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OBJECTIVES AND OUTPUTS

OMVS/USAID Project 625-0958
Groundwater Monitoring Project

Final Report

Volume I

June 1990

INTERNATIONAL SCIENCE
AND TECHNOLOGY
INSTITUTE, INC.

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Volume I

Prepared jointly by:

OMVS/DIR/PES
International Science and Technology Institute, Inc.

June 1990

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LIST OF ACRONYMS AND ABBREVIATIONS USED

OMVS	: Organisation pour la Mise en Valeur du Fleuve Sénégal
OMVS/DIR	: Département de l'Infrastructure Régionale de l'OMVS
USAID	: United States Agency for International Development
USAID/IWME	: Irrigation Water Management Engineering Department of USAID
GMU	: Groundwater Monitoring Unit
USGS	: United States Geological Survey
ISTI	: International Science and Technology Institute, Inc.
P.I.L.	: Project Implementation Letter (lettre d'exécution)
SAFOR	: Société de Forage Africaine
GES	: Computerized groundwater data management system (Gestion des Eaux Souterraines)
BRGM	: Bureau de Recherche Géologique et Minière
INFORMISSION	: Subcontractor to ISTI for development of the GES system
DNHE	: Direction Nationale de l'Hydraulique et de l'Energie
CEFIGRE	: Centre de Formation Internationale à la Gestion des Ressources en Eau
LANASOL	: Laboratoire National d'Analyses des Sols et de l'Eau
SONADER	: Société Nationale pour le Développement Rural
SAED	: Société pour l'Aménagement et l'Exploitation de la Vallée du fleuve Sénégal
ORSTOM	: Organisation de Recherche Scientifique et Technique Outre-Mer
IGN	: Institut Géographique National
MB	: Mega Bytes
KB	: Kilo Bytes
DOS	: Disk Operating System
LOTUS	: Electronic spreadsheet software LOTUS 123 generates *.WK1 files
DBF	: Data base software dBase 111+ generates *.dbf files
ISRA	: Institut Sénégalais des Recherches Agricoles
CNRADA	: Centre National de Recherche Agronomique et de Développement Agricole (Mauritanian equivalent of ISRA)
PC1	: Work station #1 IBM - XT of the GMU
PC2	: Work station #2 IBM - XT of the GMU
cpi	: Characters Per Inch
ASL	: Above mean Sea Level
R.I.G.	: Regional Inspector General

C'

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)

In 1972, Mali, Mauritania, and Senegal created the Senegal River Development Organisation (Organisation pour la Mise en Valeur du fleuve Sénégal - OMVS) in order to combine their efforts for the coordinated development of the river basin.

With construction of two dams (Diama and Manantali) it will now become possible to develop:

a) irrigated agriculture (375,000 ha),
b) the production of hydroelectric energy (800 GWH annually),
c) navigation of the river from its mouth at St. Louis to Kayes in Mali.

Agricultural development is the responsibility of the member countries, OMVS being responsible only for coordination at the sub-regional level.

In contrast, energy production and navigation projects constitute the second phase of the OMVS regional infrastructure program (DIR) which will permit integrated development of the Senegal River basin.

AGRICULTURE

The development of irrigated agriculture, dependant upon regularization of the river's discharge by the Manantali and Diama dams, is being performed during an initial period, in parallel to traditional flood-recession agriculture. The increasing development of irrigated agriculture will result in a progressive decrease of recession agriculture and, ultimately, in its total disappearance.

The zones which are suitable for irrigation were estimated (FAO 1977) to be 376,443 ha distributed as follows:

Upper Valley	:	14,229 ha
Middle Valley	:	132,360 ha
Lower Valley	:	190,381 ha
Delta	:	39,473 ha
Total		376,443 ha

The total land surface developed for irrigated agriculture in 1984 was 39,383 ha. In 1989, the total irrigated land surface exceeded 48,334 ha.

ENERGY

The focus of the OMVS energy sector is on the following activities:

1) the construction of a hydro-electric power plant at the foot of the Manantali Dam with a capacity of 200 MW (5 turbines of 40 MW)

2) the creation of a sub-regional high tension energy transmission network, interconnecting with the member countries' national networks and including:

a) a double set of transmission lines (225 KV) linking Manantali -Kayes - Bakel - Matam - Dagana - Sakel - Tobène for a total length of 930 km; two extensions provisionally dimensioned for 90 KV linking these lines with the right bank: Matam - Kaedi (78 km), and Dagana - Nouakchott (267 km).

b) a line (225 KV) Manantali - Kita - Bamako, for a total length of 295 km.

d

NAVIGATION

The main objective of this sector is to permit navigation of the Senegal River, yearlong from St.Louis (Senegal) to Kayes (Mali). The minimum discharge required for navigation is 100 m^3/s at Bakel, as controlled by Manantali Dam.

The essential components of the navigation project include:

* the creation (by dredging and rock removal) of an appropriately marked, navigable channel, 55 m wide and 1.9 m deep in the transitional period, to ensure a draft of 1.5 m for river transport,

* the construction of a wharf at St.Louis, a river port at Kayes and 10 stop-over ports along the river,

* the installation of organizations for maintenance of the navigable channel and the economic development of a riverboat fleet,

At present, this project is the topic of a study which updates previous studies and will propose a step-by-step plan for the project's implementation.

1 INTRODUCTION

1.1 Project origin

The Senegal River Development Organization (L'Organisation pour la Mise en Valeur du Fleuve Sénégal, OMVS) and the United States Agency for International Development (USAID) signed a Grant Agreement for the Groundwater Monitoring Project 625-0958, on August 30, 1983. This grant agreement was made possible following an environmental study by Gannet Fleming in 1970, reviewed in 1979 by Mr. George C. Taylor.

The project commenced field activities in January 1985 and concluded them on June 30, 1990.

1.2 Project objectives

The overall objective of project was to help OMVS with the structuring and coordination of activities of a newly created entity, designated the Groundwater Monitoring Unit, in St. Louis, Senegal. This Unit was, and still is, supervised by the OMVS Departement de l'Infrastructure Régionale.

Project activities, covering the Senegal River valley and the area near Manantali dam, were focused on the collection and analysis of hydrogeological, climatic and water level data, and the development of a computerized data management system. These were obtained:

* by the construction of the OMVS piezometric network containing 569 piezometers located in the Senegal River valley (West of Bakel) and 20 piezometers in the area near Manantali Dam,

* by the inclusion of village wells to the OMVS piezometric network, bringing the total number of hydrogeological observation points to 1151 sites,

* by the hydrogeological monitoring of the network,

* by the collection of water level and climatic data recorded by other organizations.

Through this project, OMVS aimed to acquire a hydrogeological observation system which would permit it to monitor the evolution of the upper aquifer in relation to current and future development works in the Senegal River valley (dams and irrigated perimeters).

The topics to be studied (long-term objectives) through analysis of the collected data should permit a better understanding of:

a) the rise of saline groundwater within the irrigated perimeters, especially downstream of Podor,

b) the natural recharge of alluvial aquifers and deep aquifers underlying the Senegal River valley,

c) the impact of the Diama and Manantali dams on the aquifers in contact with the river bed,

d) groundwater contamination mechanisms related to the use of fertilizers and pesticides,

e) the hydrogeological potential of the different aquifers with respect to agricultural development.

None of these study topics, nor the results obtained, were required as expected outputs in the project terms of reference.

The goals and expected outputs (short and medium term objectives) listed in the Project Paper Document were:

1) development of a master plan for the management of surface and groundwater,

2) development of an information management system for the OMVS,

3) development of a data compilation and analysis system,

4) training of OMVS personnel for the management of surface and groundwater according to the master plan,

5) construction of an OMVS piezometric network.

1.3 Project contributors

The production of this report was made possible through the combined efforts of many persons, among whom:

* the local sector office personnel (Mr. L. Sangare, St. Louis, Senegal sector chief, Mr. A. Ndiayes, Rosso, Mauritania sector chief, and Mr. Toure, Manantali, Mali sector chief) responsible for the collection and pre-analyses of field data,

* the local central office personnel (Mr. O. Ngom, project chief, Ndar Toute, St. Louis), responsible for coordination of the field activities of each sector office.

This project, implemented by OMVS/DIR (Département de l'Infrastructure Régionale), benefitted from the support of technical experts; long-term (ISTI) and short-term (USGS, BRGM and INFORMISSION).

In matters of regular project management, ISTI provided assistance to OMVS by assigning a consulting engineer, Mr. D. Richard, to work with the Groundwater Monitoring Unit project chief.

INFORMISSION was responsible for the development and installation of the computer data base (GES) through the contributions of computer specialists, Mr. M. Fortin, Mr. L. Brunelle and Mr. M. Migneault.

BRGM (Mr. M. Vandenbeusch, hydrogeologist) and USGS (Mr. E. Bolke, hydrogeologist, Mr. R. Hollway, computer specialist in hydrogeological applications, and Mr. E. Weiss, hydrogeological modelling specialist), participated in orienting the data interpretation work.

The experts performing the final evaluation of the Groundwater Project (Mr. S. Dendrou and Mr. R. Reeser), dynamic and constructive in their work, greatly stimulated the reflection by the Groundwater Monitoring Unit personnel which was necessary for production of this report.

1.4 Report authors

This report, available in French and English, dealing with the synthesis of project achievements and providing recommendations for the future of the GMU, was written by the consulting engineer (ISTI) and the chief of the Groundwater Monitoring Unit.

This final report deals with actual project outputs (Chapter 2), conclusions (Chapter 3), lessons learned (Chapter 4) and recommendations made concerning continuity of operations upon termination of USAID financing (Chapter 5).

Annex #1 provides a brief history by quarter of the important steps made and the resulting outputs during the period from July 1, 1984 to June 30, 1990.

Annex #2 presents a list of technical, programming, cartographic and administrative documents, as well as reports written by expert consultants. All were written and prepared for the good outcome of

the project. A total of 95 documents, an average of 1.4 documents per month, were produced. All of these documents represent a major project output and have contributed to its success.

Annex #3 is a list of goods, materials and equipment turned over to OMVS by the project on June 30, 1990.

Annex #4 introduces the reader to sources of documentation describing the study zone.

Annex #5 describes the reports which can be produced with the GES computer system, listing the various codes used for management of the hydrogeological data.

2 PROJECT OUTPUTS

2.1 Institutional assistance to OMVS

The OMVS had created a Groundwater Unit, under the supervision of the Department of Regional Infrastructure (OMVS/DIR) before project activities were begun. The Funding Agency was to use this newly created entity in order to help OMVS in its efforts to obtain and analyze groundwater related data.

In the first phase, the resident team of the Groundwater Monitoring Project (the project chief, the technical adviser to the project chief, the person responsible for data collection and analysis, and the person responsible for field operations) opened the central office in St. Louis, Senegal. The national experts of the resident team were detached from the Ministries of Hydraulics from the member countries to the OMVS and the technical adviser was provided by ISTI, Washington, U.S.A..

During the second phase, the central office progressively opened sector offices located in each of the OMVS member countries. The sector chiefs were detached from the Ministries of Hydraulics of their countries of origin and were paid by the project. The personnel for each sector office were recruited locally and paid by the project.

The first offices opened (in October 1984) were the sector offices of Rosso, Mauritania and St. Louis, Senegal, followed by that of Manantali, Mali (in March 1988).

This organizational structure was necessary in order to ensure the management of this regional project (three countries). The progressive opening of sector offices was dependent upon the accomplishment of work done (writing of contractual documents for SAFOR and DNHE) in preparation for the construction of the OMVS piezometric network, the cornerstone of the project's field activities.

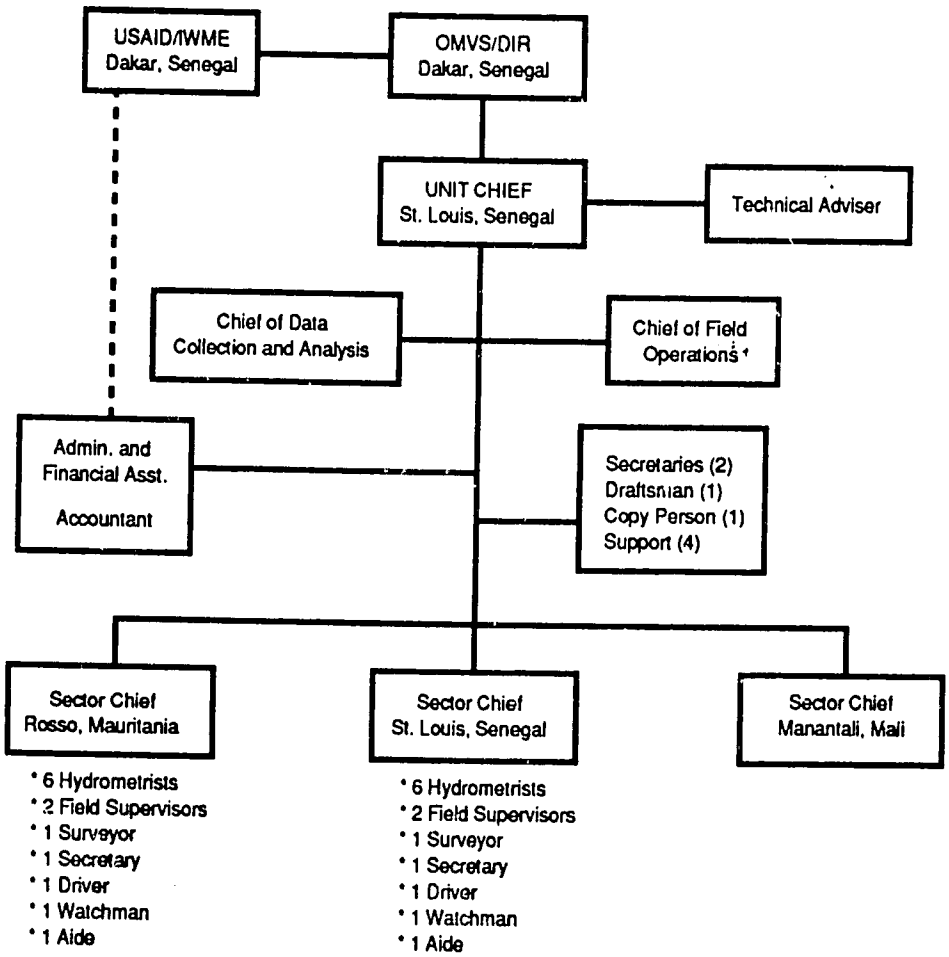
The composition of central and sector office personnel evolved according to the advancement of field work and circumstantial constraints. A major event in the project's history was the returning of the central office resident team to the disposition of the OMVS member countries in the third quarter of 1988. It is clear that this event engendered a complete revision of the central office team, and to a lesser extent, the revision of the sector office teams.

In the following pages, the project team composition is compared for the periods before and after the third quarter of 1988 and as it was at the project's termination (June 30, 1990). The organizational structures represented by these three organigrams have been, and still are for the persons who continue the work thence begun, a major project output in terms of institutional assistance to the OMVS.

The heritage which the Funding Agency, USAID, leaves to OMVS upon termination of USAID financing on June 30, 1990 (composition of the remaining team and the goods, material and equipment (see Annex #3)) provides it with the institutional capability to continue the data collection and analysis activities begun by the project.

In Annex #1, the reader will find a description of the important steps undertaken and their results, by quarter, from July 1, 1984 to June 30, 1990, corresponding to the duration of project activities. In reading this annex, it is interesting for the reader to consider the importance of the administrative tasks as opposed to the technical tasks. Symptomatically, a large part of the technical experts' energy was focused on purely administrative activities in spite of the project's technical vocation.

ORGANIGRAM OF THE
GROUNDWATER MONITORING UNIT
BEFORE THE 3RD QUARTER OF 1988



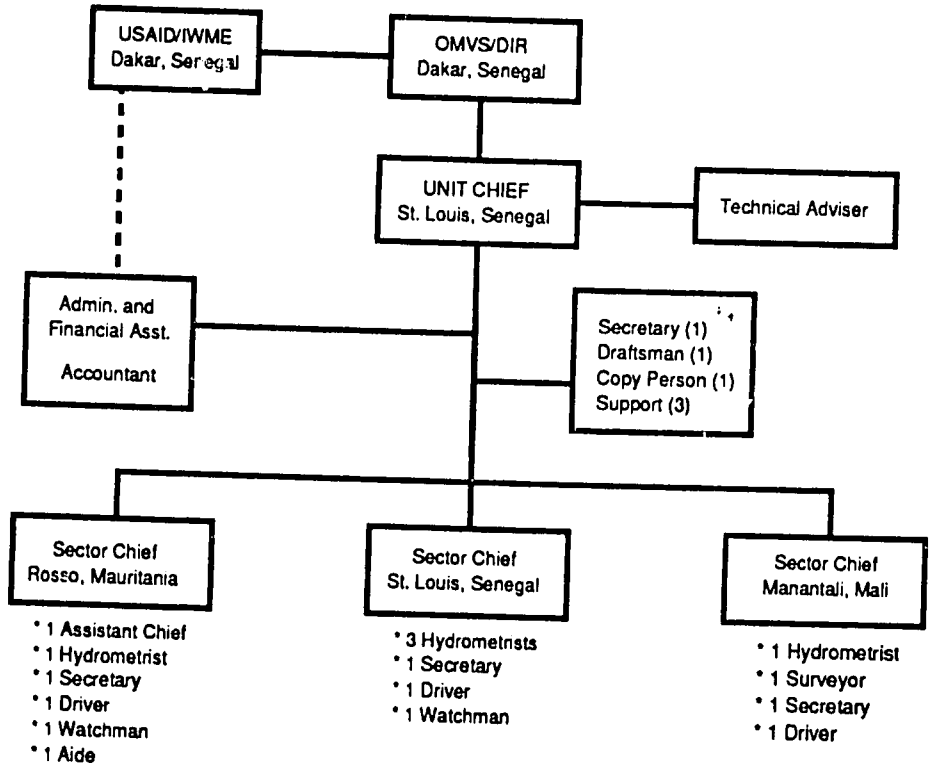
This organigram indicates the composition of the central and sector office teams before the resident team was returned to the disposition of the member countries, during the phase of the piezometric network's construction. It also indicates the two information flowpaths; formal (continuous line) and informal (dashed line).

The Manantali, Mali sector team, limited to the sector chief, is explained by the progressive start-up of contracted work by sector, and the subsequent hydrogeological monitoring of the piezometric network.

The field supervisors, directed by the Chief of field operations and under the supervision of the sector chiefs, inspected the SAFOR company's work. The length of their involvement with the project was related to the time needed for the completion of this company's work.

The surveyors, were independent, subcontracting their work with the central office on a fixed fee basis.

ORGANIGRAM OF THE
GROUNDWATER MONITORING UNIT
AFTER THE 3RD QUARTER OF 1988



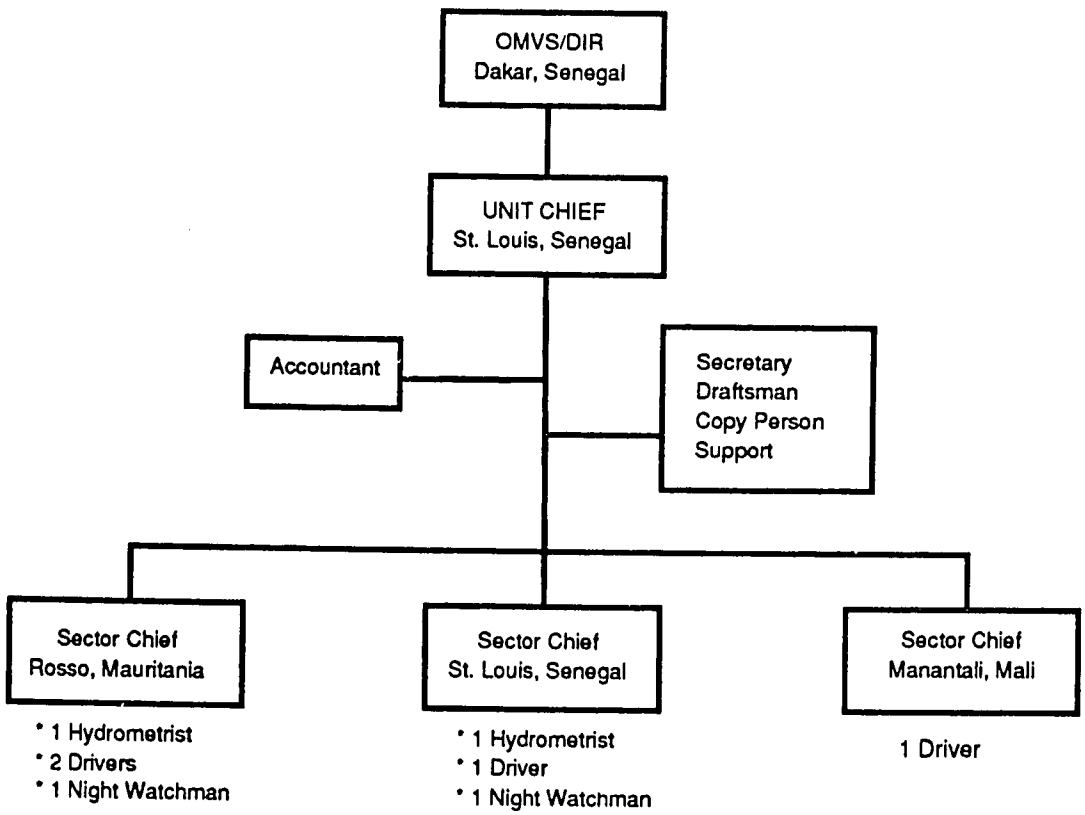
This organigram illustrates the composition of the central and sector office teams, after the resident team was returned to the disposition of the member countries, following construction of the piezometric network. It also indicates the two information flowpaths; formal (continuous line) and informal (dashed line).

The previous project resident team (project chief, chief of data collection and analysis, chief of field operations) was replaced by one person. The project chief adopted a second function as chief of data collection and analysis. Since the contracted work was completed, the field operation chief was not replaced.

The decrease in the number of hydrometrists by sector results from an individual evaluation of each technician and the application, as required by all the international funding agencies, of the conclusions presented in Alexander Gibbs report which strongly recommend the restructuring of the OMVS staff (loss of a driver).

The surveyor of the Manantali, Mali sector, an independent subcontractor with the field office completed the field work on a fixed fee basis. Similar work in Senegal and in Mauritania had already been completed.

ORGANIGRAM OF THE
GROUNDWATER MONITORING UNIT
UPON TERMINATION OF USAID FINANCING
ON JUNE 30, 1990



This organigram presents the minimum staffing needs of each sector in order for the OMVS to ensure the continuity of field operations upon termination of USAID financing.

This plan, proposed by the project and approved by the OMVS was implemented on May 31, 1990, with the exception of the two night watchmen who are yet to be recruited by the OMVS.

However, this organigram does not permit the remaining team to continue the analysis and interpretation of data collected in the field. The Unit Chief, faced with a variety of administrative and technical tasks, should be provided with computing and hydrogeological support (see recommendation 5.1.3).

2.2 Periodic hydrogeological monitoring

The hydrogeological monitoring (chronological data) of the OMVS piezometric network was begun in November 1986, with visits conducted on a monthly basis in Senegal and Mauritania. In the area near the Manantali Dam in Mali, the hydrogeological monitoring of the network was begun in February 1989 on a weekly basis.

In November 1986, the hydrogeological monitoring was performed uniquely on the village wells included in the OMVS network. As the drilling and construction work progressed, piezometers were added to the hydrometrists' programs (early June 1987).

The data collected, specific to each piezometer, concern the site of the structure, its accessibility, the structure's above-ground condition, the environs of the structure to a radius of 200 meters, the piezometry, the physical-chemical characteristics, and others.

The reporting form utilized by the hydrometrists has been standardized. The reader can find this Monthly Visit Form in the project presentation document which was distributed to the OMVS member countries (see Annex #2 Section 3,3.1). For each observation point visited, a corresponding Monthly Visit Form is prepared (approximately 1071 forms per month).

These forms are collected and pre-screened in each of the sector offices, then sent monthly to the data base chief at the central office for further exploitation (screening, entry, and interpretation through use of various computing tools) (see section 2.5 of this report).

2.3 OMVS piezometric network

The piezometric network of the OMVS is located within the boundaries of two distinct geographic, geological and hydrogeological regions:

* the Senegal River Valley, stretching from the sea coast at St. Louis to Bakel (approximately 600 km inland),

* the upper basin in the environs of Manantali Dam at approximately 1300 km from the mouth of the Senegal River.

2.3.1 The piezometric network of the Senegal River Valley

This part of the piezometric network, composed of 1151 observation points (village wells and piezometers) required the construction of 569 piezometers (SAFOR contract), totalling 10,300 drilled meters.

Figure #1 indicates the distribution of the depths of the piezometers constructed by the project. This histogram covers a population of 575 drilled piezometers of which 569 were equipped with protective tubing.

The reader will find in figure #2 the standard technical cross section of the piezometers constructed by SAFOR.

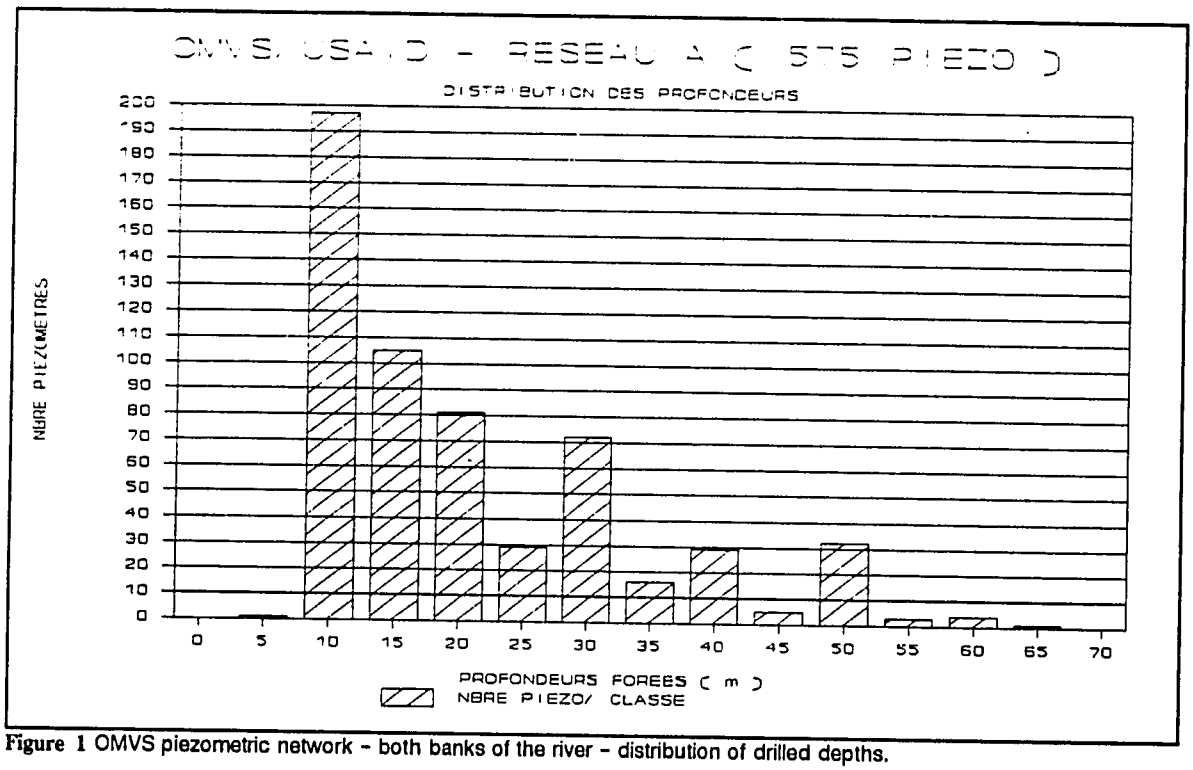


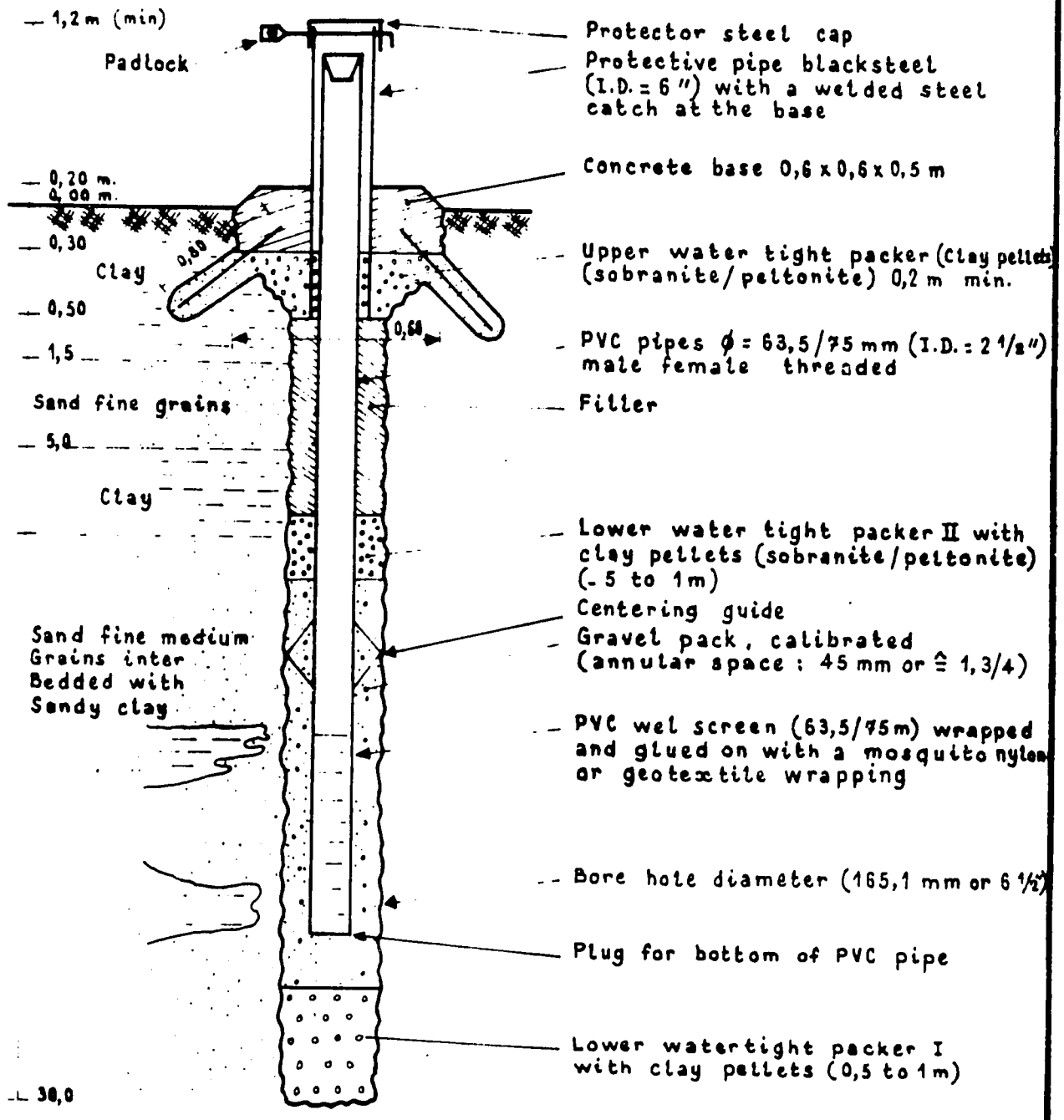
Figure 1 OMVS piezometric network - both banks of the river - distribution of drilled depths.

OMVS NETWORK - Senegal and Mauritania, distribution of drilled depths.

Category (m)	Number Piezos	% Total Piezos
0	0	0.00%
5	3	0.52%
10	195	33.91%
15	106	18.43%
20	82	14.26%
25	30	5.22%
30	68	11.83%
35	18	3.13%
40	28	4.87%
45	4	0.70%
50	29	5.04%
55	7	1.22%
60	4	0.70%
65	1	0.17%
70	0	0.00%
Beyond category	0	
Total Piezometers	575	
Equipped Piezometers	569	

Fig. N° 3

SHALLOW AND INTERMEDIATE PIEZOMETERS



Note : Minimum depth to be reach under the static water level : 2 m

The site selection criteria, cited in the Project Document (Ref. AID, 1983) were rigorously respected and the quality of the network has been confirmed as the Vandenbeusch and Bolke reports (see Annex #2, Section 3) and the project's final evaluation report attest.

The criteria are:

1) one piezometer/100 ha within the limits of large irrigated perimeters (shallow piezometers).

2) along 10 pre-determined piezometric profile lines (kilometric spacing) perpendicular to the Senegal River valley (shallow, medium and deep piezometers).

3) with an approximate density of one piezometer per 100 km^2 (shallow, medium and deep piezometers).

4) along several piezometric profile lines (metric spacing) perpendicular to the river in the zone which is influenced by the Diama Dam (shallow and medium piezometers).

5) depending on the probable structure of the underlying aquifers, one piezometer per distinct geologic target.

Point #5 resulted in the construction of two and sometimes three piezometers at the same geographic site, each tapping a different geologic target.

Each equipped piezometer was developed by pumping for two hours, and then, upon recovery of the static water level, was tested for hydraulic conductivity (KK) with the dropping level method (slug test - see ref.: SEBJ, 1983). The interpretation of the test data was made with the Hvorslev method (see ref.: Freeze and Cherry, 1979).

The chemical analysis (major anions and cations) of water samples (268 samples of which 193 were drawn by SAFOR) was performed by the SONADER laboratory (LANASOL) in Nouakchott, Mauritania (some samples were analyzed by the BRGM laboratory in Dakar, Senegal).

Several pumping tests of short duration (24 hours) were carried out (X continuous stages of equal time periods and increasing discharges, followed by observation of the water level recovery) and of long duration (48 to 72 hours of drawdown with a steady discharge followed by observation of the water level recovery during a time period equal to that of the drawdown).

The construction of each piezometer also included soil sampling at each meter drilled. All of the soil samples (10,300 samples) were identified by piezometer number, and are stored in the sector offices in St. Louis, Senegal and in Rosso, Mauritania. These samples have been stored in a very orderly, rational arrangement and are, consequently, accessible and available for future consultation.

The field descriptions of the soil samples were essentially textural (granulometric) in nature (clay, sand, etc.).

The SAED soil laboratory in Ross Bethio, Senegal, performed the granulometric analyses (710) of the soil samples using a standard method developed by ORSTOM (Robinson pipette). The soil samples are of two categories:

* B1 - taken 10-20 cm below the surface
* B2 - taken at the level of the piezometer intake

All of the technical, geologic and hydro-geochemical characteristics of the aquifers in the study zone were collected on standardized forms, which were photocopied and catalogued in the sector offices. The original documents were sent to the data base chief for subsequent use. The reader can find an example of the standard data collection forms in the project presentation document presented to the OMVS member countries (see Annex #2, Section 3,3.1).

2.3.2 Piezometric network of the Upper Basin

This second part of the OMVS piezometric network, located in the environs of Manantali Dam, required the construction of 20 piezometers (DNHE Force Agreement) in the fractured bedrock, for a total of 1200 linear meters drilled.

The typical piezometer is identical to that shown in figure #2, however the drilling technique was different: hammerbits.

All of the technical, geological and hydrogeochemical characteristics of the aquifers in the study zone were sent to the central office in the manner described above.

2.4 Topographic surveying of the OMVS piezometric network structures

The elevation of each observation point in the OMVS piezometric network (wells and piezometers) has been determined with respect to zero ASL (Above mean Sea Level).

The work was completed by independent subcontractors between November 27, 1987 and January 6, 1989 in Senegal and Mauritania, and in Mali during the months of April and May 1989.

2.5 Computing resources

The size of the piezometric network (1171 points), the diversity of the natural environment (multiple study topics), the geographical expanse (1300 km long and 10 to 20 km wide), and the frequency of the site visits (about 1171 data forms monthly) require the persons in charge of the data base to maintain a remarkable data management system (a colossal mass of data). These persons must also be very effective at controlling the quality of the data entered, at extracting system output and interpreting the results. This quality of work is possible only by use of the new technology being applied to hydrogeology: microcomputers.

The project's computing resources consist of three work units. The computerized system for the management and exploitation of the data is composed of three elements:

* the software product "Groundwater",
* the groundwater management system (Gestion des Eaux Souterraines, GES)
* the software products "SURFER" and "GRAPHER".

2.5.1 Project computer equipment (hardware)

The central office staff possesses a total of three computers:

* a Northgate 386, AT-compatible computer equipped with a 60 MB hard disk and two disk drives (360 KB, 720 KB, 1.2 MB and 1.4 MB) linked to a Fujitsu DL-2400 color printer and a data storage system (Fastape Backup System),

* two basic IBM - XT computers (PC1 and PC2), equipped with 60 MB hard disks and two disk drives (360 KB and 720 KB). The two work stations (PC1 and PC2) are individually connected to an Okidata Microline 192/193 Plus printer. The PC2 is also connected to a Hewlett-Packard 7445A plotter.

In addition to this equipment there is a large model ALTECK digitizing table. . All of this equipment is located in a computer room, especially remodelled for this purpose (with obligatory dust protection and air-conditioning) and is protected by safety power supplies, voltage regulators, and emergency battery back-up systems, all essential equipment intended to protect the machines from fluctuations in electric voltage and power outages.

The different work units are autonomous and can be linked together by a communication software (LAPLINK). The units are not interconnected in a network.

The sector offices do not possess computer equipment of any kind.

2.5.2 GROUNDWATER software

GROUNDWATER software, produced by GROUNDWATER, Inc., and available on the market, permits the manipulation of the fixed parameters (non-changing with time) of the OMVS piezometric network such as descriptive technical characteristics (geologic, equipment related, etc.). This software, which is user-friendly (questions and answers) but still rigidly limited, allows one to plot, according to professional standards, geologic and technical cross sections per structure, geologic cross sections (combination of several individual geologic cross sections, diagrams of chemical analysis results, time-drawdown curves of pumping tests, etc.).

The results obtained through use of this software are principally documented in the Hydrogeological Repertoires (see Annex #2, Section #2) and in the Pumping Test Interpretation Reports (see Annex #2, Section #1).

2.5.3 GES - Groundwater Management System

The Groundwater Management System GES, produced by ISTI/INFORMISSION and not available on the market, was developed for the specific needs of the Unit. This data management system, which is user-friendly (question and answer menu) allows:

1) the entry of chronological data collected in the field (rainfall, piezometry, water-level data, physico-chemical parameters and some non-chronological data)

2) the control of the consistency and the validity of the chronological data,

3) the entry of measurements taken during hydraulic conductivity tests and their interpretation,

4) the visualization, for an observation period fixed by the user, of variations in:

i) piezometry and/or depth of the water level (up to three structures superimposed on the same graphic),
ii) physico-chemical parameters (pH, temperature and electrical conductivity),
iii) daily precipitation (35 raingauges - histograms),
iv) water levels (20 water level scales),

5) the juxtaposition of one or more of the graphics mentioned above on the same screen in order to establish a correlation,

6) the selection of a sample population of OMVS piezometric network observation points on the basis of certain criteria (geologic, geographic, cartographic section, coordinates, intake depth, geomorphologic, type of structure, etc.),

7) the exportation of characteristic values of the selected sample to SURFER and GRAPHER cartographic software,

8) the creation of intermediate files, DOS, LOTUS, DBF, etc., in order to use the results with other software,

9) the editing of results obtained through use of the functions cited above as summarizing tables, individual reports or graphic reports,

10) the consultation of maps and graphics produced with SURFER and GRAPHER software.

INFORMISSION (1988) prepared a technical report (detailed technical description of the GES system) and a User's Manual, for the resident team (see Annex #2, Section 3,3.5). In this document, are found technical comments concerning the conceptual model, the physical model, the structure of the data base files, a definition of the fields, a diagram of the system functions, the procedures: listing and entry of menus, listing and entry of data selection criteria, data compilation and edition of links between the programs, the list of programs written in Pascal, the transfer procedures of all the executable programs, including Pascal and CLIPPER programs, from the test index to the production index, etc..

The User's Manual for the GES system was updated (June 1990) following the last INFORMISSION mission (see Annex #2, Section 3, 3.20).

The GES system also possesses a help function for the user, listing on the screen the menus, procedures, variables, fields, etc. The information displayed on the monitor can also be adapted and/or modified by the data base chief, if so desired.

The system programs are practically all written in the CLIPPER programming language. This language is derived from dBase III+ but is much faster in execution. Approximately 90 percent of the instructions are the same for the two languages. Some programs for the production of certain reports and graphics were written in Turbo Pascal.

Thus, the system uses three different software products:

- CLIPPER for the entry and the storage of data as well as for the printing of the majority of the reports;
- Turbo Pascal for the production of graphics and certain special reports;
- dBase III+, although it is no longer used for programming since the September 1988 version, it can still be utilized as an interface for tests or for the execution of specialized procedures.

The programs were written with many notes in the source code so that they are self documenting.

The GES data management system was developed to function on an IBM compatible microcomputer. The requirements of the physical environment are:

- an internal memory of 640 Kb;
- a CGA type graphics card;
- a programmable printer with a capacity of 17 cpi and 15 inch paper width.

The memory capacity is necessary for execution of the CLIPPER programs, while the graphics monitor is needed to show the data analysis curves. The printer capacity is important for certain reports.

The system can be easily transferred to another computer as long as the technical environment requirements, both hardware and software, are respected. However, certain hardware specifications are not essential as long as they are substituted by the following equivalents:

- the system writes temporary files on the D: drive. It is essential that the microcomputer be configured for a D drive in order for the system to function. This drive can be real or virtual.

- the CGA graphics card is necessary for screen graphics since all of the Pascal programs have been compiled for this type of card. A microcomputer which has another type of card would need executable versions of the Pascal programs for that type of card.

The data can also be exported to other types of systems. In effect, the software has a simple command for copying data banks and files according to ASCII standards. These files can then be read by other software using ASCII standards.

Many software utility products are also installed in the three work stations, all are identical in their logical configurations. These software utilities allow, as the final evaluation team members noted (ref.: REESER, 1990), for corrections or modifications to be made upon recommendation by the computer specialist who developed the GES data base.

The procedure is simple:

1) state the diagnosis (problem, causes, effects etc.) clearly,
2) transmit the diagnosis by telephone, FAX or TELEX to the attention of the specialist responsible for developing the data base,
3) await the corrections by the same means of communication,
4) implement the corrections according to the specialist's instructions.

2.5.4 SURFER and GRAPHER - cartographic and graphic software

SURFER software - version 4, produced by Golden Software, Inc., was purchased upon the recommendation of M.R. Hollway, USGS expert. In simple terms, SURFER treats a polynomial (XYZ) corresponding to a land datum where:

X = longitude expressed in degrees, minutes, and seconds or in UTM-X (Universal Transverse Mercator - MTU is French acronym, map projection) coordinates,

Y = latitude expressed in degrees, minutes, and seconds or in UTM-Y coordinates,

Z = other values (topographic elevations, chemical analysis results, depths, demographic values, etc.).

Generally, the X and Y values of the (X,Y,Z) polynomial are determined in the field and are geographically localized with some uncertainty on a uniform map grid. Certain mathematical geostatistical techniques allow one to extrapolate statistical values for uniform grid points from the X and Y values determined in the field.

After the extrapolated values are calculated, SURFER allows one to visualize the results on a 2-dimensional card diagram or a 3 dimensional block diagram. The calculations of the surface area and volume are possible from these maps, through use of utility functions.

Maps produced in this way can be viewed on the screen, printed and saved in a reserved directory (map library) for later consultation with the GES system. Results obtained with this software, can be seen in the synthesis report covering the Senegal River Delta region (see Annex #2, Section 3.3.19).

GRAPHER software, also developed by Golden Software Inc. is a tool which complements SURFER. It permits visualization of the cross section of any surface (piezometric or topographic surface, curves of equal value of a chemical element, etc.) from a map generated by SURFER. Examples of results thus possible are shown in Annex #9 of the synthesis report, covering the delta region.

2.5.5 Diverse

In addition to the computer tools mentioned above which are specifically for hydrogeological work, the project also utilized the electronic spread sheet LOTUS 123 and WORDPERFECT 5.0 word processing software.

It is obvious that the computing tool can not replace either the intelligence or the insight of the hydrogeologist. However, the tool remains indispensable and its acceptance by all of the participants is closely related to the success of any project which deals with a large quantity of data. The resident team of the Groundwater Monitoring Unit has recognized this reality.

2.6 Interpretation

All of the hydraulic conductivity tests performed were interpreted with the GES system. The results of each test can be reviewed on the screen and the interpretation examined. GES also allows printing of the interpretation report for each piezometer tested.

The pumping tests were the topic of specific interpretation reports (see Annex #2, Section 1) published and distributed in twenty copies each to OMVS/Dakar.

All the technical, geologic and hydro-geochemical characteristics of the aquifers of the study zone have been described in the *Hydrogeological Repertoires.* These indexes cover the entire piezometric network of the Senegal River valley as well as the environs of Manantali Dam.

Publication of the Hydrogeological Repertoires, made possible through the use of various computer tools mastered by the central office personnel, has been useful, if not indispensable because:

* of the number of parties (Consulting Firms, SAED, ISRA, etc..) interested in having these data, who came with increasing regularity to St. Louis to obtain information on the piezometric network of the OMVS, whereas it was not always possible for the Groundwater Unit personnel (central and sector offices) to respond adequately,

* the sector office personnel (Mauritania, Senegal and Mali) suffered from a lack of critical information and feedback about the data which they themselves had gathered in the field.

Therefore, publication of the Hydrogeological Repertoires allowed the characteristics of the OMVS piezometric network to be distributed to different users, and to deliver a basic document to the sector chiefs permitting them to better plan their field activities.

The Hydrogeological Repertoires are accompanied by a 1/200,000 topographic map and include considerable methodological information concerning the work of establishing the network. The Repertoires are made up of two parts: the TEXT and the ANNEXED DOCUMENTS accompanied by 1/50,000 topographic maps.

The Hydrogeological Repertoires are accompanied by compilation maps which are, in themselves, project outputs widely sought after by users in the field. These maps (a total of 33) are incorporated into each of the Annexed Documents identified by a 1/50,000 topographic map, and permit the precise localization of each of the structures included in the OMVS piezometric network.

The set of Repertoires provides detailed descriptions of the technical characteristics of each of the OMVS piezometric network structures as well as its localization.

The reader will find in Annex #2, Section 2, a list of Hydrogeological Repertoires, published and distributed in 20 copies to OMVS/Dakar.

The use of computer tools, the mastering of work methods and the know-how of all of the Unit participants permitted the production of two synthesis and data interpretation reports corresponding to the observation period and covering two different regions of the Senegal River valley: the delta and the environs of Manantali Dam.

These reports are an example of what the team, at the end of the project, can produce for the regions not covered by these reports, i.e., the lower valley, the upper and lower middle valley and the upper valley of the Senegal River.

These two synthesis reports, designated Volume #2 (Delta) and Volume #3 (environs of Manantali Dam) (see Annex #2, Section 3, 3.16 and 3.17) were reproduced and distributed in 20 copies to OMVS.

2.7 Training

The training which was planned as part of this project was:

* long-term in the United States of America for three candidates selected from the OMVS member countries,

* long-term within the member countries of the OMVS for six candidates from the OMVS member countries,

* short-term for the research assistants.

2.7.1 Long-term training for third parties

A part of the project funds was used to cover:

a) educational costs related to the training provided by Utah State University in the USA, living costs and a living allowance for the participants from the OMVS member countries:

* Mr. Ousmane N'Gom (Ministry of Hydraulics, Senegal) for the period from October 1985 to June 1988,
* Mr. Soungalo Togolo (Ministry of Hydraulics, Mali) for the period from July 1986 to August 1988,
* Mr. Moulaye Driss Ould Guig (Ministry of Hydraulics, Mauritania) for the period from September 1985 to August 1988.

b) training costs incurred for the training provided by the BRGM in France, living costs and a living allowance for three participants from the member countries:

* Mr. Toumane Diakite (Ministry of Hydraulics, Mali)
* Mr. Mohamed Fadel Ould Saad Bouh (Ministry of Hydraulics, Mauritania)
* Mr. Mamadou Sarr (Ministry of Hydraulics, Senegal)

This training was conducted between the months of August and December, 1986 in France, followed by field training from January to April 1987 in the home country of each of the candidates. The number of candidates was reduced to three due to the high cost of the training.

The Groundwater Monitoring project did not benefit directly from the know-how and competencies acquired by the candidates mentioned in points a and b above, since it was not intended that these persons join the ranks of the project team at the completion of their training.

However, due to certain circumstances, Mr. O. N'Gom and Mr. Fadel Ould Saad Bouh joined the project personnel as, respectively, project chief and assistant sector chief of the Rosso, Mauritania sector.

2.7.2 Short term training of project staff

In addition to the planned training, the project found it necessary to provide training to its own personnel in order to increase the project's chances for success.

The project chief received additional training (I month) in the United States of America by the USGS.

The central office secretary, who is also the person responsible for data entry, and the St. Louis sector chief, were provided with computer training (50 hours) by the Senegalese Institute of Professional Training. This training was oriented towards the utilization of LOTUS 123 spreadsheet and WordPerfect 5.0 word processing software.

The GMU accountant received computer training (I week) with IBM in Dakar plus 40 hours with the secretary and the former administrative and financial assistant (Mr. J. Onofrey).

The hydrometrists, responsible for monitoring the OMVS piezometric network received training (I month) from members of the resident team and the sector chiefs. This training focused on the tasks and responsibilities related to their mandate in their respective work zones.

The reader will find, in Annex #2, Section 4, the list of documents concerning programming of the hydrometrists' field activities. These documents constitute in themselves one of the keys to the successful hydrogeological monitoring of the piezometric network.

The field supervisors, responsible for inspecting the execution of contracted work of the drilling company, were given training (1 1/2 months) by members of the resident team and the sector chiefs.

The reader will find, in Annex #2, Section 5, a list of the documents concerning programming of the SAFOR company's contracted work.

3 CONCLUSIONS

The study topics and the expected outputs were reviewed and analyzed during the final evaluation of the Groundwater Monitoring Project. The conclusions and recommendations of the evaluation team are found in the report prepared by Mr. S. Dendrou and Mr. R. Reeser, for the Funding Agency, USAID (see references). Their report should be viewed as an annex to the present report.

The goals and expected outputs were:

1) a master plan for the management of surface and groundwater,

2) an information management system for the OMVS,

3) a method for compiling and analyzing the data,

4) the training of OMVS personnel to implement and follow-up the master plan for the management of surface and groundwater,

5) an OMVS piezometric network.

The final evaluation report concludes that points 2), 3), and 5) were fully accomplished and that points 1) and 4) were not achieved. Point 1) was judged to be too "ambitious and excessive". Point 1) was replaced with the obligation to prepare two synthesis reports covering the Senegal River delta and the environs of Manantali Dam. The explanations provided by the authors of the evaluation report are clear and probing and do not require any further details. They are based on analysis of the project's structure and on the diversity and range of study topics in relation to the period of project activity.

In the course of its activities, the project installed a piezometric observation system which permits OMVS to monitor the piezometry of the aquifers along the entire Senegal River valley and the environs of Manantali Dam (point 5).

The establishment of the Groundwater Monitoring Unit personnel (central and sector offices), their training in administrative, financial, contractual and technical management of the general project activities, their application of the different work methods taught (particularly procedures for obtaining field data and transmitting it within the project structure for analysis and interpretation) constitute achievement of point 2).

The development of the data base (GES, GROUNDWATER, SURFER and GRAPHER), the computerized management system for data compilation, classification, and research, report printing and result interpretation as well as the training received by the central office personnel in the system's use, constitute achievement of point 3).

The syntheses reports concerning the Senegal River Delta region and the environs of Manantali Dam were completed in May 1990, as requested, and constitute achievement of point 1).

Point 4 was a consequence of point 1) (master plan). In the absence of point 1), no training was provided to the OMVS staff in its application in the field. However, training in the use of the data management system was focused upon, resulting in the increased capabilities of the central office personnel with respect to GMU activities (data collection, data entry into the system and data analysis). In other words, the training foreseen in point 4) was reoriented towards development and use of the data management system, thus achieving, at least partly, point 4).

Therefore, the project attained its expected outputs.

This statement is strictly contractual and does not signify that everything was achieved. Much was accomplished, and much remains to be done. The resource persons, the working tools, and the analysis methods constitute an additional institutional competence for the OMVS. The continuity of field operations, accepted and implemented by the OMVS is the guarantee of the valorization and optimization of the project acquisitions.

A data base can be assimilated by an active organization. Its intrinsic value depends upon the quality of the input data and the continuity of the data through time (chronological series). A high performance working tool is also required in order to continually maintain the data base (software and hardware).

On the basis of these achievements, and only on this basis, can OMVS pursue its medium- and long-term scientific considerations in order to cover all the study topics proposed in the project document.

4 LESSONS LEARNED

4.1 Institutional

4.1.1 Composition of the central office personnel

After the 3rd quarter of 1988, the central office team was seriously reorganized. It became lighter, that is to say that the project chief took on two functions: project chief and chief of data collection and analysis. The consulting engineer also took on two functions: assistant project chief and technical adviser.

The diversity of the tasks (management of various contracts, technical and administrative coordination of the sectors, development of the data base and its use, analysis and interpretation of the results, public relations with external participants, etc.) constituted an overwhelming amount of work for the team and will do so to an even greater extent after June 30, 1990 in the absence of the consulting engineer.

The project chief, the sole technical representative who is competent in the technical management of all the activities related to the computerized system, will not be able to meet all the demands placed on him.

4.1.2 Distribution of information

The heavy work load placed upon such a minimal team will result in the reduction of activities oriented towards the dissemination of information to interested organizations (SAED, SONADER, CNRADA, ISRA, ORSTOM, Technical Services of the Ministries of Hydraulics, etc.). These information distribution and communication activities require adequate preparation, document production (see Annex #2, Section 3, 3.1, and 3.6) and availability in time and space for this regional project (three member countries), where the central office is decentralized (St. Louis) with respect to organization headquarters (OMVS in Dakar).

The distribution of information was problematic during the period of USAID financed activities. It will be even more so upon termination of USAID financing, when all the technical responsibilities will be consolidated in the hands of one person. Some reflection on the respective roles of all the participants (OMVS, USAID, Project) should be undertaken in this regard.

4.1.3 Decentralization of the project structure

The Groundwater Monitoring Unit benefitted structurally from relative autonomy in the daily management of its activities, with respect to personnel, local currency budget, diverse contracts with subcontractors, and techniques to be implemented in the field.

This autonomy was made possible by the terms of reference stated in the project document (written to the Funding Agency's specifications), the geographic isolation of the central office in St. Louis with respect to OMVS headquarters in Dakar, and its acceptance by the OMVS.

Having experienced this situation for more than 5 and a half years, it is possible to confirm that the recognized success of the project is, in part, due to this autonomy. It suffices to consider that there have been nine administrators (6 USAID and 3 OMVS) responsible for Groundwater Monitoring Unit activities (3 experts: national and expatriate).

4.1.4 Subcontracting of field work

The granting of contracts for construction of the OMVS piezometric network to private companies was a wise decision, even if not stipulated in the terms of reference of the project document. The high quality of the work performed has been confirmed (Vandenbeusch and Bolke), the time of completion was reduced as much as possible (SAFOR = I year; DNHE = several months) and the professional specifications were met. This decision saved the resident team, who would otherwise have had to manage the ongoing field work in addition to their other work load, both time and energy.

4.2 Long term training

The project suffered from a shortage of adequately trained local human resources, even though project funds were being spent to cover the costs of advanced studies in the United States of America. It is somewhat cynical to remark that these well-trained persons do not join the ranks of this project which deals with such a vast array of study topics (due not only to the nature of the data collected but also to the geological diversity of the study zone).

The integration of these persons into the implementing organization should be planned with the greatest care.

4.3 Technical

4.3.1 Computer Development

The development of a computerized data base is based on a new technology: micro-computer systems adapted to hydrogeological applications. This technology was brought into the Groundwater Monitoring Unit, although it was not stipulated in the terms of reference in the project document. Without this decision, recognized as appropriate, the project would not be what it is today.

Anxiety engendered by the apparent complexity of this technology and a poor understanding of computers caused delays in decision-making and underestimation of the time required to develop a data management system. Consequently, since the time required to perform the work could not be reduced (10 to 12 hours per day), the number of consultancies was increased and the calendar period required for the development of the GES became excessive in relation to the project's duration.

A clearer understanding of computing needs would have permitted a reduction in the number of consultancies, obtainment of the data management system sooner, and more in-depth testing of it. In order for this to occur, the administration would have needed to be more flexible and pay more attention to technical advice.

4.3.2 Linguistics

The linguistic compatibility of any technical expert who must interact with the resident team, as well as with the host environment, is a basic and fundamental requirement at least as important as his or her technical competence. Whether this principal is accepted or not, the facts remain. The documentation concerning the Senegal River valley is practically entirely in French. Counting on the bilingual capabilities of the resident team when programming experts' consultancies is not a remedy since the work load of the resident team is greatly increased by the supplemental tasks of hosting, coordinating visits, interpreting, translating etc..

5 RECOMMENDATIONS

5.1 Institutional

5.1.1 Continuation of field operations

For scientific reasons, and in its own best interests, OMVS has agreed to continue the hydrogeological monitoring of its piezometric network after June 30, 1990 for a transitional period of two years. In principle, the minimal length of time during which field operations will continue is to correspond to the time required for Manantali and Diama Dams to achieve regular operations, thereby regularizing the river's discharge and establishing the normal range of river level fluctuations over the annual cycle.

With respect to hydrogeological monitoring, the Groundwater Monitoring Unit has demonstrated its know-how in the field. Therefore, the remaining organizational structure (central and sector office personnel) should be maintained.

It is up to the OMVS to relocate the Unit's structure within the OMVS organigram, if needed. Any changes to the Unit's own structure could unbalance established work routines and thus jeopardize its functioning and efficiency.

5.1.2 Reduction in number of piezometers

The Groundwater Monitoring Unit team which remains upon termination of USAID financing (combined central and sector office personnel) represents the minimum staff required to perform the monthly hydrogeological monitoring of the entire piezometric network (wells and piezometers).

Any further reduction in personnel will necessitate a reduction in the number of piezometers which can be monitored on a regular basis. Such operating-cost savings would dangerously diminish OMVS's ability to interpret the various phenomena which will undoubtedly be observed in the future.

If, for reasons beyond its control, the OMVS must give up part of its piezometric network, selection of the structures to eliminate should be made using the following categories (least significant to most significant):

* #1: village wells, with the exception of those in the Delta and in the lower valley,
* #2: piezometers which are located outside of irrigated perimeters, beyond 1 km of perimeter limits,
* #3: regional piezometric lines transverse to the Senegal river with kilometric spacing,
* #4: piezometers contained within the limits of irrigated perimeters,
* #5: geographic sites containing two or three piezometers tapping different hydrogeological targets,
* #6: piezometric lines transverse to the Senegal River with metric spacing,
* #7: all of the observation points (wells and piezometers) which are located within the limits of the delta and the lower valley.

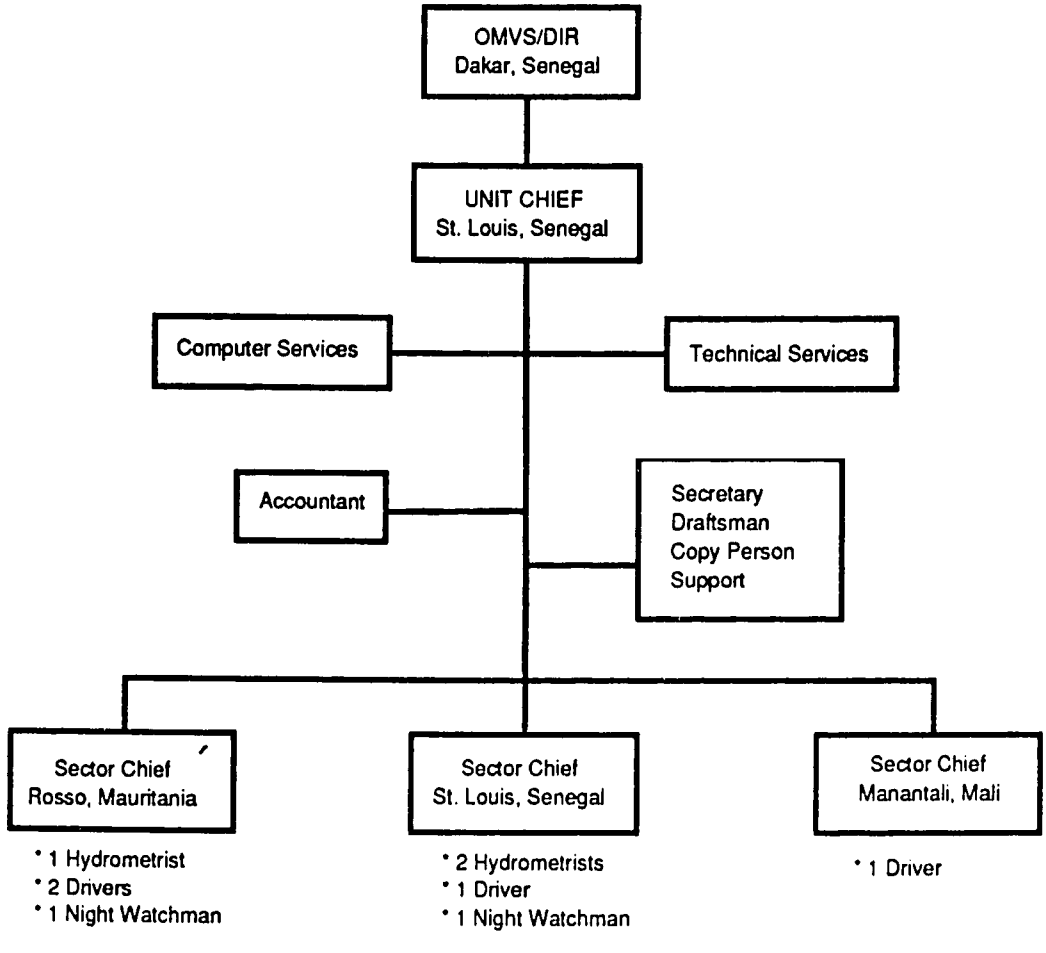
5.1.3 Support for the GMU chief

Appropriate, valuable use of the project's technical achievements will depend completely on the only technically trained person remaining in the project: the present Unit Chief. Alone and isolated, his ability to work productively will be highly limited. Therefore, it is proposed that two resource persons (national experts) be assigned to assist the Chief of the Groundwater Monitoring Unit: one computer specialist and one hydrogeologist.

The organigram below indicates, in addition to the remaining GMU team which will permit OMVS to ensure continuation of field operations upon termination of USAID financing, the hierarchical positions of the two above-mentioned specialists.

The persons responsible for computer services and technical services seem indispensable in assisting the Unit Chief to ensure continuation of field data analysis and interpretation activities.

PROPOSED ORGANIGRAM OF
THE GROUNDWATER MONITORING UNIT
UPON TERMINATION OF USAID FINANCING
ON JUNE 30, 1990



5.1.4 Short-term technical assistance

The Funding Agency terminates its financial assistance to this OMVS project on June 30, 1990, and thus, the long-term technical assistance. An abrupt disengagement may destabilize the central office personnel of which the only technical person is the project chief. Despite his competence and motivation, he cannot be expected to cope with all potential problems.

Outside, short-term support is recommended concerning:

* the up-keep and maintenance of the computer system (hardware and software)
* the up-keep and maintenance of the GES system,
* the support of a hydrogeologist,
* the training of national computer specialists and hydrogeological specialists.

Both a computer specialist and a hydrogeologist are necessary for the success of these short-term consultancies. The duration of these interventions should not exceed three or four weeks. Their scope of works should foresee time, upon their arrival in Senegal, to make a proper definition of the team's needs rather than to be constrained to an priori administrative definition.

This recommendation is in keeping with OMVS's concerns of ensuring its autonomy, consolidating its expertise and eliminating extremely short-term technical assistance.

5.1.5 Orientation for technical organizations working in the valley

The GMU's results have been communicated as multiple copies of reports sent to OMVS headquarters, OMVS member countries and the OMVS Documentation center. It appears that document reading is a more tiresome activity than the attending of meetings and seminars.

It is recommended, therefore, that a calendar of meetings be established with the technical organizations working in the valley (ORSTOM, ISRA, SAED, SONADER, CNRADA, the Universities of Dakar and Nouakchott, etc.) with the following objectives:

1) to distribute information about the GMU, its resources, the data and the results acquired since the beginning of its activities,

2) to encourage these various organizations to make direct use of the raw data, as yet untreated, which is contained in the data base (definition of consultation procedures),

3) to define the program of field work and thematic research (soil salinization, water table rise, river - water table recharge, evaporation) in collaboration with one or more of these organizations. This program should correspond to field needs and avoid being limited to theoretical research topics.

Pragmatically, it should be noted that without support for the GMU chief (recommendation of point 5.1.3), this effort is in vain.

5.2 Short term work program

5.2.1 Continuation of interpretation work - small scale

The synthesis reports - volume #2 and volume #3 (see Annex #2, section 3, 3.16, and 3.17) - deal uniquely with the delta region and the environs of Manantali Dam. These geographic limits were imposed by the June 30, 1990 deadline.

It would, obviously be desirable to continue the thematic mapping and interpretation of results for the whole valley.

On a small scale, the following geographic sectioning is proposed:

* the lower valley and the lower middle valley, (Z1) located between coordinates MTU-X 426 and MTU-X 580, corresponding approximately to the limit of influence of Diama Dam (elevation 2.5 m ASL),

* the upper middle valley and the upper valley (Z2) located between coordinates MTU-X 580 and MTU-X 818, covering the suspected Maestrichtian recharge zone.

Some of the geological maps of zone (Z1) have already been produced and all the basic digitizing work has been completed for the whole Senegal River valley.

5.2.2 Continuation of interpretation work - large scale

The cartographic scale used in this report permits the representation of regional characteristics and the exposition of hydrogeological phenomena. However, the local nature of hydrogeological phenomena related to salinization would be better studied at a larger scale and would benefit from the geographic sectioning of the delta into sub-regions:

* DLT_1 includes the zone near Keur Macène and the perimeter at Debi,

* DLT_2 includes the perimeters at Boundoum, Thiagar and M'Pourie,

* DLT_3 includes the environs of Diama Dam.

SURFER base maps of each of these sub-regions already exist in the data base. Several piezometer lines, transverse to the river, are located in each zone.

Development of the suggested thematic maps for each sub-region would be a fairly simple exercise since all the useful source files (geology, water level, piezometry, etc.) for the geostatistical treatment already exist for the entire delta region. The mapped results are practically immediate following a simple redefinition of the geographic limits of the maps (MTU-X, MTU-Y).

5.2.3 Procedural changes for the measurement of electrical conductivity

Within the limits of the delta, electrical conductivity measurements have caused some concern with regard to the degree with which they represent actual aquifer conditions. The measurement procedures used in the field are considered to be the cause.

In order to alleviate these problems, it is recommended:

1) to give priority to salinity monitoring of the piezometer lines which are transverse to watercourses and to the piezometer lines which traverse irrigated perimeters,

2) to maintain the monthly measurement schedule,

3) to systematically empty the 2½ inch PVC piezometer tubes with appropriately sized submersible pumps before measuring the salinity. The submersible pumps for emptying the piezometers are already available to the project: one per sector office. The criteria for stopping pumping would be the stabilization of the measured electrical conductivity values. In the absence of pumps, simple foot valves could be used.

4) to use the newly purchased conductivity meters with the measurement scales from 0 to 200,000 μS/cm.

5.3 Medium and long term work program

Work programs are determined by the needs of the technical organizations working in the valley (see recommendation 5.1.5). The GMU is specialized in hydrogeology and, consequently, can only make contributions to current problems within the limits of this science. The scope of subjects researched must be proportional to the available means, and should be limited, as much as possible, to unique, precise topics. Support from organizations which have already dealt with similar research topics would obviously be desirable.

Several study proposals have already been made during the course of project activities.

5.3.1 Soil salinization monitoring (BRGM recommendation)

The phenomenon of soil salinization is in the domain of agronomic science. It occurs in relation to evaporation and evapotranspiration of water from surface sources (irrigation water from developed areas of the valley) and from shallow groundwater which rises due to capillarity. Physical and chemical soil phenomena are also involved.

The quantitative evaluation of this phenomenon could be undertaken with the installation of measurement stations which would be located in function of:

- the geology (geological profiles) and pedology of the areas: these criteria would be established with the organizations concerned with agricultural development (ISRA, SAED, etc.),

- the depth of the water table and its annual fluctuations (use of the data base concerning piezometric evolution data)

- the local environment of each site (proximity to water courses, swamps, irrigated zones, etc.), how representative it is of other zones where salinization is likely to occur (agronomic criteria), and its proximity to meteorological stations.

It is suggested that 4 stations be installed, each comprising the same equipment:

- a piezometer of small diameter, full-tubed as far as the water table,

a set of tensiometers, installed so as to measure the soil water potential in the non-saturated zones (depths of 0.20 m, 0.40 m, 0.60 m, 1,0 m and every 0.50 m thereafter until the water table is reached).

It would be possible to install these stations at shallow depths in the existing piezometer profile lines perpendicular to the river. The measurement of evapotranspiration losses thus obtained could be used to refine the calculations of the lateral river-aquifer exchanges. Two stations would be installed near the experimental agricultural perimeters.

The stations would be monitored monthly (piezometers, salinity and soil moisture content), necessitating field equipment including a neutron probe, which could cause certain difficulties.

The data thus collected would permit an evaluation, for each period of time, of the water volume evaporated through the soil surface. Bi-weekly monitoring could be required in case of strongly varying equilibrium states.

The calculated flow volumes would later be used to quantify the exchanges between the river and the alluvial aquifer.

5.3.2 Lateral hydraulic exchanges with the Quaternary formations (BRGM proposal)

Operation of the dams will induce changes in the water level of the river, spatially and with time. Lateral exchanges with the alluvial aquifer will be affected by the new conditions.

Begun in 1984 with one profile (BRGM 1984), then continued by EUROCONSUL during restoration of the irrigated perimeter at BOUNDOUM, the quantification of the lateral exchanges will be continued through the analysis of piezometric profiles perpendicular to the river. Determination of the hydrodynamic parameters of the alluvium permits the calculation of flows and their variation with time.

The OMVS piezometric network, constructed for several purposes (geologic prospection, hydraulic conductivity tests, piezometric measurement), contains 7 profiles which are transverse to the river (L1 to L7) within the limits of the delta and several others further upstream.

Analysis of lateral flow can be made with the following procedure:

- examination of the piezometric evolution recorded up to the end of the dry period, corresponding to the last monthly visit made before the onset of the flood period,

- analysis of the geological and hydrodynamic contexts (values of hydraulic conductivity as determined by testing the piezometers): classification of profiles with similar characteristics,

- use of mathematical models to reconstruct the measured piezometric evolution as recorded with the profiles and to quantify the lateral flow.

This approach, based on the analysis of conditions at various sites along the river, would allow the characterization of the different segments of the river to be determined.

The effects of water lost by evapotranspiration would be considered on the basis of previous estimates (laws of variation deduced from Dutch studies, 1973).

5.3.3 Planning modeling activity

Among the uninitiated, the term "model" evokes the notion of simplicity and efficiency. This perception is totally false. Confusion has prevailed in regard to this term throughout the life of the project.

A mathematical model is a precious tool when applied concretely to a topic of research and when manipulated by a trained team. A structure like the GMU cannot take responsibility for any modeling activity because of its staffing limitations. It is possible, however, that the use of one or more mathematical models would be absolutely pertinent in the effort to find answers to problems which are posed.

It is recommended, therefore, that a seminar be held with one or more modelling specialists who have experience with the problems which exist in the valley and a solid understanding of the project's resources, in order to:

1) develop an inventory of the different mathematical models which are likely to be of use in solving the problems,

2) estimate the complexity and the difficulties involved in using these models,

3) describe the various work scenarios which are possible in light of human and financial resources available at the time,

4) choose the most appropriate modeling program.

REFERENCES

Reeser R. M. and Dendrou S., May 1990 - OMVS Groundwater Monitoring Project (project 625-0958) Final Evaluation, prepared for USAID Senegal.

AID, 1983 - Project Paper, OMVS/Groundwater Monitoring Project (625-0958), Annex A, page A-5.

Development Assistance Corporation, July 1986 - Study of the Structures of the Senegal River Development Organization (OMVS).

SEBJ, March 1988 - Service Géologique et Méchanique des Sols, Manuel de l'inspecteur, fascicule no. 7, Essai de perméabilité in-situ, Société d'Energie de la Baie James.

FREEZE and CHERRY, 1979, Groundwater, pages 340-341.

HISTORY BY QUARTER

Important steps (*) and results (**)
covering the period from
July 1, 1984
to
June 10, 1990

ANNEX 1

1984

1st & 2nd QUARTERS

* OMVS and USAID technical and administrative start-up of the Groundwater Monitoring Project,

* Search for a long-term technical assistant, first from the USGS, then from ISTI,

* Long-term recruitment of the financial and administrative assistant (Mr. J. Onofrey),

1985

1st & 2nd QUARTERS

* Central office opened in St. Louis with assignment of the resident team to the project's central office in St. Louis, Senegal, (Mr. M. O. Hmednah, project chief, Mr. D. Diegane, responsible for data collection and analysis, and Mr. B. Diakité, responsible for field operations),
** *Restoration of the project's head office, property of OMVS,*

* Arrival of the assistant to the project chief, long-term technical assistant, (Mr. D. Richard),
** *Field activities begun,*

* Opening of sector offices in St. Louis, Senegal (Mr. L. Sangare, sector chief, detached from the Ministry of Hydraulics, Senegal) and in Rosso, Mauritania (sector chief, Mr. A. Ndiaye, detached from the Ministry of Hydraulics, Mauritania),
** *Restoration of the sector office in St. Louis, Senegal, and construction of the sector office in Rosso, Mauritania,*

* Research and analysis of studies already done in the proposed project zone followed by the development of a proposed contract with a Contractor for construction of the OMVS piezometric network.

3rd QUARTER

* Approval of the contract by the OMVS and USAID Administrations,
** *A realistic work plan is laid out, taking into consideration the technical specifications of the piezometric network, the available manpower and the deadlines stated in Implementation Letter #7 (P.I.L. #7)*

* Writing of an International Request for Bids for construction of the OMVS piezometric network, located partly in Senegal and partly in Mauritania,
** *International Request for Bids file,*

4th QUARTER

* Publication of the International Request for Bids
** *Four international bids submitted,*

32

1986

1st QUARTER

* Examination of international bids submitted,
** *Report of analysis of the bids submitted, followed by Implementation Letter #12 (P.I.L. #12),*

2nd QUARTER

* Contract signed with the SAFOR company, Mauritania,
** *OMVS/SAFOR contract,*

* Writing of work program documents with the SAFOR company,
* Identification in the field of drilling sites in Senegal and Mauritania,
** *SAFOR - Documents concerning contracted work program (see appendix #2, section 5)*
** *Revision of 33 compilation maps (using IGN base maps) at the scale of 1/50,000 for the entire Senegal River Valley,*

* Writing of program documents for the hydrometrists,
** *Documents concerning the programming of the hydrometrist's activities in Senegal and Mauritania (see annex #2, section 4),*

3rd QUARTER

* Writing of the terms of reference of the OMVS/DNHE Force Agreement,
** *Proposed File - Force Agreement OMVS/DNHE,*

* Writing of the terms of Reference for the development of a computerized Groundwater Management system (Gestion des Eaux Souterraines - GES),
** *International Request for Bids file,*

* Long-term advanced University training (3 years)in the U.S.A. for three nationals of the OMVS member states (Mr. Ousmane Ngom, Mr. M. Driss Ould Guih, Mr. Soungolo Togolo),
** *Professional upgrading of three nationals of the member states, one of whom, Mr.O Ngom later became Project Chief,*

* English language Training (4 years) for the secretary (Ms. Victorine Diagne) with the British-Senegalese Institute, in St. Louis,
** *Improvement of the linguistic capabilities of the central office secretarial staff,*

* Medium-term theoretical training (4 months) in France (BRGM) of three nationals from the Ministries of Hydraulics of the OMVS Member States (Mr. Toumane Diakite, Mr. Mamadou Sarr, Mr. Mohamed Fadel Ould Saad Bouh).
** *Professional upgrading of three nationals of the Member States of whom one, Mr.M. Fadel Ould Saad Bouh, became assistant Project Chief in Rosso Mauritania,*

4th QUARTER

* Recruitment and on the job training (1 month) of the hydrometrists of the sector offices in St. Louis, Senegal (6) and Rosso, Mauritania (6),
** *Data collection activities in the field are begun,*

* Recruitment and on the job training (1 month and a half) of construction inspectors for the SAFOR company contracted works, Senegal (2) and
Mauritania (2),
** *Inspection of contracted work performed by SAFOR is begun,*

* Commencement of periodic monitoring of village wells which make up an initial sub-group of the OMVS piezometric network,
** *Field data acquired (wells only),*

33

1st QUARTER

* Groundwater Management System (Gestion des Eaux Souterraines - GES), consultancy by ISTI/INFORMISSION (Mr. M. Fortin) to begin development of the computerized data base -phase #1,
** *Creation of a Groundwater Management System, a beginning,*

* SAFOR, commencement of contracted work and first drilling campaign,
** *First piezometers of the OMVS network are constructed and geological description of the aquifer (soil samples, granulometric analyses and water analysis) obtained (see appendix 2, section 2, the list of Hydrogeological Repertoires),*

* Sector chiefs coordinate the supervision of work done by the SAFOR company,
** *Control of inspection procedures,*

* Commencement of data entry into the computerized system (GES),
** *Training in procedures to manage and analyse data before compilation, and commencement of data entry activities,*

* Writing of the "PP Supplement" for a revision of the project budget and its approval by the administrations,
** *Increase of the project budget by 1.5 million USDLRS, which was the subject of an amendment to the OMVS Grant Agreement,*

* medium term practical training (5 months) by the BRGM to 3 nationals of the Ministries of Hydraulics of the OMVS member countries in each of their respective countries,
** *Consolidation of the theoretical training and application in the field,*

2nd QUARTER

* Commencement of periodic monitoring of the piezometers constructed by SAFOR, constituting the second sub-group of the OMVS piezometric network,
** *Acquisition of chronological field data (wells and piezometers),*

* SAFOR, second drilling campaign,
** *Increase in the number of piezometers in the OMVS network and continuation of the geologic characterization of the aquifer (soil samples, granulometric analysis and water analysis) (see annex 2, section 2, the list of Hydrogeological Repertoires) ,*

* Replacement of the technical and administrative assistant by his successor (Mr. T. Rosche),
** *Continuity in the administrative and financial follow-up of the project,*

* Training of the project accountant (Mr. M. L. N'diaye), 1 week with IBM in Dakar and 40 hours using LOTUS.
** *Improved competence of the project accountant,*

* Presentation of the project to the OMVS member countries including visits to the SAFOR work sites,
** *Increased awareness by the authorities of the member countries of the project's acquisitions and future,*

3rd QUARTER

* Approval of the OMVS/DNHE Force Agreement,
** *Finalization of the OMVS/DNHE Force Agreement,*

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* English language training (1 year) for the central office resident team by an ex-Peace Corps volunteer,
* English language training (1 year) for the project chief (Mr. Moussa Ould Hmednah) by the British-Senegalese Institute in St. Louis,
** *Improved linguistic capabilities of the central office resident team,*

4th QUARTER

* Sub-contracting of the topographic surveying work for Senegal (Mr. Lo) and Mauritania (Mr. Diop),
** *Commencement of the surveying work in Senegal and in Mauritania,*

* SAFOR, third and last drilling campaign,
** *Delivery of the total OMVS piezometric network in Senegal and in Mauritania; increased number of piezometers in the OMVS network and continuation of the geologic characterization of the aquifer (soil samples, granulometric analysis and water analysis) (see annex 2, section 2, the list of Hydrogeological Repertoires),*

1988

1st QUARTER

* SAFOR, first pumping test campaign made in Senegal and in Mauritania,
** *Hydrogeological characterization of the aquifer by interpretation of the pumping tests (see annex #2, section 1),*

* Opening of the sector office in the OMVS building at Manantali, Mali, and assignment of the sector chief (Mr. M. Toure, detached from the Ministry of Hydraulics in Mali),
* Writing of the DNHE work program documents,
* Identification in the field of drilling sites in the environs of Manantali Dam,
** *DNHE - Documentation related to the programming of contracted works (see annex #2, section 5),*

* DNHE, geophysical prospecting campaign; electric and magnetic,
** *Geophysical prospecting interpretation report and definitive establishment of the drilling sites,*

* DNHE, commencement of the first drilling campaign,
** *Geologic characterization and acquisition of the first OMVS network piezometers in the environs of Manantali Dam,*

2nd QUARTER

* By decision of the OMVS High Commissioner, personnel of the central office resident team are returned to the disposition of the Member Countries,
** *Improved tripartite relationships: OMVS, USAID and project,*

3rd QUARTER

* Departure of the project chief and 2 hydrogeologists, all three members of the central office resident team, and temporary paralysis of the data entry activities into the GES system,
** *Functional reorganization of central and sector office personnel resulting in increased autonomy of the sector offices,*

* Groundwater management system (GES), consultancy by ISTI/INFORMISSION (Mr. L. Brunelle) for the development of the computerized data base - phase #2,
** *Increased functional capabilities of the GES data base system,*

* BRGM (Mr. M. Vandenbeusch), first and last consultancy, evaluation,
** *First proposal for an action plan regarding short term technical assistance consultancies,*

* SAFOR, second and last campaign of pumping tests made in Senegal and in Mauritania,
** *Hydrogeological characterization of the aquifer by interpretation of the pumping tests (see annex #2, section 1),*

4th QUARTER

* Assumption of duties by the new project chief in the central office (Mr. O. Ngom, M.S., Civil and Environmental Engineering, Utah State University),
** *Consolidation of professional and institutional acquisitions with the continuation of data entry activities into the GES data base system,*

* Second and last drilling campaign by DNHE, Mali,
** *Continuation of the geologic characterization and acquisition of the last piezometers in the OMVS network, in the environs of Manantali Dam,*

* Commencement of periodic monitoring of the piezometers constructed by DNHE, constituting the OMVS hydrogeological observation network, in the environs of Manantali Dam,
** *Acquisition of chronological field data (piezometers),*

1989

1st QUARTER

* SAFOR, commencement of rehabilitation work on the OMVS piezometric network following vandalism in Senegal and Mauritania,
** *Complete rehabilitation of the OMVS piezometric network,*

* DNHE, pumping tests performed,
** *Hydrogeological characterization of the aquifer by interpretation of the pumping tests (see annex #2, section 1),*

* Completion of all the contracted works undertaken in relation to the OMVS/SAFOR contract, to the OMVS/DNHE Force Agreement and to topographic surveying contracts in Senegal and Mauritania,
* Groundwater management system (GES), consultancy by ISTI/INFORMISSION (Mr. L. Brunelle) for the development of the computerized data base - phase #3,
** *Increased functional capabilities of the GES data base system,*

* Rejection by USAID of the action plan proposed by the BRGM,
* USGS, first consultancy, evaluation of the OMVS piezometric network (Mr. Bolke),
** *End of the technical isolation of the project's resident team and second proposal of a work program regarding short term technical assistance together with a report attesting to the quality and the value of the OMVS piezometric network,*

* Short term computer training (50 hours) for the central office secretary/data entry agent and the St. Louis sector chief, focused on use of the LOTUS 123 spreadsheet and the WP5.0 word processor,
** *Increased computing competence for the central office personnel and discovery of the computer for the sector chief,*

2nd QUARTER

* Proposed Terms of Reference for the project's final evaluation,
** *Draft of a request for services to be rendered,*

* Administrative procedures to justify an extension of the project from December 31, 1989 to June 30, 1990, at the request of OMVS,
** *Granting of a 6 month project extension, subject of a "Project Authorization Amendment",*

* Price Waterhouse, audit of the OMVS/SAFOR contract,

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** *Report reaffirming the proper financial management of this contract (see annex #2, section 3),*

* Closure of the Senegal-Mauritanian border in April 1989,
** *Loss of physical contact between the central office and the sector office in Rosso, Mauritania,*
* Recruitment of an hydrometrist, a secretary and a driver for the sector office in Manantali, Mali,
** *Assignment of sector office personnel,*

* Commencement of topographic surveyng work in the environs of Manantali Dam (contracted work),
** *Acquisition of elevation data for the OMVS piezometric network points,*

* Presentation of the project during a training seminar organized by the CEFIGRE for representatives of francophone Africa,
** *Awareness by representatives of francophone Africa of the project's acquisitions and future and a report (see annex #2, section 3),*

* Short term training (2 weeks) with the Rank Xerox company in Dakar,in the maintenance of the document and map reproduction equipment, for the person responsible for the copy room,
** *Increased competence of the person responsible for the operation and maintenance of the equipment,*

3rd QUARTER

* Approval by OMVS and USAID, without an overall increase of the budget, of the extension of the project until the end of June 1990,
** *Improved capabilities of the resident team to optimize the acquired results,*

* Short term theoretical training (1 month) for the Project Chief, in the USA with USGS
** *Increased technical competence in mathematical modeling and development of institutional contact with USGS,*

* R.I.G., inventory control of project goods, materials and equipment,
** *Report on the management system of project goods, materials, and equipment,*

* USGS, second consultancy (Mr. Weiss), revision of the second proposed work program (Mr. Bolke) regarding short term technical assistance,
** *Third proposal of an action plan concerning short term technical assistance through the project's termination (06/30/90),*

4th QUARTER

* Administrative and contractual procedures to define the scopes of work of the ISTI and USGS technical assistants during the project extension period,
** *Amendments to the ISTI and USGS contracts,*

* USGS, third consultancy (Mr. R. Hollway),
** *Reception and installation of a digitizing table and training of the resident team in the use of cartographic software (SURFER),*

* Approval by the OMVS of the third action plan regarding short term technical assistance needed through the project's termination,
** *Clarification of the work plan to be adopted by the resident team,*

* Reflection about the composition, in terms of human resources, of the minimal team (OMVS) which would permit the continuity of project activities after termination of USAID financing,
** *Proposal for the minimal team (OMVS),*

1st QUARTER

* Groundwater management system (GES), consultancy by ISTI/INFORMISSION (Mr. L. Brunelle) for the development of the computerized data base - phase #4,
** *Increased functional capabilities of the GES data base system,*

* USGS, fourth consultancy (Mr. Weiss) reflection on the methodology to be used for production of the hydrogeological maps,
** *Definition of the final report contents (3 Volumes),*

* Recruitment of an independent consultant for the production of documents to be annexed to the final reports (hydrological and climatic),
** *Subsequent reports (see annex #2, section 3),*

2nd QUARTER

* Groundwater management system (GES), consultancy by ISTI/INFORMISSION (Mr. L. Brunelle and Mr. M. Migneault), phase #5,
** *Delivery of a user-friendly version of the GES data base system and training for OMVS personnel,*

* USGS, fifth consultancy (Mr. Weiss),
** *Support to the central office resident team for the production of volume #2 (one of the final reports),*

* Production of the final reports (3 volumes),
** *Delivery of the three (3) final reports (see annex #2, section 3),*

* Closure of the OMVS/SAFOR contractual dossier and of the OMVS/DNHE Force Agreement,
** *Closure of the contractual dossiers,*

* Establishment of the minimal team (OMVS) which will permit the continuity of operations after termination of USAID financing,
** *Reduction of personnel in the central and sector offices and transfer of responsibilities for the management of field activities to OMVS,*

* Project evaluation by the Louis Berger team (Mr. S. Dendrou and Mr. R. Reeser), in April and May 1990,
** *Project Final Evaluation Report (see annex #2, section 3),*

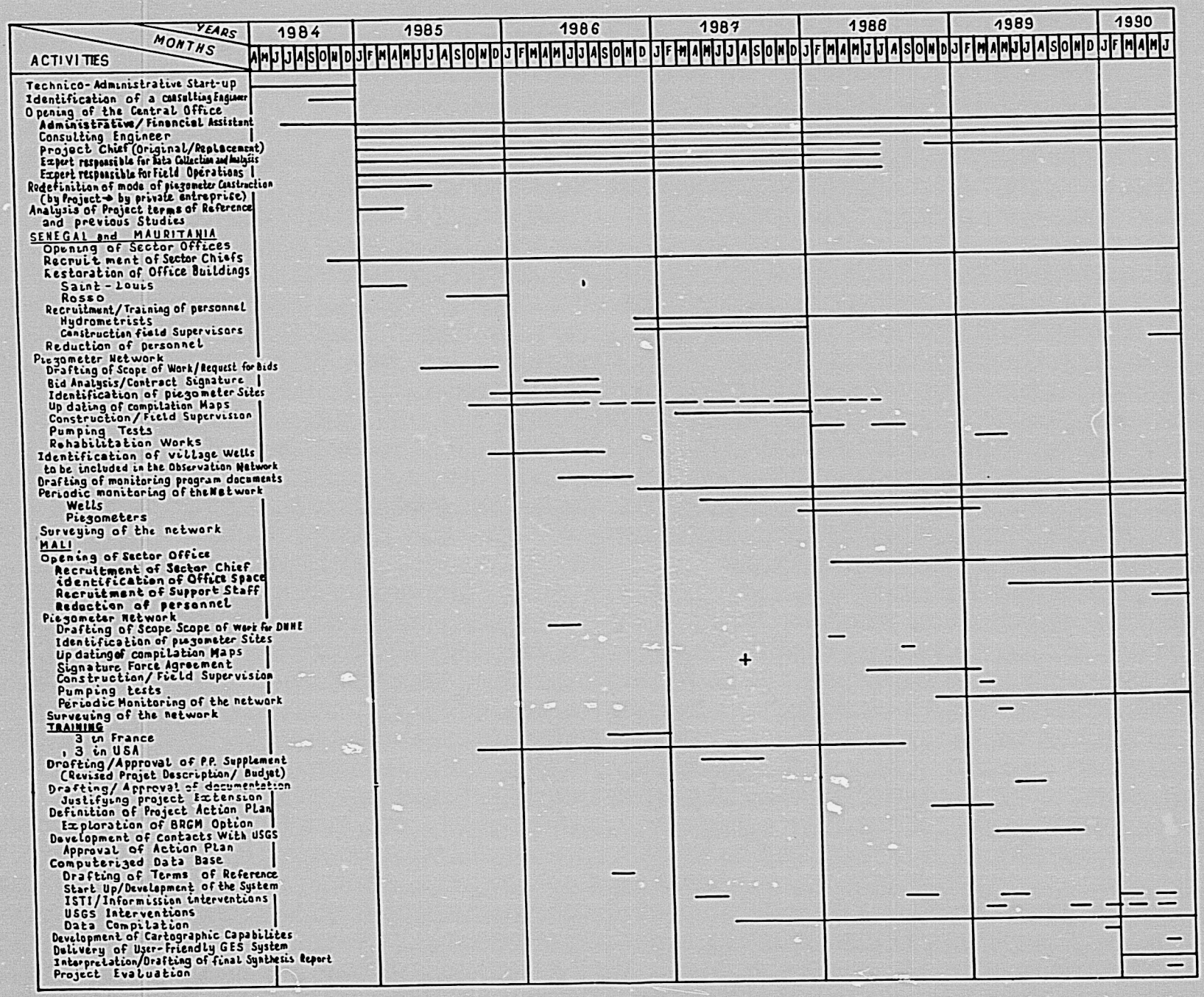
* Turn over of the all the project materials, equipment and documentation to OMVS,
** *Turn over of all the goods and materials purchased for the project to OMVS (see annex #3, list of goods, etc.),*

* Departure of USAID technical assistance and end of financial assistance on June 30, 1990.
** *Turn over of an organized structure giving autonomy to OMVS for the continuity of field operations, data collection and analysis,*

OMVS/USAID (PROJECT 625-0956)

OMVS - GROUNDWATER MONITORING UNIT

CALENDAR OF PROJECT ACTIVITIES



39.

List of documents
produced and distributed
by the
groundwater monitoring project
up to
June 30, 1990

ANNEX 2

1 PUMPING TEST INTERPRETATION REPORTS

1.1 Dispositif de pompage RIM/DA001, Résultats et interprétation, Carte topographique 1/50 000, 06 Saint-Louis 2C, Rapport essai de pompage, Fichier DA001.RAP.

1.2 Dispositif de pompage RIM/DA032, Résultats et interprétation, Carte topographique 1/50 000, 06 Saint-Louis 4A, Rapport essai de pompage, Fichier DA032.RAP.

1.3 Dispositif de pompage SEN/GA036, Résultats et interprétation, Carte topographique 1/50 000, 06 Saint-Louis 4A, Rapport essai de pompage, Fichier GA0036.RAP.

1.4 Dispositif de pompage SEN/GA255, Résultats et interprétation, Carte topographique 1/50 000, 06 Saint-Louis 2D, Rapport essai de pompage, Fichier GA0255.RAP.

1.5 Dispositif de pompage SEN/GA0264, Résultats et Interprétation, Carte Topographique 1/50 000, 07 DAGANA 1C, Rapport Essai de pompage.

1.6 Dispositif de pompage RIM/DA083, Résultats et Interprétation, Carte topographique 1/50 000, 07 DAGANA 1D, Rapport Essai de pompage.

1.7 Dispositif de Pompage SEN\GA0205, Résultats et Interprétation, Carte topographique 1/50 000, 07 DAGANA 3B, Rapport Essai de pompage.

1.8 Dispositif de pompage RIM\DA098, Résultats et Interprétation, Carte Topographique 1/50 000, 07 DAGANA 3B, Rapport Essai de pompage.

1.9 Dispositif de pompage RIM/DA139, Résultats et Interprétation, Carte Topographique 1/50 000, 07 DAGANA 4B, Rapport Essai de pompage.

1.10 Dispositif de pompage SEN/GA0283, Résultats et Interprétation, Carte Topographique 1/50 000, 08 PODOR 2C, Rapport Essai de pompage.

1.11 Dispositif de Pompage SEN\GA0237, Résultats et Interprétation, Carte topographique 1/50 000, 08 PODOR 3A, Rapport Essai de pompage.

1.12 Dispositif de pompage RIM\DA199, Résultats et Interprétation, Carte Topographique 1/50 000, 08 PODOR 3B, Rapport Essai de pompage.

1.13 Dispositif de pompage SEN/GA0283, Résultats et Interprétation, Carte Topographique 1/50 000, 09 KAEDI 2C, Rapport Essai de pompage.

1.14 Dispositif de Pompage SEN\GA0237, Résultats et Interprétation, Carte topographique 1/50 000, 09 KAEDI 3A, Rapport Essai de pompage.

1.15 Dispositif de pompage RIM\DA199, Résultats et Interprétation, Carte Topographique 1/50 000, 09 KAEDI 3B, Rapport Essai de pompage.

2 HYDROGEOLOGICAL REPERTOIRES

Text with accompanying 1/200,000 topographic maps. Annexed documents (compilation maps and annexes) with accompanying 1/50,000 topographic maps. The annexed documents contain:

* Geologic and technical cross sections
* Granulometric analyses
* Water analysis diagrams

2.1 Répertoire hydrogéologique, Carte topographique 1/ 200 000, St-Louis 06, Texte et Documents annexes, St-Louis 2A, St-Louis 2B, St-Louis 2C, St-Louis 2D, St-Louis 4A, St-Louis 4B,

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2.2 Répertoire hydrogéologique, Carte topographique 1/ 200 000, Dagana 07, Texte et Documents annexes Dagana 1C, Dagana 1D, Dagana 3A, Dagana 3B, Dagana 4A, Dagana 4B.

2.3 Répertoire hydrogéologique, Carte topographique 1/ 200 000, Podor 08, Texte et Documents annexes Podor 2B, Podor 2C, Podor 2D, Podor 3A, Podor 3B, Podor 4A, Podor 4B.

2.4 Répertoire hydrogéologique, Carte topographique 1/ 200 000, Kaedi 09, Texte et Documents annexes Kaedi 2B, Kaedi 2C, Kaedi 2D, Kaedi 3A, Kaedi 3B, Kaedi 4A, Kaedi 4B.

2.5 Répertoire hydrogéologique, Carte topographique 1/ 200 000, Matam 15, Sélibabi 16, Bakel 21, Texte et Documents annexes, Matam 2D, Matam 3D, Matam 4A, Matam 4B, Matam 4C, Selibabi 1A+1B+1C+3A et Bakel 3D.

3 EXPERT'S REPORTS - TECHNICAL ASSISTANCE

3.1 PES, Janvier 1987 - Cellule eaux Souterraines, Présentation du Projet OMVS/USAID à l'attention des Etats Membres de l'OMVS, Texte et Annexes, Organisation pour la Mise en Valeur du Fleuve Sénégal, Direction de l'Infrastructure Régionale, Projet OMVS/USAID 625-0958, St-Louis, Sénégal.

3.2 Anderson J. and Schulz A., April 1987, - OMVS Groundwater Monitoring Project, Project Paper Supplement 625-0958, prepared for U.S. Agency for International Development.

3.3 DNHE/OMVS, 1988 - Rapport prospection géophysique de la zone du barrage de Manantali pour l'implantation de 19 piézométres, Ministère du Développement Industriel et du Tourisme, Direction Nationale de l'Hydraulique et de l'Energie.

3.4 Vandenbeusch, M. 1988 - Mission de consultant en hydrogéologie de Michel Vandenbeusch, BRGM, 12 septembre 88 - 7 octobre 88, rapport de mission.

3.5 Fortin M. et Brunelle L., Octobre 1988 - Système Informatisé de Gestion des Eaux Souterraines, Version "septembre 1988", Manuel de l'usager et Documentation Technique, préparé pour OMVS/USAID, Projet 625-0958, Cellule Eaux Souterraines, St-Louis par Informission Ltée, mandatés par International Science and Technology INstitute, Inc.

3.6 PES, 1989 - CEFIGRE - OMVS, Technologies Nouvelles et Gestion des Grands Fleuves, L'expérience OMVS et des Pays Membres, OMVS, Direction de l'Infrastructure Régionale, Cellule Eaux Souterraines, Projet OMVS/USAID 625-0958

3.7 Bonkel A., 1989 - Etude de la répartition des paramètres hydrochimiques des eaux souterraines de l'aquifère alluvial situé en rive droite du fleuve Sénégal entre Keur Macène et Dagana, Institut des Sciences de la Terre (I.S.T.), Université Cheick Anta Diop, Dakar.

3.8 Bolke E. L. and Stephens C. J., 1989 - Senegal River Valley Ground-Water project: Summary report on piezometer evaluation, February-March 1989, U. S. Geological Survey, Open-File Report 89-411, prepared for the Organisation pour la Mise en Valeur du Fleuve Sénégal and the U. S. Agency for International Development.

3.9 Weiss E., Richard D. and Ngom O., September 89 - Modeling Feasibily Study for the Senegal River Valley, Groundwater Monitoring Project, Preliminary Report,

3.10 DNHE, 1989 - Programme OMVS Exécution de 20 piézométres à Manantali, Rapport Final, Ministère de l'Industrie de l'Hydraulique et de l'Energie, Direction Nationale de l'Hydraulique et de l'Energie, établi par M. Bagayoko et S. M. Fofana.

3.11 Weiss E., February 1990 - Organization, Methodology, and Limitations of the Synthesis Report of the Ground Water Monitoring Project of the Senegal River Valley #625-0958.

3.12 Price Waterhouse, 7 Juillet 1989 - Contrôle financier du marché de travaux de construction d'un réseau de forage piézométrique dans la vallée du fleuve Sénégal, préparé pour USAID et OMVS.

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3.13 Ndiaye B., Juillet 1989 - Etude hydrogéologique du delta du fleuve Sénégal, Colorado State University Civil Engineering Department, Financée par le Council for International Exchange of Scholars.

3.14 Diagana A., 20 janvier 1990 - Etude des paramètres hydrodynamiques des aquifères de la basse vallée du fleuve Sénégal entre St-Louis et Podor, D.E.A. de Géologie Appliquée, mention: hydrogéologie, Université Cheick Anta Diop de Dakar, Faculté des sciences, Département de Géologie.

3.15 Piekutowski T., May 1990 - Paramètres climatiques de la vallée du fleuve Sénégal, observés sur la période 1986 - 1989, rapport préparé pour USAID/OMVS, Projet Eaux Souterraines.

3.16 Piekutowski T., May 1990 - Paramètres hydrologiques du barrage de Manantali, observés sur la période 1986 - 1989, rapport préparé pour USAID/OMVS, Projet Eaux Souterraines.

3.17 Piekutowski T., May 1990 - Paramètres hydrologiques du fleuve Sénégal observés sur la période 1986 - 1989, rapport préparé pour USAID/OMVS, Projet Eaux Souterraines.

3.18 Reeser R. M. and Dendrou S., May 1990 - OMVS Groumdwater Monitoring Project (project 625-0958) Final Evaluation, prepared for USAID Sénégal.

3.19 Weiss E., Richard D. et Ngom O., mai 1990 - Delta du fleuve Sénégal, Rapport hydrogéologique de synthèse, Période d'observation 1986 - 1989, Volume 2, Fichier WP.5: VL2.TXT.

3.20 Richard D., Ngom O. et D.Diagana, mai 1990 - Environs du barrage de Manantali, Carte de Bafoulabe (27), Répertoire hydrogéologique, Période d'observation, 1988 - 1989, Rapport de synthèse, Volume 3, Fichier WP.5: VL3.TXT

3.21 Migneault M. et Brunelle L., Mai 1990 - Manuel d'utilisation du Système GES, Version conviviale (V3 R1), Système réalisé dans le cadre du Projet USAID No AFR-0958-C-00-5008-00, Informission Ltée, Québec, Canada pour International Science and Technology Institute, Inc., 1129 20 th St. NW-8th FL. Washington, D.C. 20036.

3.22 Migneault M. et Brunelle L., Mai 1990 - Réalisation de la version conviviale, Intervention faite dans le cadre du Projet USAID No AFR-0958-C-00-5008-00, Informission Ltée, Québec, Canada pour International Science and Technology Institute, Inc., 1129 20 th St. NW-8th FL. Washington, D.C. 20036.

3.23 Piekutowski T., June 1990 - Calculated discharges through Diama Dam, covering the period 1986 1989, report prepared for USAID/OMVS, Groundwater Monitoring Project.

4 DOCUMENTATION CONCERNING THE HYDROMETRIST'S TECHNICAL ACTIVITY PROGRAMMING

4.1 Notice explicative relative aux inventaires des points d'observations hydrogéologiques, Série A et B Rives Droite et Gauche,10 juin 1986.

SENEGAL

4.2 SENEGAL - RIVE GAUCHE, Inventaire des puits villageois - Série-GB, Par carte topographique 1/50 000, 29 Mai 86.

4.3 SENEGAL - RIVE GAUCHE, Répertoire des Fiches Inventaire des Puits, Villageois - Série GB, Tome I, Degrés Carrés de Saint-Louis et de Dagana, 8 Juillet 1986.

4.4 SENEGAL - RIVE GAUCHE, Répertoire des fiches d'inventaire des puits, Villageois - Série GB, Tome II Degré Carré Podor, 8 Juillet 86.

4.5 SENEGAL - RIVE GAUCHE, Répertoire des fiches d'inventaire des puits, Villageois - Série GB Tome III, Degrés Carrés Kaédi, Matam, Sélibaby, Linguère, Louga, Bakel, 8 Juillet 86.

4.6 SENEGAL - RIVE GAUCHE, Inventaire des puits villageois - Serie GB Par carte topographique 1/50 000, Programmation des prélèvements des échantillons d'eau superficielles et souterraines, 8 Septembre 86.

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4.7 Sénégal, Zone d'intervention No 1, Saint-Louis/16é Parallèle (Station de Roncq), Programmation de l'Hydrométriste, 30 Juin 86.

4.8 Sénégal, Zone d'intervention No 2, Roncq/Keur Sadio, Programmation de l'hydrométriste, 30 Juin 86.

4.9 Sénégal, Zone d'intervention No 3, Keur Sadio/Le Gayo Diamal, Programmation de l'hydrométriste, 30 Juin 86.

4.10 Sénégal, Zone d'intervention No 4, Le Gayo Diamal/Vinding, Programmation de l'hydrométriste, 30 Juin 86.

4.11 Sénégal, Zone d'intervention No 5, Vinding/Ourossogui/Matam, Programmation de l'hydrométriste, 30 Juin 86.

4.12 Sénégal, Zone d'intervention No 6, Ourossogui Matam/Bakel, Programmation de l'hydrométriste, 30 juin 1986.

MAURITANIA

4.13 MAURITANIE - RIVE DROITE, Inventaire des puits villageois - Série DB par carte topographique 1/50 000, 21 Mai 86.

4.14 MAURITANIE - RIVE DROITE, Répertoire des fiches d'inventaire des puits Villageois - Série DB Tome I, Dégrés Carrés Saint-louis Dagana, Podor, 8 Août 86.

4.15 MAURITANIE - RIVE DROITE, Répertoire des fiches d'inventaire des puits Villageois - Série DB Tome II, Degrés Carrés, Kaédi, Matam, Sélibaby, Août 86.

4.16 MAURTANIE, Zone d'intervention Diama/Marigot-Bell, Programmation de l'hydrométriste, 30 juin 86.

4.17 MAURITANIE, Zone d'intervention No 1, Lac MBell/NGarak Lac Tambass, Programmation de l'hydrométriste, 30 juin 86.

4.18 MAURITANIE, Zone d'intervention No II, Garak/Bawadji, Programmation de l'hydrométriste, 30 juin 86.

4.19 MAURITANIE, Zone d'intervention No III, Bawadji/Olo-Ologo, Programmation de l'hydrométriste, 30 juin 86.

4.20 MAURITANIE, Zone d'intervention No IV, Olo-Ologo, Programmation de l'hydrométriste, Juin 86.

4.21 MAURITANIE, Zone d'intervention No V, MBagne Diovol-Lexeiba, Programmation de l'hydrométriste, 30 Juin 86.

5 SAFOR - DOCUMENTATION CONCERNING CONTRACTED WORK PROGRAMMING

5.1 SENEGAL - RIVE GAUCHE, Inventaire des piézomètres - Série GA par carte topographique 1/50 000, Lot Sénégalais, 29 Mai 86.

5.2 SENEGAL - RIVE GAUCHE, Lot Sénégal, 375 Piézomètres - Série GA, Répertoire des croquis d'implantation, 8 Juillet 1986.

5.3 SENEGAL - RIVE GAUCHE, Inventaire des Piézomètres - Série GA par carte topographique 1/50 000, Lot Sénégalais, Programmation des prélèvements des échantillons d'eau superficielles et souterraines, 8 Septembre 86.

5.4 SENEGAL - RIVE GAUCHE, Inventaire des piézomètres - Série GA, Lot Sénégalais - Programmation des analyses granulométriques et des essais de perméabilité multiples, 8 Septembre 86.

5.5 SENEGAL - RIVE GAUCHE, Lot Sénégalais - Programmation des essais de pompage, 11 Novembre 86.

5.6 MAURITANIE - RIVE DROITE, Inventaire des piézomètres Série DA, Lot Mauritanien, 25 Avril 86.

5.7 MAURITANIE - RIVE DROITE, Lot Mauritanien, 286 piézomètres -Série DA, Répertoire des Croquis d'implantation, 26 Juin 86.

5.8 MAURITANIE - RIVE DROITE, Inventaire des piézomètres, Série DA par carte topographique 1/50 000, Lot Mauritanien, Programmation des analyses granulométriques et essais de perméabilité multiples, 8 Septembre 86.

5.9 MAURITANIE - RIVE DROITE, Inventaire des piézométres, Série DA par carte topographique 1/50 000, Lot Mauritanien, Programmation des prélèvements d'eau superficielle et souterraine, 8 Septembre 86.

5.10 MAURITANIE - RIVE DROITE, Lot Mauritanien, Programme des essais de pompage, 20 Novembre 86.

5.11 DOSSIER D'APPEL D'OFFRES, Pour la Mise en Place d'un réseau de 660 piézomètres subdivisés en 2 lots

- Lot Mauritanien
- Lot Sénégalais

LIST OF DOCUMENTS WHICH MAKE UP THE REQUEST FOR BIDS FILE

1. Avis d'appel d'offre - Instructions aux fournisseurs
2. Termes de Références (T.R)
3. Cahier des Prescriptions Spéciales (C.P.S)
4. Cahier des Prescriptions Techniques (C.P.T)
5. Cadres des Bordereaux des Prix Unitaires - Hors Taxes lot Mauritanien
6. Cadre des Bordereaux des Prix Unitaires - Hors Taxes Lot Sénégalais
7. Cadre du Devis Estimatif - Hors Taxes - Lot Mauritanien
8. Cadre du Devis Estimatif - Hors Taxes - Lot Sénégalais
9. Modèle du Cautionnement Définitif
10. Modèle de Cautionnement Provisoire
11. Modèle de Retenue de Garantie
12. Modèle de Soumission
13. Modèle de Convention

6 DNHE - DOCUMENTATION CONCERNING CONTRACTED WORK PROGRAMMING

6.1 OMVS/DNHE Force Agreement is constituted of the following documents:

1) Modèle de Convention
2) Termes de Références
3) Cahier des Prescriptions Spéciales (CPS)
4) Cahier des Prescription Technique (CPT)
5) Cadre du Bordereau des Prix Unitaires Hors Taxes
6) Cadre du Devis Estimatif Hors Taxes

7 ADMINISTRATIVE AND CONTRACTUAL REPORTS PREPARED BY THE CONSULTING ENGINEER

7.1 Rapport Trimestriel d'Avancement des Travaux No 1 couvrant la période du 1 Janvier au 3 Avril 1985, version française.

7.2 Rapport Trimestriel d'Avancement des Travaux No 2 couvrant la période du 3 Avril au 17 Juillet 1985, version française.

7.3 Rapport Trimestriel d'Avancement des Travaux No 3 couvrant la période du 18 Juillet au 30 Décembre 1985, version française.

7.4 Rapport Trimestriel d'Avancement des Travaux No 4 couvrant la période du 20 Décembre 1985 au 27 Mars 1986, versions française et anglaise.

7.5 Rapport Trimestriel d'Avancement des Travaux No 5 couvrant la période du 29 Mars au 28 Juin 1986, version française.

7.6 Rapport Trimestriel d'Avancement des Travaux No 6 couvrant la période du 29 Juin au 30 Septembre 1986, version française.

7.7 Rapport Trimestriel d'Avancement des Travaux No 7 couvrant la période du 1e Octobre 1986 au 5 Janvier 1987, version française.

7.8 Rapport Trimestriel d'Avancement des Travaux No 8 couvrant la période du 6 Janvier au 30 Juin 1987, version française.

7.9 Rapport Trimestriel d'Avancement des Travaux No 9 couvrant la période du 1 Juillet au 31 Décembre 1987, versions française et anglaise.

7.10 Rapport d'Activités du mois de Février 88, versions française et anglaise.

7.11 Rapport Trimestriel d'Avancement des Travaux No 10 couvrant la période du 01 Janvier 1988 au 31 Mars 1988, versions française et anglaise.

7.12 Rapport d'Activités du mois de Avril 88, versions française et anglaise.

7.13 Rapport d'Activités du mois de Mai 88, versions française et anglaise.

7.14 Rapport Trimestriel d'Avancement des Travaux No 11 couvrant la période du 01 Avril au 30 Juin 1988, versions française et anglaise.

7.15 Rapport Trimestriel d'Avancement des Travaux No 12 couvrant la période du 01 Juillet au 30 Septembre 1988, versions française et anglaise.

7.16 Rapport d'Activités du mois d'Octobre 88, versions française et anglaise.

7.17 Rapport d'Activités du mois de Novembre 88, versions française et anglaise.

7.18 Rapport Trimestriel d'Avancement des Travaux No 13 couvrant la période du 01 Octobre au 31 Décembre 1988, versions française et anglaise.

7.19 Rapport d'Activités du mois de Janvier 89, versions française et anglaise.

7.20 Rapport d'Activités du mois de Février 89, versions française et anglaise.

7.21 Rapport Trimestriel d'Avancement des Travaux No 14 couvrant la période du 01 Janvier 1989 au 31 Mars 1989, versions française et anglaise.

7.22 Rapport d'Activités du mois d'Avril 89, versions française et anglaise.

7.23 Rapport d'Activités du mois de Mai 89, versions française et anglaise.

7.24 Rapport Trimestriel d'Avancement des Travaux No 15 couvrant la période du 01 Avril au 30 Juin 1989, versions française et anglaise.

7.25 Rapport Trimestriel d'Avancement des Travaux No 16 couvrant la période du 01 Juillet au 30 Septembre 1989, versions française et anglaise.

7.26 Rapport d'Activités du mois d'Octobre 89, versions française et anglaise.

7.27 Rapport d'Activités du mois de Novembre 89, versions française et anglaise.

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7.28 Rapport Trimestriel d'Avancement des Travaux No 17 couvrant la période du du 01 Octobre au 31 Décembre 1989, versions francaise et anglaise.

7.29 Rapport d'Activités du mois de Janvier 90, versions française et anglaise.

7.30 Rapport d'Activités du mois de Février 90, versions française et anglaise.

7.31 Rapport Trimestriel d'Avancement des Travaux No 18 couvrant la période du 01 Janvier 1990 au 31 Mars 1990, versions française et anglaise.

7.32 Rapport d'Activités du mois d'Avril 90, versions française et anglaise.

7.33 Rapport d'Activités du mois de Mai 90, versions française et anglaise.

7.34 Rapport Final du mois de Juin 90, version française et anglaise.

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List of goods, materials and equipment turned over to
OMVS upon termination of USAID financing
June 30, 1990

ANNEX 3

List of goods and equipment turned over to the Groundwater Monitoring Unit upon termination of USAID financing (June 30, 1990).

Category	Quantity Descriptions
CENTRAL OFFICE	
VEHICLES	2 Toyota Corollas 2 Toyota Landcruisers 1 Landrover 110 1 Mitsubishi Pickup
COMPUTER EQUIPMENT	2 Computers, IBM-XT 640 K with 60 M hard disks 2 Printers, Okidata 192/193 3 Monitors, Princeton color 1 Plotter, HP 7475 1 Data storage system, Fastape 4 Power/Frequency regulators, Imunilec 1 Computer, Northgate-AT 640 K, 60 M hard disk 1 Color monitor, CGA card 1 Printer, Fujitsu FJ2400 color 1 Digitizing table, AKTEK, large model
INSTRUMENTS	1 pH meter, Schott-Gerate 1 Conductivity meter, Schott-Gerate 4 pH meters, old models 4 Conductivity meters, old models 2 Water depth sounders, MARTEK Groundwater monitoring XIV 5 Water depth sounders, electric 3 Water samplers
TOPOGRAPHIC INSTRUMENTS (OMVS PROPERTY FROM PREVUIOUS PROJECT)	4 Theodolites 5 Surveyor's Levels 2 Tachymeters 6 Tripods 6 Surveyor's rods
DIVERSE	1 Radio transceiver, MACKAY MS 8000 1 Submersible pump 1 Photocopier, XEROX 1040 1 Photocopier, 3M 1 Blueprint machine 1 Duplicator, REX ROTARY 1 Typewriter, XEROX 575 1 Typewriter, IBM 196c 2 Calculators, FACIT
RESERVE VEHICLES	1 Mitsubishi Pick up 8 Honda 125 motorcycles (used) 2 Toyota Landcruiser Pickups (1 damaged)
ON ORDER	4 Conductivity meters (0 - 100,000 μS/cm) 1 Computer, 386 complete compatible with the Northgate 3 Water analysis kits for field use

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ST. LOUIS, SENEGAL SECTOR

VEHICLES	2 Mitshibishi Pickups 3 Honda 125 motorcycles
INSTRUMENTS	4 pH meters, Schott-Gérate 4 Conductivity meters, Schott-Gerate 4 pH meters, old models 4 Conductivity meters, old modes 4 Water samplers 1 Surveyor's level, Wild 1 Tripod, Wild 2 Surveyor's rods, Wild 3 Submersible pumps 2 Water depth sounders, MARTEK Groundwater monitoring XIV 4 Water depth sounders, electric
DIVERSE	1 Radio transceiver, Mackay MS 8000 1 Typewriter, manual, Hermès 1 Typewriter, IBM 196c

ROSSO, MAURITANIA SECTOR

VEHICLES	2 Mitshubishi Pickups 2 Honda 125 motorcycles
INSTRUMENTS	2 pH meters, Schott-Gerate 2 Conductivity meters, Schott-Gerate 2 pH meters, old models 2 Conductivity meters, old models 3 Water samplers 1 Surveyor's level, Wild 1 Tripod, Wild 2 Surveyor's rods, Wild 2 Water depth sounders, electric
DIVERSE	1 Radio transceiver, MACKAY MS 8000 1 Typewriter, manual, Hermès 1 Photocopier, XEROX 2830

MANANTALI, MALI SECTOR

VEHICLES	1 Mitshubishi Pickups 1 Honda 125 motorcycles 1 Toyota Pickup
INSTRUMENTS	1 pH meter, Schott-Gerate 1 Conductivity meter, Schott-Gerate 1 Surveyor's level, Wild 1 Tripod, Wild 2 Surveyor's rods, Wild 1 Water depth sounder, electric 2 Water samplers
DIVERSE	1 Typewriter, manual, Hermès 1 Photocopier, Xerox 1012 1 Radio transceiver, MACKAY MS 8000

DESCRIPTION OF THE STUDY ZONES

ANNEX 4

The description of the study zone has been the subject of several reports written by the Groundwater Monitoring Unit, of which:

* Volume #2 - interpretation report - specifically treating the Senegal River Delta (see the exact reference in annex #2, section 3, 3.19),

* Volume #3 - interpretation report - specifically treating the environs of Manantali Dam (see the exact reference in annex #2, section 3, 3.20).

The Lower, Middle and Upper Valley zones have not been the subjects of interpretation reports. However, a project presentation document (CEFIGRE, 1989) describing the physical geography of the upper and lower basins of the Senegal River, the geology, and the groundwater of the Senegal River Valley (see Annex #2, section 3, 3.6) was written by the Unit.

The description of the valley's environmental characteristics (geography, geology and groundwater), developed in this document (CEFIGRE, 1989), is largely taken from the reference below.

"Etude Hydro-agricole du bassin du Fleuve Sénégal
Organisation pour la Mise en Valeur du Fleuve Sénégal
Rapport du Synthèse des études et Travaux"

AG:DP/RAF/65/061
Rapport Technique #1

Programme des Nations Unies pour le Dévéloppement
Organisation des Nations Unies pour l'alimentation et
l'Agriculture,
Rome, 1977.

The descriptions in the document cited above are models of synthesis and conciseness.

It did not appear useful, therefore, when writing this final report, to annex the various reports produced by the Unit describing the study zone. Many copies of these documents have been distributed to the administrative authorities and are available at the OMVS Documentation Center.

The reader will find on the next page a table entitled: " Terrain encaissant de la Vallée du Fleuve Sénégal - caractéristiques hydrogéologiques connues".

This table is a compilation of hydrogeological parameters, for each of the lithostratigraphic series found in the Senegal River Valley. The table summarizes the known parameters of the sedimentary terrains of the Quaternary (Nouakchottian, Ogolian, Inchirrian and Ancient and Middle Quaternary), of the surrounding sedimentary terrains of the Tertiary (Terminal Continental, Middle Eocene, Lower Eocene, Paleocene) and of the underlying terrains of the Secondary (Maestrichtian). These parameters were determined through previous studies and the references are indicated.

This table permits the reader to:

1) situate, geologically, the aquifer being studied through the project activities,

2) to understand the hydrogeological nomenclature being used in the valley, which varies from one river bank to the other although it describes the same situation.

Most of the OMVS piezometric network taps the alluvial aquifer contained in the Quaternary sediments, corresponding to the upper part of the table. A smaller part of the network taps the surrounding and underlying sediments which are geologically older.

Before the Groundwater Monitoring Project, the structural characteristics of the aquifers and the hydrodynamic characteristics of the Quaternary sediments were little known. The interpretation of the data acquired by the project contributes to increase the hydrogeological knowledge of these sediments (see Annex #2, section 3, 3.16), particularly within the limits of the Senegal River delta.

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The variations of the recorded monthly average climatic parameters (temperature, relative humidity, evaporation and evapotranspiration (calculated values), insolation and precipitation) were the subject of a document written by Mr. Piekutowski (see annex #2, section 3, 3.15). This document includes graphs and tables of monthly average values from the meteorological stations at St. Louis, Richard Toll, Podor, Matam and Bakel (the Senegal River Valley), and the station at Mahina, located near Manantali Dam.

The fluctuations of the Senegal River water level from Diama Dam to Manantali Dam, observed during the period 1986-1989 were the subject of two documents (hydrology of Manantali Dam, and of the Senegal River Valley) written by Mr. Piekutowski (see annex #2, section #, 3.16 and 3.17). These documents include graphs indicating water level variations recorded at most of the water level scales along the Senegal River and the calculated river discharges at Bakel, Kaedi and Saldé.

The calculation of river discharges through Diama Dam was also the subject of a document written by Mr. Piekutowski (see annex #2, section 3, 3.23).

TERRAINS ENCAISSANTS DE LA VALLEE DU FLEUVE SENEGAL

CARACTERISTIQUES HYDROGEOLOGIQUES CONNUES

DESIGNATION LOCALE	STRATIGRAPHIE + SYMBOLE	NAPPES OU AQUIFERE / AQUICLUDE	CARACTERISTIQUES HYDROGEOLOGIQUES T m²/sec (m²/j)	S	SALINITE mg/l	COMMENTAIRES + (Références)
MOUAKCHOTTIEN 5 500 BP	MK	ALLUVIALE	- K: TRES FAIBLE	-	15.000 à 50.000	Alimentation : inondation Vidange : évaporation (Audibert 1970, III, p. 21)
OGOLIEN 30.000 BP	O1		-	-	-	Aucune information hydrogéologique affleure en rive gauche de Dembakané jusqu'à Thilogne (Illy 1973, p. 19)
	O2		- K: ELEVE NON SATURE EN EAU	-	SALEE L'ORSQUE CAPTEE	Réservoir hydrogéologique de faible extension. Faible infiltration (Audibert 1968, p. 29)
	O3		-	-	-	Aquifère principale dans les alluvions épaisseur variable 23 m Max. à Kanet (Illy 1973 p. 16)
INCHIRIEN 40000 BP	I2		K: FAIBLE A L'EST 8.64 x 10⁻³ (746) K ELEVE A L'OUEST	- 8 x 10⁻⁴	3 000 à 70 000 (Audibert, 1970 p. 17)	Alimentation = inondation Vidange = évaporation Variation de salinité : très importante (Audibert 1970, p. 18) Influence par les marées (SOGREAH, COYNE, BELIER 1970, p. 58) Mémoire
	I1		- K: FAIBLE	-	-	(Audibert 1970, p. 16)
QUATERNAIRE ANCIEN ET MOYEN 100.000 à 1.5 M.A.	Qam		-	-	-	Aucune information hydrogéologique (Illy 1973, p. 17)
CONTINENTAL TERMINAL 1.5 à 38 M.A.	CT	RG: CONTINENTAL TERMINAL RD: NAPPE DU TRARZA	RD: RIVE DROITE (TRARZA) 6 - 10⁻³ (450)	0.1	100 à 400 (RES. SECS)	RD: Rive Droite Puissance moyenne = 40 m (Illy 1973, p. 62 et 65)
			RG: RIVE GAUCHE (CONT. TERMINAL) 2 - 10⁻³ (173)	-	100 à 400	RG: Rive Gauche
EOCENE MOYEN 4.5 à 4.9 M.A.	EMm, EC	EOCENE ARGILO-CALCAIRE FACIES MARIN RESEAU AQUIFERE DE L'AMECHTIL	RD: RIVE DROITE (AMECHTIL) 3 - 10⁻⁴ ou (24)	10⁻⁴	JUSQU'A 2 000	RD: Rive Droite
			RG: RIVE GAUCHE (EOCENE ARG. CALC.) 3 - 10⁻⁴ (24)	-	100 à 400 (RESO. SECS)	RG: Rive Gauche Jamais été capté (Illy 1973, p. 69 et 70)
EOCENE INFERIEUR	EMi, EC	FACIES CONTINENTAL	RD: RIVE DROITE (BRAKNA) 4 - 10⁻² (3460)	-	100 à 400	RD: Rive Droite Puissance de l'aquifère = mal connu (Illy 1973, p. 62 et 63)
PALEOCENE 49 à 65 M.A.	EMp	PALEOCENE CALCAIRE NAPPE DU BRAKNA	RG: RIVE GAUCHE (PAL. CALCAIRE) 10⁻² (860) (1800) *	-	≅ 1000 JUSQU'A 5000 EST OU LAC DE GUIERS	RG: Rive Gauche K = bon à très bon grâce à la dolomitisation (Illy 1973, p. 68 à 70) * (Selon Bechtel 1976)
MAESTRICHTIEN 65 à 90 M.A	MA	NAPPE DU MAESTRICHTIEN	10⁻² (860) (1010) BECHTEL	10⁻⁴ 3 10⁻⁴ BECHTEL	< 300	. Puiss. à Sémé : 80 m . Semble libre en bordure du fleuve . Maestrichtien + Eocène (Faciès continental : milieu hydraulique homogène) (Illy 1973, p. 55 à 61)
SERIE DE MBOUT ET BAKEL	Co	MASSIFS ANCIENS	- FISSURE K: FAIBLE	-	2400	(Illy 1973, p. 55)

NAPPE DU GUEBLA MAURITANIEN (RD) — NAPPE DU FERLO (RG)

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LIST OF GES CODES

ANNEX 5

The reader will find in this annex, the list of codes used in the computerized GES data base system.

These are lists of:

* geologic codes, according to geologic age classes, accompanied by descriptions and references,

* geomorphologic codes,

* codes of "Unités Naturelles d'Equipement (U.N.E.)" by Juton, with their respective surface areas,

* codes of topographic maps 1:200.000,

* numeric codes of raingauges with indication of country where the gauge is located and the range of dates for which data are contained (beginning and end) in the GES system,

* numeric codes of water level scales with indication of country where the scale is located and the range of dates for which data are contained (beginning and end) in the GES system,

* numeric activity zone codes, by country, corresponding to a logistic sectioning which is internal to the project.

All these codes can be used as criteria, singly or in combination, in order to perform a data search in the GES data base.

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)
DIRECTION DE L'INFRASTRUCTURE REGIONALE (DIR)
CELLULE DES EAUX SOUTERRAINES - SAINT-LOUIS
PROJET OMVS/USAID 0625-0958

Liste des codes géologiques

Ordre	Code	Description		Référence
1	ACT	QUATERNAIRE	- DEPOTS ACTUELS OU SURACTUELS	SEDAGRI/FAO, 1973, p. 35 A 42
2	PNK	QUATERNAIRE	- DEPOTS POST-NOUAKCHOTTIENS	SEDAGRI/FAO, 1973, P. 35 A 42
3	NK	QUATERNAIRE	- NOUAKCHOTTIEN	AUDIBERT 1970, TOME 1, p. 17.
4	IN	QUATERNAIRE	- INCHIRIEN	AUDIBERT 1970, TOME 1, p. 16.
5	OG	QUATERNAIRE	- OGOUEN	ILLY 1973, p. 18. ET 19
6	QAM	QUATERNAIRE	- MOYEN ET ANCIEN	ILLY 1973, p. 17.
7	QT	QUATERNAIRE	- INDIFFERENCIE	
8	CT	TERTIAIRE	- CONTINENTAL TERMINAL	ILLY 1973, p. 16. - P. MICHEL, TOME 1 p. 84
9	EC	TERTIAIRE	- EOCENE A FACIES CONTINENTAL	ILLY 1973, p. 14.
10	EMI	TERTIAIRE	- EOCENE INFERIEUR A FACIES MARIN	ILLY 1973, p. 14. - MICHEL, TOME, 1, p. 77
11	EMM	TERTIAIRE	- EOCENE MOYEN A FACIES MARIN	ILLY 1973, p. 15. - MICHEL, TOME 1, p. 77
12	EMP	TERTIAIRE	- EOCENE A FACIES MARIN/PALEOCENE	ILLY 1973, p. 14. - P. MICHEL, TOME 1, p. 77
13	EM	TERTIAIRE	- EOCENE A FACIES MARIN INDIFFERENCIE	
14	M	SECONDAIRE	- MAESTRICHTIEN	ILLY 1973, P. 13. - P. MICHEL, TOME 1 p. 76
15	CO	PRIMAIRE	- CAMBRIEN ORDOVICIEN/SERLE MBOUT ET BAKEL	ILLY 1973, p. 13.
16	BA	PRECAMBRIEN	- PROTEROZOIQUE/GROUPE DU BAKOYE	

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ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)
DIRECTION DE L'INFRASTRUCTURE REGIONALE (DIR)
CELLULE DES EAUX SOUTERRAINES - SAINT-LOUIS
PROJET OMVS/USAID 0625-0958

Liste des codes géomorphologiques

Code	Description
A	DEPOTS ACTUELS ET SUBACTUELS/CUVETTES ARGILEUSES DE DECANTATION
A-G	DEPOTS ACTUELS ET SUBACTUELS/CUVETTE DE DECANTATION SUR VASIERE ANCIENNE
B	DEPOTS ACTUELS ET SUBACTUELS/PARTIES BASSES DES CUVETTES
C	DEPOTS ACTUELS ET SUBACTUELS/BANCS DE SABLE
D	DEPOTS ACTUELS ET SUBACTUELS/LEVEES ACTUEL LES
E	DEPOTS ACTUELS ET SUBACTUELS/LEVEES SUBACTUELLES
F	DEPOTS ACTUELS ET SUBACTUELS/VASIERE ACTUEL LE
G	DEPOTS ACTUELS ET SUBACTUELS/ VASIERE ANCIEN NE DENUDEE
I	DEPOTS ACTUELS ET SUBACTUELS/BORDS DE CUVET TES SALEES A REMANIEMENT FOLIEN
J	DEPOTS ACTUELS ET SUBACTUELS/DUNES VIVES
K	DEPOTS ACTUELS ET SUBACTUELS/DUNES SUBACTUEL LES SEMI-FIXEES
L	DEPOTS ACTUELS ET SUBACTUELS/DUNES ROUGES REMAINEES
M	DEPOTS POST NOUAKCHOTTIENS/HAUTES LEVEES
M'	DEPOTS POST NOUAKCHOTTIENS/FLUVIO-DELTAIQUE
M'A	DEPOTS POST NOUAKCHOTTIENS/FLUVIO-DELTAIQUE (PARTIES BASSES)
M'B	DEPOTS POST NOUAKCHOTTIENS/FLUVIO-DELTAIQUE (PARTIES HAUTES)
MAN	ENTABLEMENT DU PLATEAU MANDINGUE
N	DEPOTS POST NOUAKCHOTTIENS/DELTA DE RUPTURE DELEVEES
O	DEPOTS POST NOUAKCHOTTIENS/PETITES LEVEES
P	DEPOTS POST NOUAKCHOTTIENS/CORDON LITTORAL
P'	DEPOTS POST NOUAKCHOTTIENS/CORDON LITTORAL ARASE
Q	NOUAKCHOTTIEN/TERRASSE MARINE
Q'	NOUAKCHOTTIEN/DEUXIEME REMBLAI SABLO-ARGILEUX
R	OGOLIEN/DUNES ROUGES NON DIFFERENCIE
S	OGOLIEN/PREMIER REMBLAI SABLO-ARGILEUX
S-T	OGOLIEN PREMIER REMBLAI NON DIFFERENCIE
T	OGOLIEN/PREMIER REMBLAI SABLO-ARGILEUX ARASE
U	OGOLIEN/DUNES ROUGES ARASEES
V	QUATERNAIRE ANCIEN ET MOYEN/BAS GLASIS SABLEUX
X	DIERI

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ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)
DIRECTION DE L'INFRASTRUCTURE REGIONALE (DSR)
CELLULE DES FAUX SOUTERRAINES - SAINT-LOUIS
PROJECT OMVS/USAID 0625-0958

Liste des unités naturelles d'équipement Juton

Code	Nom	Superf
BO1	BOGHE 1	5325
BO2	BOGHE 2	2325
BO3	BOGHE 3	920
DA	DAGANA	3990
DAO	DAO	5200
DE1	DEMBAKANE 1	4665
DE2	DEMBAKANE 2	2790
DE3	DEMBAKANE 3	3112
DI1	DIAMEL 1	7310
DI2	DIAMEL 2	1495
DI3	DIAMEL 3	1450
DI4	DIAMEL 4	5812
DI5	DIAMEL 5	9800
DI6	DIAMEL 6	16700
DLT	DELTA	134384
DO1	DOUE 1	7830
DO2	DOUE 2	2890
DO3	DOUE 3	1657
GA1	GARAK 1	10400
GA2	GARAK 2	6800
GI	GARLI	2792
GOR	GORGOL	10000
GU	GUIDAKAR	3404
HUE	HORS UNITE NATURELLE	0
KI1	KAEDI 1	11480
KO1	KOUNDI 1	5480
KO2	KOUNDI 2	10068
KO3	KOUNDI 3	15400
KO4	KOUNDI 4	5400
KO5	KOUNDI 5	15300
KO6	KOUNDI 6	12750
KO7	KOUNDI 7	4600
KO8	KOUNDI 8	15416
MB1	TIANGOL-MBAGNE 1	3990
MB2	TIANGOL-MBAGNE 2	6365
MB3	TIAGNOL-MBAGNE 3	9174
MD1	MAGHAMA-DEMBAKANE 1	8190
MD2	MAGHAMA-DEMBAKANE 2	7475
MD3	MAGHAMA-DEMBAKANE 3	4268
MD4	MAGHAMA-DEMBAKANE 4	5465
MD5	MAGHAMA-DEMBAKANE 5	5710
MK1	MATAM-KANEL 1	7000
MK2	MATAM-KANEL 2	19883
MK3	MATAM-KANEL 3	3375
MO1	MORPHIL 1	2800
MO10	MORPHIL 20	4800
MO11	MORPHIL 11	12650
MO12	MORPHIL 12	7550
MO13	MORPHIL 13	5150
MO14	MORPHIL 14	5650
MO15	MORPHIL 15	

ORGANISATION POUR LA MISE EN VALEUR DU FELUVE SENEGAL (OMVS)
DIRECTION DE L'INFRASTRUCTURE REGIONALE (DIR)
CELLULE DES EAUX SOUTERRAINES - SAINT-LOUIS
PROJET OMVS/USAID 0625-0958

Liste des unités naturelles d'équipement Juton

Code	Nom	Superficie
MO16	MORPHIL 16	2630
MO17	MORPHIL 17	2390
MO18	MORPHIL 18	2250
MO2	MORPHIL 2	8950
MO3	MORPHIL 3	16950
MO4	MORPHIL 4	4300
MO5	MORPHIL 5	3850
MO6	MORPHIL 6	2550
MO7	MORPHIL 7	9500
MO8	MORPHIL 8	4000
MO9	MORPHIL 9	10400
NG1	NGALENKA 1	3640
NG2	NGALENKA 2	3635
NG3	NGALENKA 3	6800
NG4	NGALENKA 4	14900
OT1	OREFONDE-THILOGNE 1	11447
OT2	OREFONDE-THILOGNE 2	15380
OT3	OREFONDE-THILOGNE 3	4380
OT4	OREFONDE-THILOGNE 4	8800
OT5	OREFONDE-THILOGNE 5	11450
OT6	OREFONDE-THILOGNE 6	9600
TB1	TIAGNOL-BALLEL 1	10990
TB2	TIAGNOL-BALLEL 2	8825
TB3	TIANGOL-GALLEL 3	7030

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)
DIRECTION DE L'INFRASTRUCTURE REGIONALE (DIR)
CELLULE DES FAUX SOUTERRAINES - SAINT-LOUIS
PROJECT OMVS/USAID 0625-0358

Liste des cartes topographiques

Code	Nom	Année	Pays
06	SAINT-LOUIS		
07	DAGANA		
08	PODOR		
09	KAEDI		
12	LOUGA		
13	LINGUERE		
15	MATAM		
16	SELIBABY		
21	BAKEL		
22	KAYES		
26	KOSSANTO		
27	BAFOULABE		

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)
DIRECTION DE L'INFRASTRUCTURE REGIONALE (DIR)
CELLULE DES EAUX SOUTERRAINES - SAINT-LOUIS
PROJECT OMVS/USAID 0625-0958

Liste des postes pluviométriques

Numéro	Nom	Pays	Début	Fin
1	ST LOUIS/AEROPORT	SENEGAL	02/02/86	21/09/88
2	ST. LOUIS/J. BOTANI	SENEGAL	03/08/87	30/09/89
3	NDIOL/OUALLO	SENEGAL	09/07/87	01/10/87
4	NDIOL DIERI	SENEGAL	19/07/87	30/09/89
5	DIAMA/BARRAGE	SENEGAL	12/06/87	12/09/88
6	NDIAYES/CENTRE	SENEGAL	09/07/86	30/08/89
7	ROSS BETHIO	SENEGAL	09/07/86	06/09/89
8	BOUNDOUUM BARRAGE	SENEGAL	10/07/86	07/09/87
9	KOUR MACENE	MAURITANIE	09/07/86	30/09/89
10	ROSSO	MAURITANIE	10/07/86	29/09/87
11	RICHARD TOLL/KM 8K	SENEGAL	01/08/86	21/09/88
12	RICHARD TOLL/KM 15	SENEGAL	03/09/86	21/09/88
13	RICHARD TOLL/DOMBO	SENEGAL	11/06/87	21/09/88
14	RICHARD TOLL/MBILOR	SENEGAL	22/06/87	21/09/88
15	DAGAMA	SENEGAL	12/06/87	30/09/89
16	FANAYESS/OUALLO	SENEGAL	01/09/86	20/09/89
17	FANAYES/DIERI	SENEGAL	17/04/86	21/09/88
18	TITLE BOUBACAR	SENEGAL	03/09/86	27/09/86
19	PODOR	SENEGAL	18/04/86	30/09/88
20	GUEDE CHANTIER	SENEGAL		
21	NDIOUM	SENEGAL	21/06/87	20/09/89
22	BOGHE	MAURITANIE	09/07/86	21/08/87
23	KAEDI	MAURITANIE	10/07/86	30/09/87
24	HAIRE LAO	SENEGAL	10/06/86	30/09/89
25	GALOYA	SENEGAL	27/06/86	25/10/89
26	THILOGNE	SENEGAL	01/06/86	21/09/89
27	SALDE	SENEGAL	06/07/86	04/10/87
28	MATAM	SENEGAL	27/06/86	29/09/89
29	OUROSSOGUI	SENEGAL	08/06/87	29/09/89
30	KANEL	SENEGAL	06/06/87	27/09/89
31	SEME	SENEGAL	07/06/87	30/09/89
32	BAKEL	SENEGAL	12/06/86	24/09/89
33	MANANTALI	MALI	15/03/88	27/09/89
34	RICHARD TOLL 6X	SENEGAL	11/06/87	18/09/88
35	RICHARD TOLL/KH 14	SENEGAL	11/06/87	21/09/88

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL (OMVS)
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CELLULE DES EAUX SOUTERRAINES - SAINT-LOUIS
PROJECT OMVS/USAID 0625-0958

Liste des échelles limnimétriques

Numéro	Nom	Pays	Début	Fin
1	DIAMA/BARRAGE AMONT	SENEGAL	01/05/86	21/02/90
5	RICHARD TOLL/ELEUVE	SENEGAL	01/01/86	31/12/90
6	SANENTE/LAC DE GUIERS	SENEGAL	01/01/86	30/12/89
7	ROSSO	SENEGAL	01/01/86	31/12/89
8	DAGANA	SENEGAL	01/01/86	31/12/89
9	PODOR	SENEGAL	01/01/86	01/01/89
10	BOGHE	MAURITANIE		
11	GUDED CHANTIER	SENEGAL	01/01/86	31/12/89
12	NGOUI	SENEGAL	01/01/86	31/01/90
13	SALDE	SENEGAL	01/01/86	31/12/89
14	KAEDI	MAURITANIE	01/01/86	31/12/89
15	MATAM	SENEGAL	01/01/86	15/02/90
16	BAKEL	SENEGAL	01/01/86	30/12/89
17	MANANTALI/BARRAGE AMONT	MALI	01/07/87	30/11/89
21	MANANTALI/BARRAGE AVAL	MALI	01/01/88	30/11/89
22	RICHARD TOLL/LAC DE CUIERS	SENEGAL	01/01/86	30/09/89
23	LAC DE GUIERS/GNIT	SENEGAL	01/01/86	30/11/89
24	DIAMA/BARRAGE AVAL	SENEGAL	01/7/87	01/12/89
25	DAKAR BANGO	SENEGAL	01/01/86	15/12/89

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CELLULE DES FAUX SOUTERRAINES - SAINT-LOUIS
PROJECT OMVS/USAID 0625-0958

List des zones d'intervention

Ccepays	Numéro	Nom	Pays
D	0	DIAMA/MARIGOT-BELL	MAURITANIE
D	1	LAC MBELL/GARAK-LAC TAMBASS	MAURITANIE
D	2	GARAK/BAWADJI	MAURITANIE
D	3	BAWADJI/OLO-OLOGO	MAURITANIE
D	4	OLO-OLOGO/MBAGNE	MAURITANIE
D	5	MBAGNE/DIOVOL-LEXBIBA	MAURITANIE
D	6	DIOVOL-LEXEIBA/GOURAYE	MAURITANIE
G	1	SAINT-LOUIS/16 MERIDIEN	MAURITANIE
G	2	RONCQ/KEUR SADIO	SENEGAL
G	3	KEUR SAIO/LE GAYO-DIAMEL	SENEGAL
G	4	LE GAYO-DIAMAL/VINDING	SENEGAL
G	5	VINDING/OUROSSOGUI-MATAM	SENEGAL
G	6	OUROSSOGUI-MATAM/BAKEL	SENEGAL
M	0	MADINA GOUNGOU	SENEGAL
M	1	AVAL BARRAGE MANANTALI RIVE GAUCHE	MALI
M	2	DIALAKOTO RIVE GGAUCHE	MALI
M	3	BADEKA	MALI
M	4	BARRAGE AVAL MANANTALI RIVE DROITE	MALI
M	5	NOUNKALA - BARRAGE AMONT	MALI
M	6	BINGASSI	MALI