reclamation offices in Denver, Colorado, and Washington, D. C., as well as in USAID/Washington offices. The team assembled at Kennedy International Airport in New York the evening of October 28, 1976. They flew directly to Dakar, Senegal, arriving there the morning of October 29, 1976, and proceeded to the USAID office where they were met and briefed by Glen Slocum, USAID/OMVS program coordinator.

The next few days were spent in review of available data and discussions with numerous individuals from USAID, OMVS, ASECNA,

ORSTOM, BRGM, and various officials of the Senegalese Service Hydraulique; Urban and Rural Hydrology, etc., in the Dakar area.

On November 2, 1976, the team drove in a USAID car to Saint Louis, Senegal, located 264 kilometers North of Dakar. Initial contact was made with OMVS and the Service Hydraulique Senegal, pertaining to streamflow, precipitation and groundwater data. These discussions were continued on November 3, 1976, after which the team returned to Dakar.

On the morning of November 4, 1976, the team, accompanied by Mr. Garon Konare, Engineer-Hydrologist, OMVS, and Mr. George Poulin, USAID/Dakar, departed from Dakar, utilizing a chartered Air Senegal plane for an aerial reconnaissance of the Senegal River. We flew up the Senegal coastline to the estuary of the Senegal River, located south of Saint Louis. The continued route of the flight was up the Senegal River and the Diama damsite, over the wildlife refuge area, Boundoum irrigation perimeter, Rang pumping plant and perimeter, Roosa, the Lac de Guiers inlet canal and pumping plant, and the sugar plantation near Richard Toll.

After refueling at Richard Toll, we continued up river to Dagana, observing the pumping plant and irrigated perimeters in that area. Downstream from Podor, we observed the point of junction of the Senegal River and the Doue. It is proposed to try to determine the discharge of the Doue at this point. Our flight continued up to Podor,

Guede, Chantiers, Baghe Salde and to the point of channel interconnection between the Senegal River and the Doue upstream from Salde.

During our continued flight, we observed an irrigated perimeter west of Kaedi and the junction of the Senegal River and the Diammel, downstream from Matam. We observed the river and overflow channel at Matam, irrigated perimeters in this area, the intervening area between Matam and Oauounde, the Goude and Mouderi areas, Darawa, Bakel and the adjacent irrigated perimeters. Our flight took us further up-river to Aroundou, the junction of the Senegal and Faleme Rivers, then up the Faleme to Kidira at which point we flew back to Tambacounda, Senegal, to refuel the aircraft.

The overflight of the lower reach of the Senegal River Basin revealed a flood plain of varying width, only slight evidence of flooding during the 1976 rain runoff season and considerable recession agriculture plantings. It also appeared that the land most suitable and susceptable to irrigation, was generally situated within the major river floodplain area. In certain reaches of the river there are numerous overflow channels as well as channels which often carry more flow than the main river channel.

After refueling at Tambacounda, we flew back to Kidira on the Faleme River, over to Ambidedi on the Senegal River and up the Senegal River to Kayes, Mali, where we concluded the flight for the day. From Bakel upstream to Kayes, the river flood plain is relatively narrow and the channel is incised into the flood plain about 8 to 12 meters.

Mr. Konare, a native Malian, whose hometown is Kayes, arranged for a vehicle to take us to the existing gaging station at Kayes. The station consisted of a series of staff gages covering a range of about 12 meters. These gages were attached to concrete piers of a loading platform or to concrete and masonary posts constructed for the sections of gage.

The water surface at the station was 3.88 meters. Mr. Konare sent for the gage keeper and the operation of the station was discussed with him.

An item of great importance emerged from this discussion. No readings from this station had been transmitted to OMVS or the Malian Service Hydraulique since May 1976, a period of 6 months, and apparently no one had requested the information or tried to determine why the data had not been forwarded at the end of each month. When asked why the data had not been forwarded as scheduled, the observer stated that the Malian Government had reduced his wage by 50%; therefore, he would not send the data although he apparently was still reading the gage. This is a typical and major problem in many countries of the world in their hydrometric programs, i.e., poorly paid or inconsistently paid observers, poorly trained, uninformed or unmotivated observers and the lack of supervision and understanding on the part of officials in charge of these programs, regarding the importance and critical need of accurate basic data. This fact cannot be over-emphasized. All water resource development is dependent upon these basic data and inaccurate data is worse than no data at all.

In the river at Kayes, we were shown a riffle in the river about one kilometer upstream from the gaging station and were informed that it was caused by a rocky ridge formation across the river channel, which has been slightly improved by concrete or masonry and is used as a ford for vehicles during low flow periods of the year. Upstream from this formation would appear to be a good site for a gaging station if the rating curves at the current station are somewhat erratic.

On November 5, 1976, the party took off from Kayes airport and continued up the Senegal River to the junction of the Bafing and Bakoye Rivers at Bafoulable. Enroute we observed the rapids and powerplant at Felou situated about ten (10) kilometers upstream from Kayes. as well as the Gouina Falls near Banganoura, Mali. The river below the junction of the Bafing and Bakoye Rivers is designated the Senegal River. It was noted that the Bakoye River was carrying a much heavier sediment load than the Bafing River which was readily discernable due to the coloration differential of the waters of these two major tributaries to the Senegal River. It was also noted that the vegetal cover of the watershed area upstream from Bakel, Senegal, and in Mali, was more dense and much greener, this being the result of more precipitation in these different parts of the catchment area.

Our flight continued up the Bafing River, the floodplain of which is quite restricted in width. There were several rapids and falls in the reach of the river from Bafaulabe and Sitafeto, Mali. Sitafeto is

approximately 50 kilometers north of the Guinea border, and was the highest point on the Bafing River that we observed. Uncertainty of our fuel supply made it necessary to divert westerly toward the Faleme River and Tambacounda, Senegal, at this point.

We were able to observe the Manantali damsite, the watershed area, river channels, rapids and floodplain. Many of the plateaus and ridge lines were void of or had a limited stand of vegetation on them. This was due to exposed bare rock or a soil mantle too thin to support a heavy vegetal cover.

The escarpment situated easterly of the Faleme River in the vicinity of Kenieba is very abrupt and steep. The steepness of the terrian, exposed rock and shallow soil mantle adversely affects the moisture retention capability of the watershed area, thus resulting in the rapid and high peak runoff that is reflected in the historical hydrographs of existing streamflow gaging stations.

After intersecting the Faleme River downstream from Kenieba, we followed the river downstream past the Gourbassi dams and nearly to Kidira at which point we flew to Tambacounda, Senegal, to refuel and return to Dakar.

Additional discussions with various officials of the OMVS and Senegal Government were held subsequent to this field trip.

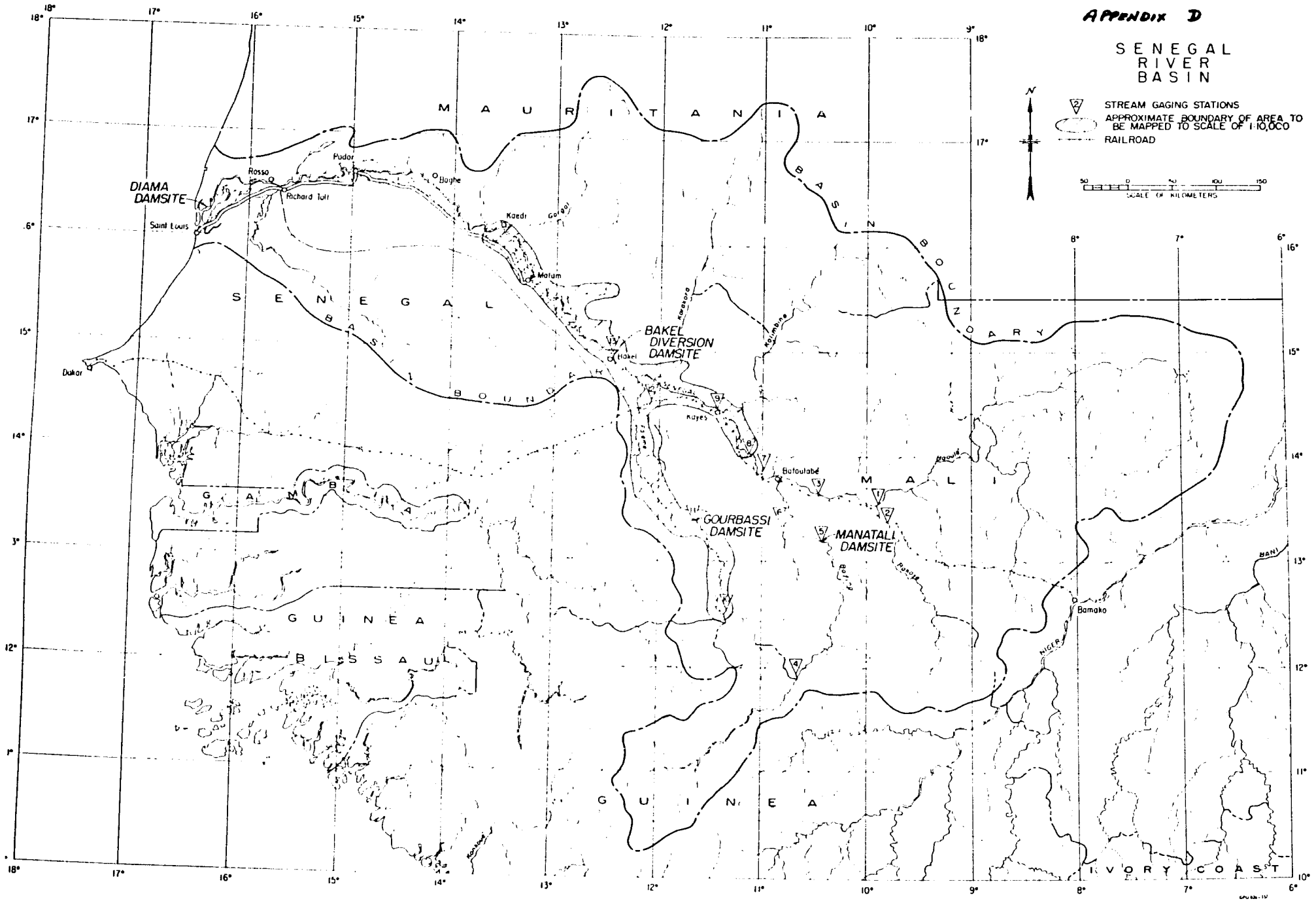
On November 9, 1976, Mr. Babcock departed for Nauakchott, Mauritania to discuss groundwater conditions and review data related

to the Senegal River Basin. Mr. Dudley departed for Bamaka, Mali, to discuss streamflow and precipitation stations, records and data with Malian officials of the Hydraulique on Meterological Services. Mr. Long departed for Niamey, Niger, to discuss the CILSS Agromet-Hydromet Program with Dr. D. A. Rijks, Program Coordinator. This program covers part of the Senegal River Basin and close coordination with this program together with the ORSTOM and ASECNA programs in the basin is important to minimize or eliminate duplication of facilities and services. Discussions were also held with USAID officials and Mr. Charles Joyce, Engineer for the Niger River Commission, exploring the possibility of securing streamflow and precipitation data for the Guinea area of the Senegal River Basin watershed.

By November 12, 1976, the members of the team had returned to Dakar where summary discussions were held with AID and OMVS officials in Dakar.

The team departed from Dakar on November 14, 1976, and arrived in the United States on the same day.

APPENDIX D


SENEGAL RIVER BASIN
STREAM GAGING STATIONS
APPROXIMATE BOUNDARY OF AREA TO BE MAPPED TO SCALE OF 1:10,000
RAILROAD
SCALE OF KILOMETERS
MAURITANIA
SENEGAL
GAMBIA
GUINEA BISSAU
GUINEA
MALI
IVORY COAST
BASIN BOUNDARY
DIAMA DAMSITE
BAKEL DIVERSION DAMSITE
GOURBASSI DAMSITE
MANATALI DAMSITE
Dakar
Saint Louis
Richard Toll
Rosso
Podor
Boghe
Kaedi
Matam
Bakel
Kayes
Bafoulabé
Bamako
NIGER
BANI
Gorgol
Karakoro
Kolimbine
Bafing
Bakoye
Baoulé