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STRATEGIES FOR IRRIGATION DEVELOPMENT

CHAD

USAID

WATER MANAGEMENT SYNTHESIS II PROJECT

WMS REPORT 41

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CHAD/USAID

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All reported opinions, conclusions or recommendations are the sole responsibility of the authors and do not represent the official or unofficial positions of any agency of the country of Chad or the United States or Utah State University or the Consortium for International Development.

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ACKNOWLEDGMENTS

Dr. Jack Keller of Utah State University was originally designated as Team Leader, selected the Team members and planned the study. While en route to Chad, Dr. Thomas F. Weaver, Head, Department of Resource Economics, University of Rhode Island, was asked to take over as Team Leader, as Dr. Keller had sustained a neck injury and was incapacitated.

The Water Management Synthesis II Project expresses its sincere appreciation to Dr. Weaver for graciously accepting the Team leadership and preparing this final report. The Project also appreciates the efforts of the other members of the Team, with special thanks to Dr. Milton Barnett for filling in for Dr. Keller.

PREFACE

This study was conducted as part of the Water Management Synthesis II Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University, Colorado State University and Cornell University serve as co-lead universities for the project.

The key objective is to provide services in irrigated regions of the world for improving water management practices in the design and operation of existing and future irrigation projects and give guidance for USAID for selecting and implementing development options and investment strategies.

For more information about the Project and any of its services, contact the Water Management Synthesis II Project.

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FOREWORD

The review team consisted of six persons, an agricultural economist, irrigation engineer, two agronomists and two anthropologists. Five of the six team members spoke French, four of them fluently so that the primary language of communication for the team was French. Field trips were taken through the central and north and northeast section of the Sahelian Zone and through the southwestern section of the Sudanian Zone of the country.

Numerous documents assembled by USAID in Washington and the capital city, N'Djamena, and from sources in Paris were utilized in the study and there were many discussions with professionals within the Chadian government and from donor agencies currently active within the country. The trip report which follows this introduction, contains the names of most of the individuals who lent their support to this effort. This study could not have been carried out without their encouragement and cooperation.

Overall, the team found that there was a realistic understanding of both the need for and limitations of irrigated agriculture by the Chaddian Government and foreign agencies and donors alike. There was a sound appreciation that civil war and the recent drought had severely strained government's capacity to supply the necessary trained manpower and capital required to learn to exploit the available water resources. There was also a recognition that the development of the agricultural economy of the country would require much more than irrigation, i.e. that all of the dimensions necessary to agricultural and rural development would have to be addressed.

To date however, there are no well-articulated government policies which provide for a systematic development and exploitation of the available water resources. Focus is mostly provided by the historical interests of government agencies who are anxious to reestablish their activities in locations in which they have prior experience and investments. This is an understandable outcome when there is no new information to provide new directions and when there is the pressure to provide for food security in the face of the drought. This study team attempted to look beyond the immediate relief problem and to lay the groundwork for the development of a sustainable irrigated agriculture in those regions where irrigation is appropriate.

During its discussions with government officials team members were continually impressed with the thoughtful attention that has been given to the identification of the problems and difficulties associated with irrigated agriculture. This experience is clearly a resource and any donor assistance would do well to draw on it for both the design and implimentation of their projects. The irrigation team was especially appreciative of the efforts of the USAID mission personnel, Mr. John Woods and Mr. Larry Harms who worked with the team in defining the activities and who provided the support of their good offices in getting the job done.

Although the focus of the team was on irrigation, it was impossible to ignore the state of the agricultural economy in general. The recent drought has captured the primary attention of both government and donor agencies and relief efforts have tended to dominate. Overall, the team did not encounter

evidence that modern packages of agricultural practices have been developed that are tailored to irrigated agriculture. The great physical and social diversity across the country suggests that there will be no universal package and that it will take great attention to detail to eventually modernize irrigated agriculture. Added to this, the recent civil war has left the agricultural support institutions, including both the University and government agencies, seriously short of physical and human capital. There is little evidence of a research program that will either create or evaluate technological alternatives. Some PVOs are engaged in pilot projects that have adaptive research dimensions, but they lack experience and strong technical support and can not be looked to under the present circumstances to provide immediate solutions.

It will take a major and long term commitment on the part of USAID and other donor agencies if the institutions which are required to support a modern agricultural sector are to be developed in the forseeable future. In this regard, the need to pool resources and experiences among the countries of the region must be obvious to many observers. No doubt REDSO could be especially helpful in such efforts.

TRIP REPORT
Chad Irrigation Sector Review
June 17 through July 27, 1985

Monday, June 17. Arrival of Adoum and Waldstein in N'Djamena at 15:20. Briefing with Mr. Larry Harms, ADO.

Tuesday, June 18. Briefing with AID Representative Mr. John Woods, development of schedule and itinerary. Visit to Mr. Acyl, Director of FAO Documentation, to get documents relating to FAO irrigation activities in Chad. Study/reading documents.

Wednesday, June 19. Visit to CEFOD to request documents and studies. Briefing of Ambassador. Study documents.

Thursday, June 20. Return to CEFOD to read documents. Visit to IRCT in search of documents. Study documents in office.

Friday, June 21. Departure for Karal. Meetings with Ramadan Ramadan, ONDR extension agent.

Saturday, June 22. Visit to irrigation sites in the Karal area.

Sunday, June 23. Return to N'Djamena. Meeting with Mr. Frederick Goume of Caisse Centrale for la Cooperation Economique.

Monday, June 24. Meeting with Mr. Tyrone Gaston, AFRICARE Director. Arrival of Mr. Don Humpal.

Tuesday, June 25. Meeting with Secretary of State for Agriculture, Director General for Agriculture, Director General of SODELAC, Sahel division of ONDR and Director of VITA.

Wednesday, June 26. Meeting with CARE/Chad.

Thursday, June 27. Meeting with CARE Director, Mr. Allan Turnbull, and Mr. Marc Henderson, Irrigation Specialist.

Friday, June 28. Waldstein, Adoum and Humpal visited two clients of VITA who are cultivating 6 hectares and 11 hectares, respectively, around 20 km north of N'Djamena along the Chari. On this same day team members Weaver, Barnett and Balbo departed from Charles DeGaulle Airport (11:59 p.m.). Earlier Jack Keller had reported his neck injury and consequent unavailability and arranged for certain gear and supplies he had in Morocco to be delivered for pickup at the Paris airport (Mr. Wilbur Thomas kindly performed the courier duties). At approximately 03:32 a.m., 29 June 1985, the aircraft made an emergency landing in Algeria due to a "bomb threat." Exit from the aircraft was by rubber chutes. All were quartered in the Algerian airport transcient lounge until Sunday, 12:30 a.m. when the aircraft departed for N'Djamena.

Saturday, June 29. Reading and assembling documents.

Sunday, June 30. Arrival of Balbo, Weaver, Barnett. Briefing sessions by Waldstein and Humpal on activities to date.

Monday, July 1. Team meeting with USAID Program Officer Kurt Shafer, Agricultural Development Officer Larry Harms, and Project Development Officer Leroy Jackson. Team met with AFRICARE Representative Tyrone Gaston who outlined the experiences and general difficulties of their program in small parameter irrigation development. Problems included mismatched pumps and motors, ineffective canal layout, socio/economic studies not carried out, maintenance schedule not set up, food for work programs brought in outsiders who are not project participants and so on.

Tuesday, July 2. Document reading by most team members. Set up northern trip schedule. Met with AID Representative John Woods. Visited CARE offices and met with SODELAC (Societe Development du Lac).

Wednesday, July 3. Entire team departed 6:00 a.m. by private plane for Bol and visited the Guini Polder Project. This project has fallen into complete disrepair following the drought. The flood waters, which were to have supplied the project, never appeared. Also visited the research center associated with the project located at Matofolo, which has fallen to the same level as the project. On the polders, the PVC pipe system has heaved out of the ground by alternative wetting and drying cycles. The network is useless and pipes are being used for road markers. A recent World Bank team has recommended that the project is technically unsound and has decided not to provide additional funding. The teams also had a meeting with the Prefect and SODELAC personnel assigned to the area.

Thursday, July 4. The team departed Bol for Mao at 08:30. Along the way they attended a meeting with farmers and household heads at a wadi in Ngolio. The most striking feature of this wadi environments was the fragile relationship between cultivation and water use. Farmers were well aware of their problem with soil salinity and observed that as the well-water available for irrigation diminished because of the current drought, some farmers had to abandon their fields and move south. Some reported they had sold their beds and the doors to their homes.

The team then moved on to Mao where they visited yet another wadi, more oasis like, where the team observed a very sophisticated level of traditional irrigation utilizing small basins. One farmer at least had worked out his crop coefficients and regulated his irrigation quantities to allow for changes in crop water requirements with the season and allowed water for drainage to control salinity. A great mixture of fruits (dates, papaya, and lemons) and crops (millet, sorghum, maize, and vegetables of all types) and, in other seasons, wheat are grown. The team spent the night under the stars in Mao.

Friday, July 5. The team left for Chadara at first light where they met with CARE personnel including Patric Sayer of the UK, newly arrived to take charge of assigning refugees to development efforts in unsettled wadis in the region. The team visited a CARE project wadi on Bahar El Ghazal, an ancient river bed which floods as a backflow from Lake Chad every ten years or so.

The Red Cross, CARE and UNICEF have all worked in the area. Refugees, mostly semi-nomads from 150 miles north, were being settled, provided with a shadoof (cost approximately 3,000 CFS) and vegetable seeds. This program was under the so called food for work effort.

In the afternoon, Waldstein, Humpal and Barnett departed for N'Djamena. Weaver, Balbo, and Adoum remained and visited two more resettlement sites that afternoon where they recorded conversations and collected data on farm layouts. This team then proceded to Massakory where they spent the night on the veranda of an unused storehouse.

Saturday, July 6. In the morning, a planned trip to Doum Doum was cancelled when the windshield of the Toyota land cruiser mysteriously blew out.

Barnett, Humpal and Waldstein met with Allan Turnbull of CARE and reviewed the program and future expansion plans.

Weaver, Adoum and Balbo limped back to N'Djamena stopping at various sites along the way to inspect well levels, examine soils and consider cropping alternatives.

Sunday, July 7. Team visited Sunday market to collect price data, examine food stocks and availability.

Monday, July 8. Meeting with FAO librarian. At 10:00 a.m. met with SODELAC Director General, Rahim Idris, who discussed his program, funding needs, programmatic aspirations, personnel problems and so on. At 12:00 met with Larry Harms to discuss additional trips, USAID position on SODELAC, traditional agriculture and need for low cost investment strategy.

Tuesday, July 9. In the morning the team met with ONDR (Office National de Development Rural), Sahelian Zone, to discuss their projects, ongoing and planned, and their personnel and training situation. They spoke with S. Abdelivahab Cherif, Program Analyst, Ndoa Ngar Gaingai, Program Director for the Sahel, Thomas Joel, French consultant, and Ngaromillet Michel, Chief of Division of Agricultural Production. For the rest of the day the team read documents and planned the southern trip.

Wednesday, July 10. Barnett and Balbo visited AFRICARE irrigation project at Mailao. Meeting with Joao Mije, general extension person and with a consultant engineer working on system design. The team met with farmers and then traveled to Guelendeng where they visited a small-scale, pump-oriented irrigation perimeter built by SATEC in the mid-1970's and now operated by ONDR. There are problems with farmer repayment of water charges, low rice yields, and drainage. Heavy rains drove them to shelter in an empty ONDR bungalow.

On the same day, Adoum and Waldstein traveled to Doum Doum, a traditional polder in the Lake Chad area north of N'Djamena. They talked with officials, the Prefect and with farmers.

Thursday, July 11. Barnett and Balbo continued their visit in Guelendeng. At 7:00 a.m. they met with the ONDR representative and discussed problems of record keeping, official reporting and so on. He reported that ONDR has two persons in the area, one for rainfed agriculture and the other for irrigated agriculture. They do not normally work jointly on projects. They discussed the long delays in purchasing supplies. The officers return monthly for briefings in N'Djamena. IRR-8 is grown in the area. There are no reported disease problems. There is no economic data for the project.

Next the team visited a 20 hectare irrigated rice perimeter in Kalala, 10 kilometers south of Guelendeng. The perimeter is not currently being operated because none of the farmers had paid their water charges and had been asked to get off the project. One farmer said that they did not care because they had ample rainfed land.

Fifty kilometers north, the team visited a five hectare rice perimeter with water supplied by a pump from the Chari River. The perimeter was being operated by CARE. CARE was experimenting with mud lining of canals to reduce seepage losses. This was a PIC government project. The village chief reported that he was in charge of water, land and all village affairs. "There is an irrigation committee but it doesn't meet." The chief said their greatest needs were fuel, seed and food. The chief said that if the fuel was delivered on time and things went well that they were willing to pay.

The team next visited Bougomene, a village further north, to see both a new and an old irrigated rice perimeter. These are organized by GARED, a religious organization. They operated a center of horticulture and rural development. A unique feature was that credit is extended on a group basis and is guaranteed by the group. The GARED organization operates some 20 perimeters of this type.

On this same day Waldstein and Adoum returned from Doum Doum and Weaver and Humpal read more documents and further prepared for the trip south.

Friday, July 12. On this day, the team worked on notes and materials and produced an outline for the final report. The team met in the evening until 10 p.m. to begin the process of consolidating their thoughts.

Saturday, July 13. The team worked in the AID offices in the morning and returned to the hotel in the afternoon to begin writing. Again, a late evening discussion lasted until 10:30 p.m.

Sunday, July 14. The team had a brunch with Larry Harms. Team members read and wrote most of the day. Another evening meeting to begin to discuss recommendations based on experiences to date lasted until 11:00 p.m.

Monday, July 15. Barnett and Weaver met with Phillipe Mengin, FAO Country Representative. He spoke of FAO's involvement in the larger rice perimeter schemes. He indicated FAO is interested in the polders in the lake area, prefers simpler traditional technologies, and thinks that more hydrologic information is needed. FAO is delaying work in the wadi areas to see how many

people remain in those areas after this year's rainy season. He reported that the Italians wanted to work in the polder areas and had 1.2 million to spend in the next 18 months. Mr. Mengin spoke of his support for BIEP (the International Bureau for Planning Studies) and indicated that FAO would be providing assistance to that organization.

On the same morning Mr. Humpal and Balbo visited FED and learned of their program and interest in investment in irrigation. Waldstein and Adoum spent the day writing.

Tuesday, July 16. Dr. Waldstein left for Paris on the morning flight. In the morning Weaver and Waldstein met with USAID Representative John Woods and discussed the recommendations that the team had developed to date. In the afternoon the remaining members of the team continued to read documents and work on the recommendations and final report.

Wednesday, July 17. Weaver, Humpal and Balbo departed by plane for Bongor at 06:00 a.m. On the flight down five irrigation perimeters utilizing river water were sighted on the Cameroon side of the Chari River. From the air three of them appeared to be quite new. These perimeters are probably over 50 hectares in size. Obviously, there may be some lessons to be learned from the Cameroon experiences which would be relevant for similar projects in the planning stages in Chad.

Arriving in Bongor at 07:45 a.m. the group met with the Prefect and Secretary of Agriculture who happened to be in town inspecting Casier B. CARE/Chad had a project the past season to provide fuel, repair the main canal using food for work and provide seed for planting.

According to the Secretary of Agriculture and the Prefect, although the rains started late rainfall has been heavy and regular since. The river is reportedly at its highest level in the past ten years. Anticipating conditions similar to last year's drought, many cultivators have planted millet and sorghum in low-lying places. With the heavy rains and some flooding, these crops in many areas are inundated and showing signs of severe stress.

On discussing the history of the Casier B project, it was reported that when the scheme was under the direction of the Chinese they supplied all of the inputs for operating the system including fuel, paid for canal maintenance, and, although this is not confirmed, provided seed for the cultivators. There was no charge to the cultivators. There was a rule, however, that if the farmer did not obtain a set minimum big yield, he would not be allowed to continue on the project.

Casier B was originally built by the Taiwanese and later reworked by the Chinese. The project is a 500 hectare rice perimeter supplied with water from the Chari River. Operations were cut off during the civil war but last year with CARE supplying seed and fuel for the pumps, a dry season rice crop was harvested. At the present time the second or rainy season crop is being planted. There were a number of questions about the rice system including:

(1) fertilization rates, (2) labor for planting especially of the second crop, (3) timing of water release, (4) use of small scale tractors, and (5) charges to the cultivator.

Over all, there are serious management problems with the project. What is very apparent, however, is that cultivators are interested in growing rice. For the last dry season crop, the charge to the cultivators was 50% of the crop. Cultivation rights were taken away from those who refused to pay and from those whose yields were so low that they were not sufficient to make a reasonable payment. Reportedly 70% of the farmers have already paid.

On this same day Barnett and Adoum met Hassad Adoum Haggar, Director General of the Ministry of Planning and National Reconstruction. He feels keenly that basic research on water management is critical especially in the river and lake zone. He sees planning as a constraint to development as there are no plans yet finalized. He noted that BIEP, recently formed, would be useful if it could get underway. He noted the need for fellowships.

He said that he needed a research base for policy formation. He felt that his unit could utilize the services of a resident expatriate irrigation/water specialist. He looked forward to future participation with USAID and to the irrigation team's report.

Also on this day Adoum met with Mr. Tom Erdime, Dean of the Faculty of Applied Sciences at the University of Chad, to discuss the role of the University. They have a three year training program in hydrology. However, the faculty is understaffed and there is a need to send students out of the country for additional training. He also noted the need to train Chadian experts to the M.S. level.

Thursday, July 18. The team of Humpal, Balbo and Weaver met with ONDR beginning at 07:30 a.m. The objective of the meeting was to establish the nature of the agency operation and their plans for the establishment of irrigated perimeters and to explore general problems with the development of irrigated agriculture.

Next the group met the French technician responsible for the installation of the rice perimeter irrigation projects. Earlier, there was a project to build dikes for holding flood waters of the Logone River and rainfed rice was to be grown. For the last three years, with the drought, there has not been sufficient rainfall to produce a crop, so, to date, the dike project has not produced results. The project was constructed with large earthmoving equipment. The new project is one of 24 irrigation perimeters varying in size from 15 to 20 hectares. They are designed by ONDR and are to be constructed using hand labor. They will be pump supplied using river water. They are planning on double cropping rice and are hoping for total per hectare production per annum of around 12 or 13 tons per paddy.

The team flew to Lai about 11:00 a.m. and visited the project at Sategui-Deressia. This river gravity irrigation flood control rice project is

being rehabilitated after the civil war. The situation is quite difficult given the circumstances of very sandy soils, a rolling topography and a river supply which is inadequate in very dry years and may not be controllable in the very wettest years. This project involves a seed farm, rice mill and an experimentation station. The greatest need is for experience with an innovative management. Husbandry practices and thus farmer organization needs to be in accord with water availability as does varietal selection and fertilization practices. The southern tour team returned to N'Djamena around 6:30 p.m. and wrote late into the night.

On the same day Barnett and Adoum met with Father Pierre Faure, the director of SECADEV. He feels that planning for irrigation under relief efforts has not been sufficient. For example, pumps were given out without adequate extension. He complained of no marketing data, no cost/benefit analysis, and spoke of the need for irrigation planning to begin with the farmer and to work with existing farmer practices. He also spoke of the need for roads all over the country. Again he called for feasibility studies and involvement of farmers. He called for attention being given to dryland agriculture since large sections of the Sahel must be farmed in this way. "Chad is a dry land, get the most out of what is available."

Friday, July 19. Weaver and Adoum met with Mr. Moussa Augrey (Chadian Director of Interministerial Office of Studies and Program, BIEP) and three of his assistants to discuss the interest of the organization in the areas of irrigation and water management. Mr. Augrey said that he though that the services of an irrigation engineer/water management specialist would be welcomed by his agency.

On the same morning, Barnett met with Tyrone Gaston. They reviewed all three AFRICARE projects, (1) Mailao, (2) Miskine and (3) Abeche, from the management standpoint. Problems stemming from lack of baseline studies and understanding of local societies and lack of socio/economic data. They discussed measures AFRICARE is taking to resolve these problems. In part this involves shifting from meaningless evaluation criteria such as length of channels built to factors such as participation in organizations to modernize agriculture.

Also, Barnett and Harms met with Jean-Claude Levasseur, coordinator of FAO project assistance regarding BIEP. They do not yet have a building but FAO is financing construction. BIEP has responsibility for coordinating 17 bureaus within three ministries which have responsibilities for agriculture. Some 80 studies are projected of which 20 deal with irrigation and agriculture. A number of expatriate staff are already in place and more are on the way. He expressed considerable interest in having an irrigation/water management specialist as part of the staff. Both Barnett and Harms feel that BIEP is a sound choice for placing such an expert.

In the afternoon the team continued writing for the final report. Humpal departed on the evening flight to Paris.

Saturday, July 20. Weaver and Adoum met with Jofi Abdelkadre to discuss groundwater surveys. He is a member of the technical commission of the Lake

Chad Basin. In general, he is opotimistic regarding the productivity of the underground water resources in the Chadian portion of the conventional Lake Chad Basin. At 300 meters there is 50 to 60 cm^3/hour in the neighborhood of Mao. This is information from the 1970's. He thought that it would be useful to have a more detailed survey in targeted areas in the Lake Chad region.

Sunday, July 21. The team wrote all day and into the late hours of the evening.

Monday, July 22. Weaver met with Mr. W. Bohlmann, Jr., Director of ESSO Exploration, to inquire about their experiences with underground water resources. He provided information on their experiences in the south and provided contacts for inquiring about CONOCO's earlier drilling in other areas of the country. Barnett spent the day writing, editing, and working on the report.

Balbo and Adoum, on this same day, saw the sunrise over the desert on an early morning flight in a small airplane on the road to Abeche, the western gateway on the camel route to Mecca. On arriving they were received by AFRICARE. They met the Prefect, Mr. Maida Augata, who discussed current development problems exacerbated by the influx of refugees. In his opinion, the wadis are the focal point of the solution to the refugee problem. This, he says, is where cultivable land is available for settlement.

Balbo and Adoum, after an unsuccessful search for documents, visited an hafir (a water catchment or small tank) within a wadi. This hafir is used for livestock and through seepage provides water for trees.

They then visited an AFRICARE dam site, one of eight dams, designed to enlarge inundated areas and provide water for the dry season. Without the dam and impounded water a dry season crop is not possible. To date all of the dams have given way because of design and management problems.

In the midst of this trip, rain blew in from the east and the team retired to headquarters and were briefed on dam structures and other wadis. They have wells of six meter depth and water at four meters -- too deep for the traditional shadoof. The Calabash is used instead. One farmer has begun to use a small gasoline powered pump and for the first season had no difficulty with drawdown. He grew tomatoes for shipment to N'Djamena.

On departing at 3:30 p.m. the team overflew the area and saw the natural drainage patterns and large area which is inundated during the rainy season.

Weaver and Barnett met with Mr. Wood and Mr. Harms to brief them on the team's findings and recommendations.

Tuesday, July 23. This was a continuation of the earlier briefing by Weaver and Waldstein. At 08:30 a.m. Team Leader Tom Weaver, Adoum, Balbo and Mr. Harms met with Mahamat Abdoul, Director of Genie Rural. The Director was briefed on the team recommendations and was very satisfied with the team orientation. Among other things the team talked about an expert who might be

placed somewhere in the Ministry of Agriculture and Rural Development. The expert will help design and implement projects in close cooperation with the various departments of the Ministry of State for Agriculture and Rural Development. The team also discussed the importance of both short and long term training and on sending some Chadians to institutions outside of the country. The team met with the State Minister of Agriculture and Rural Development, Mr. Djidingar Dono Ngardoum, the Secretary of State, Mr. Boukar and the Director of BIEP, Mr. Moussa Aggrey. The recommendations were discussed and the Minister said he was very pleased. He commented that many teams have been through Chad but none had discussed the irrigation as comprehensively as this one.

Milton Barnett and Tom Weaver departed for Chad late Tuesday afternoon.

Wednesday, July 24. Adoum wrote on Abeche and organized final draft.

Thursday, July 25. Adoum and Balbo met with the FAC (French Aid and Cooperation Fund), and discussed the French orientation in development. They (the French) work closely with NGO (non-government organizations) and with different departments. They assist in training of students. They allocate some scholarships to Chadians who go to African institutions and often to France to further studies.

Friday, July 26. Organization of the final draft.

Saturday, July 27. Adoum and Balbo depart from Chad.

EXECUTIVE SUMMARY

Recommendation No. 1

The general conclusion of the irrigation team is that irrigation has an important and necessary role to play, both in providing food security and in contributing to agricultural development, in the Sahelian region of the country, and that USAID should work towards establishing activities in that area. What is especially important in reaching this conclusion is the presence of Lake Chad and its two principle rivers, the Logone and the Chari. They have created an immense resource of flood plains and recession waters and groundwater. Here the Sahelian region is defined as extending from the 400 mm to 1000 mm isohget or just south of Bongor.

In addition to the water resource, (both surface and groundwater) soils with relatively high natural fertility by African standards and a long irrigation tradition recommend irrigated agriculture for the Sahelian zone. The types of irrigation interventions envisioned by the team are relatively small scale and might range from fractional hectares to possibly 200 hectares and might utilize ground or surface water.

There are three readily identifiable general cropping systems within the Sahelian Zone: (1) recession agriculture including polders, (2) the wadis, and (3) dune cultivation. As discussed in the main body of this report, there is a potential in all of these areas for increasing agricultural output through water management techniques which include irrigation. Traditionally irrigation and water management have been an integral part of the agriculture of the region. In the opinion of the irrigation team, at this time there are three important thrusts for USAID involvement in the development of irrigated

agriculture: (1) the development of methods and techniques of small-scale irrigation for the lands adjacent to major rivers, in the polders, wadi and recession agricultural lands of the Chadian portion of the conventional Lake Chad Basin, (see page 30, 2.62 for a delineation of this area), and in the Abeche region, (2) in the development of a monitoring system for tracking the effect of the planned development of the wadi areas on groundwater levels and on water quality and related soil salinity, and (3) to assist in the establishment of a capacity within the Chadian government to creatively design, redesign, monitor, maintain and rehabilitate small-scale irrigation systems.

To move towards the accomplishment of these objectives, it will be necessary to invest in training programs and to carry out a number of preliminary investigations and these are the basis of a series of recommenda- tions to follow which include: (1) focused groundwater hydrologic studies, (2) documentation of irrigation communities, (3) pre-feasibility irrigation engineering design work, (4) pilot projects on wadis and polders and (5) short and long-term personal assistance and training programs.

In the broadest sense, all of the recommendations to follow have the objective of and would contribute to increasing the capacity of Chadian institutions to plan and manage irrigation development and concurrently of providing assistance to PVOs currently undertaking irrigation development programs within the country. The irrigation review team was strongly convinced of the immediate need for technical assistance to the USAID supported PVO's. (See pages 21, 23, 39 and 40 for more detailed discussion of recommendations on the role of PVOs and pages A-21 through A-24 for observations on the PVO experience.)

Recommendation No. 2

On the other hand, the irrigation team does not recommend USAID investment in irrigation development at this time in the southern i.e. Sudanian Region of the country. Irrigation investment here must be compared with the investment alternatives of the development of rainfed agriculture and of providing market access primarily through improved roads and transportation systems. It is also the opinion of the irrigation team that agricultural development in one region of the country is not a substitute for development in another. Circumstances such as location of population centers, existing pattern of farming, trading and social interaction, prohibit such tradeoffs. Part III of this report gives technical observations and recommendations for the major irrigation projects already underway in the Southern or Sudanian region and explores more fully the rationale for the team's conclusions. (See espcially pages 34 through 36.)

Recommendation No. 3

The irrigation team recommends that USAID work closely with the Chadian government to develop a country capacity to identify, design and monitor small-scale irrigation systems. This investment in human capital formation is considered an essential activity for strengthening government agency capacity (see part pages 37 through 39). The features of this program should include:

1. Training to the M.S. level of ten irrigation engineers who would specialize in on-site design of small-scale irrigation systems so that systems can be adjusted at the time of construction to the great diversity of soil and topographical features that are typical of the Chadian countryside. The training/experience of the Chadian students

must include irrigation, community and farming systems studies as well as aspects of engineering. Five of these students should attend the Institute agronomique et Veterninaire Hassan II in Rabat Morocco. The other five should be sent to various Western U.S. universities and the University of Jordan, Amman (see page 37 for further details).

2. Development of a country capacity to carry out on-site design of system rehabilitation. This type of rehabilitation approach requires that engineers systematically utilize farmer experience with the irrigation system to effect improvements. This capacity might be created (1) by incorporating the concept into the M.S. training program and (2) by development of a training program for the Chadian government including parastatal organizations which would encompass:
   a. Short courses in irrigation preferably in African institutions and/or given in Chad by the Utah University International Irrigation Center.
   b. Systematic in-service training for extension and technical personnel concerned with irrigation activities.
3. Concurrent with the recommended training program and supportive of the development of this capacity within the Chadian government, USAID should provide a water management specialist trained by small system irrigation engineering for at least a three year period. This person would not be a part of the AID staff, but would be placed within another agency. The duties and role of this individual are outlined on page 39 of this report. A discussion of the possible agency association is given on page 38. On completion of their training

these individuals might be placed in government agencies such as Genie Rural and BIEP, OMVSD, ONDR, and SODELAC and possibly the University. Some of them should be assigned extension responsibilities.

Recommendation No. 4

The irrigation team recommends that phased-feasibility studies be commissioned to test the economic and technical viability of the following types of irrigation interventions in the Sahelian Zone.

1. Studies should be undertaken to develop workable irrigation systems for both supplemental as well as dry season irrigation in the Sahelian Zone encompassing the recession zone of Lake Chad, including the polder areas and related wadis, the Chari River Valley and the Abeche region. (See pages 27 through 30 for details.).
2. The irrigation team does not recommend that USAID invest in the further construction or rehabilitation of the existing Bol polders project. However some specific suggestions as to how this project might be improved are given on pages 16 and 17 of this report. The team does suggest however, that more practical methods of managing polder water resource be developed (see Recommendation No. 8).
3. Dependent upon, and concurrent with the hydrologic survey (Recommendation No. 6) and varying soil conditions, a study of the economics of shallow tube wells (up to 120 meters) with a variety of distribution systems including border furrows, small basins ect. with various combinations of, for example, open channels and PVC pipe, dependent on soil situations, should be carried out. The rationale and initial procedures for the recommendation are given on page 29.

These studies must include in their economic analysis the cost of developing indigenous repair and maintenance systems. The analysis should recognize the increasing cost of repairs and difficulty of maintenance, especially under current Chadian conditions, with increased distance from the major urban centers.

4. The construction of impoundments or off-stream storage to supply supplemental irrigation to upland crops especially in more low-lying areas where water naturally tends to accumulate should be considered. It is extremely important, where evaluating the potential of this type of intervention, to be aware of and account for the health hazards (primarily malaria, schistosomiasis and contaminated drinking water) that most often accompany stagnant ground water. (See the discussion of the Ouaddi region beginning on page 26.)

5. At the present time there is some interest in the suitability of centerpivot irrigation systems for use with smallholder agriculture in Africa, but to date there are no examples of this type of use although a pilot project is being actively considered in Morocco. Although the team does not recommend centerpivots at this time, a consideration of irrigation alternatives in Chad should include large scale sprinkler applications drawing on the experience of the Chadian sugarcane industry in the southern region of the country, on the information from the recommended groundwater studies and on the experiences with this technology in North Africa including Egypt and Morocco.

For all of these studies it is essential that they include an economic analysis that is based upon a solid knowledge of input quantities, costs and estimates of output prices for the typical cropping patterns of the area.

Furthermore, it is essential that any labor constraints for carrying out increases in labor inputs, required either for irrigation or general crop production, be assessed. Also it is absolutely essential that no irrigation systems be recommended for areas in which detailed soils information is not available and that the soils information be considered a necessary condition for the design of irrigations systems.

All of the studies suggested here should include and respond to the information on irrigation communities which is covered in Recommendation No. 5. This will enable the design team to speculate on irrigation interventions which take advantage of indigenous systems of land and water rights and of patterns of cooperation. By this approach it may be possible to avoid conflicts between water users or between water users and administration which typically lengthen the time, at considerable cost, required to develop the full potential of irrigated agriculture.

The first step in accomplishing recommendation No. 4 would be to secure the services of a two-man team of an irrigation engineer and an irrigation economist to develop some preliminary designs and cost estimates. The total time required would be from six weeks to three months. This activity would be complementary to Recommendation No. 3, on the obtaining of a water management/small systems engineering specialist.

Recommendation No. 5

Study is needed of existing and potential irrigation communities which will: (1) identify and delineate farming systems, social organizations and patterns of cooperation, and (2) identify potential areas of conflict because of ethnic and/or sedentary farming/herding activities and their effect on land and water rights and use and on market access. The details for implementing

this recommendation are given starting on page 32. This recommendation should be carried out concomitant with the other recommendations of this report.

Recommendation No. 6

The irrigation team recommends that a survey be undertaken of groundwater resources at all levels in the region of the Chadian portion of the conventional Lake Chad Basin be undertaken. This survey should be coordinated with other groundwater studies which are underway in the country and should attempt to define the relationship between groundwater levels, rainfall, and the level of Lake Chad. The first step in this activity would be for a hydrologist to define the scope and dimension of this survey. The actual survey could then be contracted to an independent firm. See page 30, 2.62 for further details on the conduct of this activity, on-going drilling, and for a delineation of the conventional Lake Chad Basin.

Recommendation No. 7

The irrigation team suggests that, concurrent with the present rapid expansion of irrigated agriculture in wadi areas, assistance be given to the development of a system of monitoring well levels and drawdown.

The rapid increase in the number of traditional shallow wells (two to five meters in depth) and shadoofs could have a drastic impact in fragile wadi areas by reducing application quantities of water and incurring the risk of increasing soil salinity. The new settlers, many of whom are pastoral peoples, cannot be expected to be as sensitive to soil and water relationships as traditional wadi farmers who have accumulated centuries of irrigation experience. The first step in this activity would be for a team of two persons, a hydrologist and water management specialist to develop a program for a wadi groundwater

monitoring survey procedure and identify coordination mechanisms within the Chadian Government (see page 31 of this report). The team considers this a priority recommendation given the speed with which wadis are being developed.

Recommendation No. 8

The Team recommends that U.S. AID sponsor pilot irrigation development projects to test different designs for developing irrigation in the wadis and polders. It is obvious from past development experiences that project designers are unfamiliar with workable irrigation system designs for dealing with these unique environments. Thus, while pre-feasibility studies are in order as mentioned in Recommendation 4, it is important that before any projects (based on such studies) are developed, that the economic, social and technical viability upon which they are based be adequately tested by pilot projects. These pilot interventions could be worked through PVOs if adequate technical support were provided.

In order to utilize the data derived from monitoring well levels and water quality in the developing and developed wadis and to better manage them, (see Recommendation 7) pilot wadis should be selected and studied. Ideally wadis (and polders) selected for such studies should be unsettled initially. Development can then be controlled and scheduled to test different rates and intensities of development and the overall effects in the water resource, etc.

The preliminary design of these pilot studies (projects) can be made part of the responsibility of the phased feasibility study team's activities (see Recommendation 4) by expanding that team to include an agronomist and hydrologist. (For further details see pages 31 and 32.)

Recommendation No. 9

It is recommended that the literature on institutional and human resources in irrigation and water resources management for agricultural production purposes be accumulated, reviewed, synthesized and brought to bear on current and longer term irrigation, rehabilitation and development problems in Chad. This work needs to be a multilateral effort and would complement and be coordinated with existing WMS II studies. WMS II could work with the Sahel programs to explore the potential for a Club du Sahel and CILSS initiative to include French, Dutch and other European institutions in the information gathering and analysis process. Outputs would include:

(1) answers to various technical questions, e.g. crop varieties that have been tested, aquifer characteristics, soils analysis, etc.

(2) identification of public institutions and individuals capable of providing support to field studies of water resources.

(3) orientation of irrigation strategies according to natural resource potential and constraints.

Recommendation No. 10

There are numerous references in this text to conflicts, real and potential, over water and especially land rights. The government policy of taking land ownership and sometimes attempting to achieve production goals through a system of penalties, has not been effective. Other policies, including popular participation in decision making and providing economic incentives, should give better results.

USAID should establish a dialogue with the Government of Chad on the development of land-rights and water charge policies which are consistent with the socio-economic circumstances of a given agricultral system (farming

system). Such issues as length and conditions of tenure and procedures for determining irrigation are always important areas of policy debate. It is important that workable policies be developed and in place in order to insure a smooth and reasonably rapid rate of irrigation project development. To this end AID should work to establish relations within the Ministry of Agriculture and, as soon as appropriate, provide the services of a consultant with special expertise in Chadian/African land tenure systems and irrigation water charges. A systematic procedure for establishing not only the costs of supplying irrigation water, but the returns to irrigated agriculture, is a prerequisite for establishing water rates which provide for amortization of project costs and at the same time are not a disincentive to cultivator participation in a project. This activity should be concomitant with the other recommendations for developing a capacity for the incorporation of irrigation into the existing farming systems (see page 41 for additional comment). The irrigation team considers this to be a priority activity given the implications on farmer response to production incentives and disincentives.

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Appendix C

Water Management Synthesis Project Reports C-1

PART I - APPROACH AND BACKGROUND

1.01 Purpose

The purpose of the Chadian irrigation assessment was basically to determine if investment in the development of irrigation was appropriate for USAID, and second, if this is the case, to provide direction to a strategy for achieving that objective. These analyses were to be carried out from a multidisciplinary focus which evaluated water resources, soils, existing cropping patterns, socio-cultural factors, especially as they involve land and water use, institutional factors and relevant economic circumstances.

1.02 Methodology and Definition of Sahelian and Sudanian Zones

The methodology used by the irrigation team consisted of (1) Direct field observation of irrigation sites in different regions of the country. Sites were chosen in consultation with USAID personal drawing on their considerable experience within the country. (2) Key informant interviews were carried out on field trips and with government officials, mostly in the capital city, and with donor agency representatives. (3) A careful review was made of published materials assembled from USAID in Washington, N'Djamena, and from sources in Paris.

A fairly detailed evaluation was written for each of the sites visited by the team. These evaluations, which follow as closely as was possible a common topical outline, were used as some of the raw materials for developing the teams recommendations. These site reports are presented as appendix material.

This report first presents a brief discussion of the philosophical and analytical perspective which provided the framework for the report followed by a general description of the country (Part I). Next are the summary statements drawn from the trip analyses for first the Sahelian Zone (Part II) and then the Sudanian (Part III) regions. Part IV gives recommendations for creating a Chaddian capacity for irrigation development.

For the purpose of this report the Sahelian Zone is defined as the region which lies between the 400mm and 800mm isohyet (equal rainfall line). This is the central portion of the country and includes an area of numerous wadis around the 400mm isohyet where annual potential evapotranspiration normally exceeds rainfall in all months of the year. In the southern extreme of this zone, the average annual rainfall of 800mm is sufficient to mature a rainfed crop. The Sudanian Zone is defined as the area south of the 800mm isohyet. In this area rainy season agriculture in normal years is not limited by water (see Fig. 1). The irrigation team is aware that is a simplistic division which ignores established climatic zones. What it does is recognize a dryland farming region where water conservation practices and irrigation are critical to agriculture compared to one where rainfed agriculture has considerable potential. In the report there is also reference to the Saharian Zone which is the area in Chad north of the 400mm isohyet.

1.03 Analytical Perspective

The irrigation team patterned their investigations to confront the most basic policy question asked by USAID. Should USAID invest in irrigation at this point in the development of the agricultural economy of the country and if so, where should that activity be concentrated? What activities should be carried out and in what sequence? Based on the climatological data and information on the indigenous cropping patterns it was obvious that the answer to these questions might well be different in the southern compared to the central and more northern regions of the country. The south or Saharan part of the country has a much larger and more reliable water supply and traditionally has had a more prosperous agricultural economy. The soils are known to be of relatively high fertility by African standards and because of considerable experience with cotton grown for an indigenous export industry, local farmers have experience with more modern agricultural methods. Accordingly the irrigation team planned its field work to concentrate on the more central region where the rainfall patterns suggested a likely greater need for irrigation and where not coincidentally, there is a greater history of cultivator use of irrigation. The south however was not ignored. Members of the team visited the more important irrigation sites in the south and reviewed on-going plans for expanding irrigated agriculture in that region.

The irrigation mandate of this team is tempered by two factors: 1) the urgency of the food situation of the past several years which is a consequence of drought and displacement of persons, and 2) the desirability of moving from an orientation of relief to one of development. It is manifest that Chad is not now self-sufficient in feeding a needy population and will not be able to do so without drastic and positive changes in physical and social infrastructure.

The development of effective water management activities is possible, but must not be taken out of the broader context of existing agricultural production patterns. Even where irrigation is feasible, most farmers use it to supplement dryland farming. Moreover, for many farming includes livestock production as an integral part of the household economy. Indeed, livestock (and forage for it) may predominate as the major activity, with crop production in an auxiliary position. And in the case of some inhabitants of Lake Chad, like the Boudouma and Kouri, crop production was subsumed by a prior interest in fishing as a source of income, suppressed today only by a limiting lake level. Clearly, there is more than one pattern of socio-economic adjustment within any one ecological zone of the country.

Elsewhere, other colleagues in irrigation studies have written, of the general African context, that "There is a strong case to insist that Farming Systems Research Projects pay more attention to irrigation." We would argue that the opposite obtains in Chad. There are compelling reasons to insist that small-scale irrigation projects pay more attention to the farming systems of the participating cultivators.

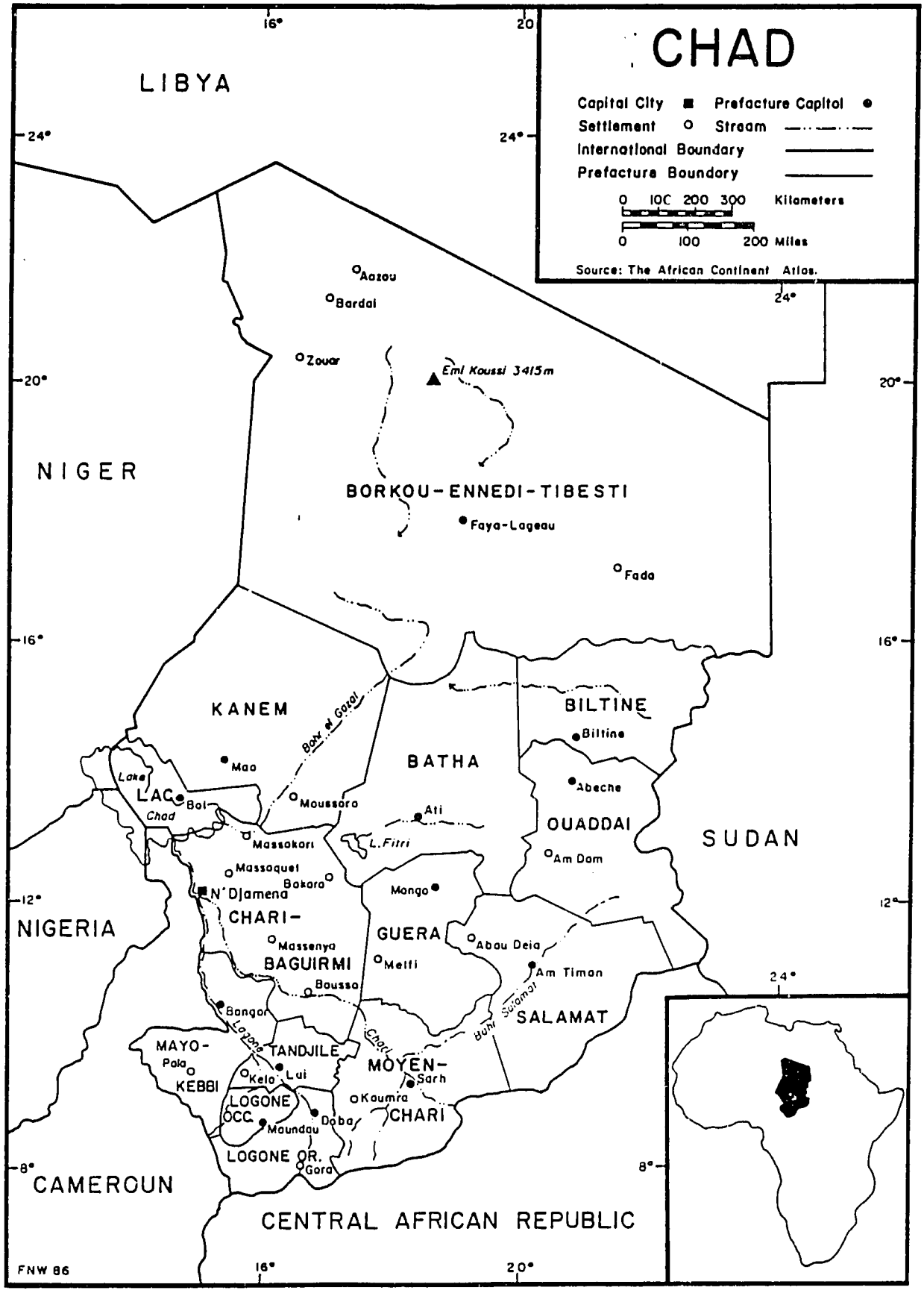
"Begin where the people are" should not be dismissed as a cliche. Underlying what appears to be, at best, an uneven record of accomplishment on most small perimeter schemes visited by the team is incomplete or faulty understanding of the respective farm communities -- their values, organization for work and life processes, and potential roles as participants and ultimately managers of their own irrigation systems. Comprehension of these agro-social

systems will enhance successful planning and implementation of an irrigation project and related activities. To ignore or be unaware of them courts lack of cooperation, limited participation, and even possible friction.

It is, of course, important to support the Government of Chad in the definition and establishment of a mode of operation which favors the greatest participation of smallholders involved in ongoing and planned irrigation projects in the country. Experience in Chad, as well as Sahelian and Saharan Africa, shows that actions neglecting the role of smallholders on paying lip service to the principle of participation have failed on agronomic, economic and social levels. On the other hand, the search for organizational arrangements that permit the greatest autonomy of actions by farmers, individually and in groups, is essential to obtain small farmer commitment and the long term mobility of projects.

1.04 Limitations of the Assessment

There is substantial literature on the physical and human resources of the country, mostly of the reconnaisance type. Agriculture and livestock production systems are described and there has been a good deal of work on the properties of Lake Chad including general hydrology, water quality and so on. Unfortunately there has not been enough work on the economics of crop production or of farming systems to provide an adequate basis for project evaluation. Given these circumstances, it was not possible to test the economic or financial viability of investment in irrigation. Likewise, while much has been done on identifying ethnic groups, there is little published information how their groups adjust to the forces of modernization. What was possible however, was to identify by observation in the field the present operation of both traditional and more modern irrigation systems. It was also possible to compare rainfall patterns against evapotranspiration and to speculate on the benefits which might occur from irrigation. The current drought has created a circumstance under which this seems somewhat academic, however any long-term investment stategy for irrigation development in Chad must account for the fact of variable returns between years and seasons.


CHAD
Capital City
Prefecture Capital
Settlement
Stream
International Boundary
Prefecture Boundary
0 100 200 300 Kilometers
0 100 200 Miles
Source: The African Continent Atlas.
LIBYA
NIGER
NIGERIA
CAMEROUN
CENTRAL AFRICAN REPUBLIC
SUDAN
Aozou
Bardai
Zouar
Emi Koussi 3415m
BORKOU-ENNEDI-TIBESTI
Faya-Lageau
Fada
KANEM
Bahr el Gazal
Mao
LAC
Lake Chad
Bol
Moussoro
BATHA
Ati
L. Fitri
BILTINE
Biltine
Abeche
OUADDAI
Am Dom
Massakori
Massaquet
Bakara
N'Djamena
Mongo
CHARI-BAGUIRMI
Massenya
Melfi
GUERA
Abou Deia
Am Timan
Boussa
Bongor
Logone
Chari
Bahr Salamat
SALAMAT
MAYO-KEBBI
Pala
TANDJILE
Kelo
Lai
MOYEN-CHARI
Sarh
Koumra
LOGONE OCC.
Doba
Moundou
LOGONE OR.
Gore
FNW 86

General Information: Country Description

1.11 Population

According to recent estimates the population of Chad is approximately 4.9 million (1984) with an annual growth rate of 2.3 percent. In the mid-1970's about half of the population lived in the southern half of the country, i.e. south of the capital city of N'Djamena and the 700 mm rainfall isohyet. Population density, which averages four persons per square kilometer, is extremely variable from 36/km^2 in Logone Occidental, a province in the south to 1/10 km^2 in B.E.T., a province in the north.

Some 85% of the population of Chad live in rural areas and 80% of the population is engaged in agriculture. Per capita incomes in 1983 averaged 83 U.S. dollars.

The population growth rate is low by African but high by world standards. The growth rate is kept low by high infant mortality and low life expectancy at birth (44 years). It can be argued that under present conditions, in relative terms compared to most other countries in Africa, the rate of population growth is not yet high enough to be a major issue. However, a decline in infant mortality and increase in life expectancy, given the current total fertility rate could result in a population growth rate approaching 3% in a relatively small number of years. Such rates are currently being experienced in most of the other Sahelian countries.

This lends further weight to arguments for exploiting available land and water resources. Given a relatively large stock of unexploited land, water is the main constraint to agricultural production in the Sahelian area of the country.

1.12 Climate

The climate of Chad ranges from semi-tropical in the far south to desert in the northern third of the country. The set of climatic zones generally found across north and central Africa all exist within the country. In the north, beyond the 350 mm rainfall isohyet (in an area mostly now occupied by Libya) is the Saharan zone. Moving south one finds the transition area around the 350 mm rainfall line into the Sahelian zone which extends to just beyond Bongor at about the 800 mm isohyet and there transitions into the Sudanian zone which extends south to around the 1100 mm rainfall line. From here the climate changes into the Guinean zone in the southern most province of Logone Oriental where average annual rainfall exceeds 1200 mm per annum.

There are two distinct seasons across the country, the rainy season and the dry season. The length of these two seasons varies dependent on location with the rainy season being longest in the South (mid-May through mid-October and peaking in August) and shorter with the rains starting later and ending earlier in the North.

Loosely analogous to the major climatic areas, local reference materials refer to Northern, Central and Southern zones of the country. This division is a convenient one because it captures broad differences in not only rainfall and temperature but soils, cropping patterns, population density and economic activity as well. Table 1 with reference to the map (Figure 1) gives population densities, and rainfall for these three zones.

Agricultural production across the country encounters not only great variation in total rainfall but at any site, extreme variation between years as well. Table 2 and Figure 2 for N'Djamena and Bongor, both in the Sahelian zone show just how great this variation is. It is under these kinds of circumstances that irrigation, in both dry seasons and as supplemental irrigation can be especially productive.

1.13 Socio-Cultural Profile

Chad is comprised of numerous ethnic groups, many of which are extremely diverse in cultural patterns and social organization, while others share a number of selected characteristics. Their economic modes are largely a reflection of adaptation to ecological circumstances, conditioned in part by the influx and contacts since the 14th century with the Arabs and more recently, by the colonial regime of the French.

The country has been subjected to invasion and migrations, both voluntary and forced, since pre-Arab times. However, movements of Kanuri and other tribes came from the west to ultimately form a number of traditional kingdoms, and, persisting today, sultanates. Many of the ethnic divisions and attitudes, institutions and recent problems of "modernization" efforts and nation-building are a consequence of historical developments that took root and shape long before the coming of the French. Groups have coalesced over time; others have splintered in disagreement; while still others co-exist in symbiotic relationship.

French and Arabic are the official languages of government but the latter serves more as lingua franca in the northern half of the country. Frequently, neither will suffice for communication, especially in tribal areas and among women of these groups.

The northern or Saharan Ecological Zone is populated by groups like the Toubou and its several clans and sub-groups, nomadic and semi-nomadic alike. Their patterns of transhumance have been severely disturbed by recent war and extended drought. Both factors have driven them farther south than usual, moving well below the traditional southern herding boundary into closer and more sustained contact with sedentary cultivators, Arab and non-Arab alike. Some have moved toward the Lake Chad region, while others have gone more south-easterly toward Abeche.

The Sahelian or Intermediate Zone, extending from the 400 mm to the 1000 mm isohyet, is the domain of greatest ethnic diversity. Its lake and wadi communities have a variety of farming system patterns. Riverine communities may fish and farm; those more inland emphasize animals, dune agriculture and where possible recessional farming. Semi-nomadic herders often farm on a part-time basis when soils, rains and drainage permit. Islam and traditional religious practices are found, with Islam sometimes in syncretism with indigenous traits, along with a broad spectrum of patterns of village social and economic organization. The latter are largely based on village autonomy with usufruct land and water rights managed by a Chef de Village or Chef de Terre.

The southern Sudanian Zone has seen the greatest amount of recent economic development. Large agricultural schemes and irrigated rice and cotton enterprises, and agro-industrial activities reflect the closer contact of this region with the French colonial administration. These co-exist with tradi-

Table 1. Population and Rainfall

	Province	Rural Pop/km^2	Rainfall 100 to 400 mm	Rainfall 400 to 1000 mm	Rainfall 1000 mm	Total Area km^2
N	B-E-T	.12				600,350
O	Kanem	1.52	X			114,350
R	Lac	5.95	X			22,320
T	Batha	3.67	X			88,800
H	Biltine	3.47				46,850
C						
E	Chari-Baguimi	4.20		X		89,910
N	Guera	3.05		X		58,950
T	Ouaddai	3.81		X		77,240
R	Salamat	1.53		X		63,000
A						
L						
S	Mayo-Kebbi	19.56			X	45,180
O	Tandjile	13.30			X	18,045
U	Logone-Occidental	25.86			X	7,695
T	Moyen-Chari	8.89			X	45,180
H	Logone-Oriental	8.77			X	28,035

tional farming systems. The Sara population, which predominates the zone, and is culturally homogeneous, and in the past provided the greater part of governmental cadre forces, their marginal position in the administration being strengthened immediately after independence. Ethnic diversity with its traditional ties of kinship and loyalty are significant factors in the nation-building process.

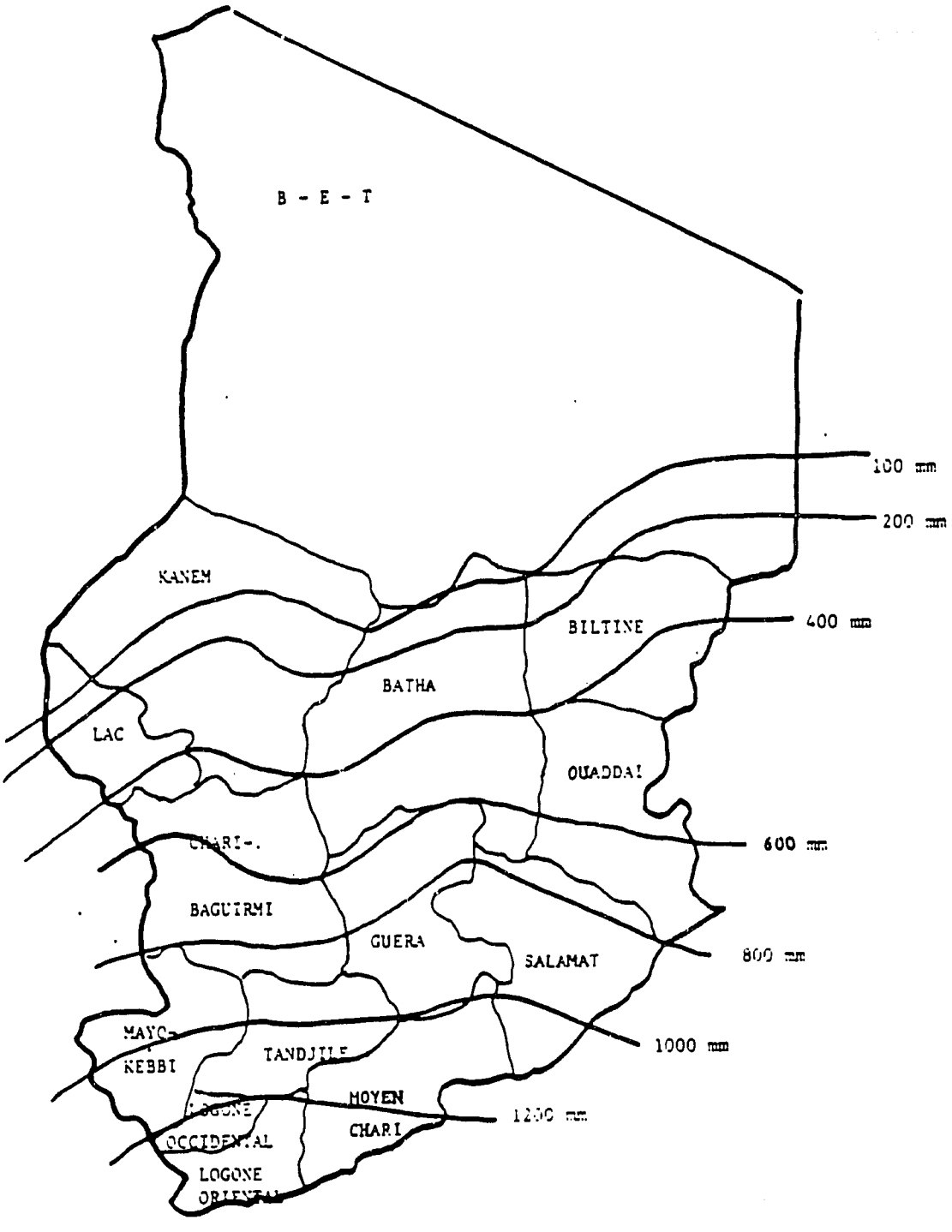
1.14 Water Resources

The major water sources in Chad are Lake Chad, Lake Fitri, the Logone-Chari River System in the south and the phreatic, middle and lower ground water aquifers.

The current drought situation withstanding, water in Chad is a renewable resource, but often it is not readily available. By some estimates, in average years, Lake Chad contains over 80 x 10^9 m^3 of water. The underground water, generally underlying much of the country is estimated to be perhaps several times larger. Not all of this vast renewable resource is available to Chad since the lake also covers parts of Niger, Nigeria and Cameroon.

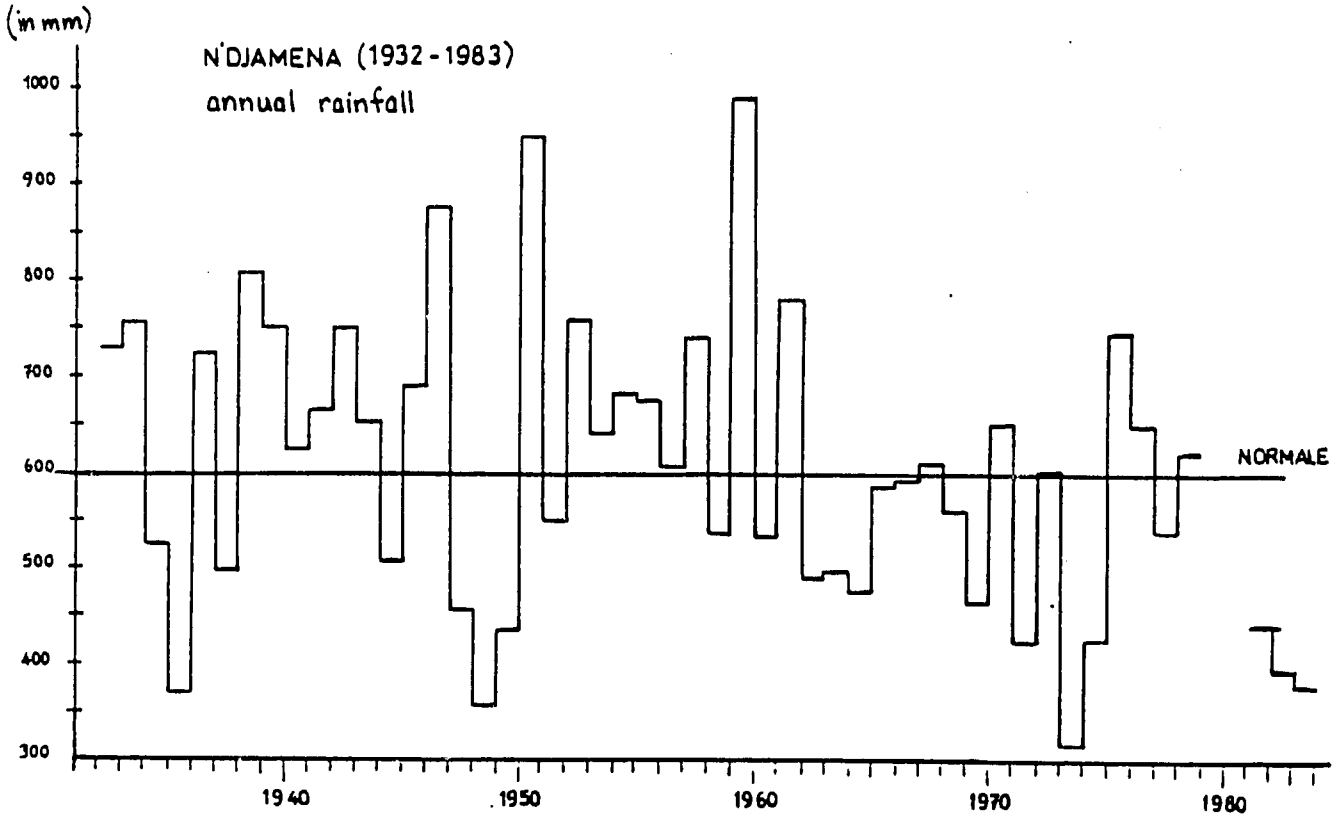
Approximately 41.5 percent (179,800 km^2) of the total Lake Chad Basin is found in Chad. On the average, about 10,000 km^2 of this is Lake Chad itself. What is especially critical in the agriculture of the lake region is the tremendous fluctuation in the total surface area, and consequently the

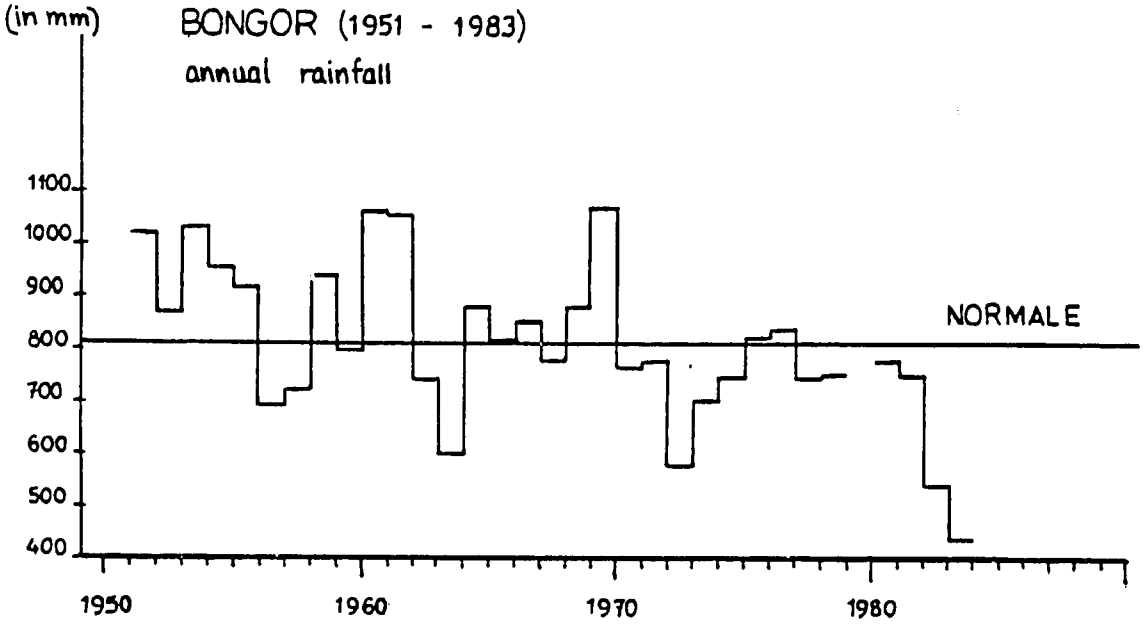
Figure 1. Total Annual Rainfall in Chad*



* Based on 25 year average

Figure 2


(in mm)
N'DJAMENA (1932-1983)
annual rainfall
1000
900
800
700
600
500
400
300
NORMALE
1940
1950
1960
1970
1980


(in mm)
BONGOR (1951 - 1983)
annual rainfall
1100
1000
900
800
700
600
500
400
NORMALE
1950
1960
1970
1980

land area of the lake. A high lake level and accompanying high rainfall brings water to the polder areas, sometimes flooding. Multiple cropping becomes possible in these polders as cultivators take advantage of rainfall and receding flood waters. A low lake level and accompanying low rainfall leaves the polder areas high and dry, dependent on inadequate rainfall and small-scale irrigation system water from shallow wells using the traditional hand-powered shadoof. As the lake level recedes recession agriculture moves after it. When it expands agricultural operations must retreat.

The main drainage areas of Chad supply the Chari and the Logone rivers. Both of these rivers have numerous tributaries and both, in normal years, overflow their banks. In a normal year the Logone-Chari catchment discharges 34,300 x 10^6 m^3 of water into Lake Chad, but there is great between year variation. From 1935 thru 1980 annual discharge from the Chari River at N'Djamena has ranged from a high of 53,700 x 10^6 m^3 to a low of 17,100 x 10^6 m^3 and in 1983 was considerably below that.

Riverflows show not only extreme between but within season variation as well. This latter variation corresponds to lagged variations in the monthly rainfall distribution. In the 1985 season, the river stopped flowing at N'Djamena for the first time since records have been kept.

Based on information available to date the main groundwater resource in Chad is concentrated in the phreatic, or upper aquifer. It is estimated that the normal recharge of this aquifer may be around 27,000 $m^3/km^2/yr$ of which 4.8 x 10^9 m^3 are recoverable annually, but the basis for these estimates are not well founded. There is almost no information available concerning the middle and lower level aquifers of the country.

1.15 <u>The Economy</u>

By any accounts, Chad is a poor country. Years of civil war and the invasion by Libya have taken their toll on an economy which has been basically agricultural (agriculture, livestock, and fresh water fishery). In recent years agriculture has contributed approximately 42% of G.D.P. compared to about 17% for manufacturing. The primary export is cotton, which is grown in the southern part of the country. (Cotton accounted for two-thirds of all exports in 1981.)

Per-capita G.N.P. is among the lowest in the world, estimated as U.S. $120 in 1980 and U.S. $83 in 1983. The entire social infrastructure is in need of re-building especially roads and transport support facilities, educational institutions, and government services. In the private sector business has not yet returned to normal. In spite of all of the difficulties, drought, poverty and war, the country was able to run a balance of payments surplus in 1981, 1982, and probably in 1983. Unfortunately other conditions desireable for stimulating growth, such as a viable banking institution and confident investors, are not in place.

The current government has indicated that agriculture is to be leading sector in the economic recovery. The traditional crops are cotton, millet, sorghum and recession sorghum (berbere), maize, rice, vegetables, groundnuts, and sugarcane. Livestock is extremely important. In 1983 livestock, including meat, hides, milk, traction and manure contributed 26% of GNP.; 29% of the

population depended entirely on livestock for their livelihood; and the industry contributed 30% of total export earnings.

1.16 Conditions for Agricultural Production

In Chad, as already noted there is a wide range of cropping environments. These environments are principally defined by three parameters: (1) climate (rainfall and temperature), (2) soils, and (3) water resources. What is of great significance for agricultural development is that in all of these cropping environments there is a significant role for water management and control in some and probably all seasons.

The great variation in rainfall within and between both seasons and years, across the country both creates the need for water management and complicates the utilization of a complex set of interrelated water resouces. In fact what is very obvious after only a brief orientation to the agriculture of the sahelian zone of the country is that irrigation and water management including dryland cultivation techniques are an integral part of the agricultural economy of the region.

The natural complexity of utilizing the natural water environments of the country is especially exaserbated by the recurrent droughts. The present (1984-85) extended drought and low level of Lake Chad, coupled with the fact that the lake stood at an all-time high little more than a decade ago emphasizes this point.

1.17 The Current Drought and Its Implications for Irrigation and Water Management

There are two schools of thought regarding the climatological significance of the current (1984-85) drought in Chad. One is that it is part of major worldwide climatic change. The other, that it falls within the expected climatic variation of a region known for wide fluctuations in annual totals and distributions of rainfall. Regardless, it is clear that in the future, based on both recent events or long term averages, water management, including irrigation, drainage and flood control, will be a necessary ingredient in managing the agricultural environments of the Sahel region as they always have been.

The general conclusion of the irrigation team is that irrigation has an important and necessary role to play, both in providing food security and in contributing to agricultural development in the Sahelian region of the country, and that USAID should work towards establishing activities in that area. What is especially important in reaching this conclusion is the presence of Lake Chad and its two priciple rivers, the Logone and the Chari. They have created an immense resource of flood plains and recession waters and groundwater.

In addition to the water resource, soils with relatively high natural fertility by African standards and a long irrigation tradition, recommend irrigated agriculture for the Sahelian zone. The types of irrigation interventions envisioned by the team are relatively small scale and would utilize both ground and surface water. The rationale for this recommendation will be apparent from the more specific recommendation on irrigation which are developed throughout this text.

PART II - THE SAHELIAN ZONE

The dominating feature of the agriculture of the central or Sahelian region of the country is Lake Chad. This large body of water literally drives the agriculture of the eastern and central Sahelian region region as it expands and contracts in response to changes in precipitation and runoff in the vast watershed which feeds it. Its waters do much to charge ground water resources through infiltration and subterranean flows.

The extremely gentle slope of the lake bed creates a situation in which relatively small changes in inflow of water result in large fluctuations in the lake's surface area and in the opportunities for agriculture on the surrounding lands. Thus this year's fields are last year's lake bottom. Recession agriculture follows both the annual and between year variation in rainfall and surface area of the lake. During the current drought the lake shore is known to have receded by as much as 30 to 40 kilometers in some areas. These circumstances create a type of shifting cultivation which puts considerable strain on farmer resources. He is forced to migrate in search of land with adequate water resources.

In addition to the recessional agricultural areas, the expanding area of Lake Chad includes, on the northern shore, an intricate network of parallel sand dunes oriented NW-SE interlaced with fingers of the lake. Dams across these parallel dunes or polders can be used to control the flow of expanding lake waters both into and out of the enclosed area. Recession and polder land varies greatly in area with changes in the lake level as does area cultivated and crop production. The innundations of these polder lands also serve to recharge the shallow ground water aquafer.

Another important feature of the northern and central Lake Chad region is the wadis. Wadi is the local term for an interdune depression. This land is beyond the reach of lake flood waters but may be directly linked to the lake through subterranean ground water flows.

2.01 Soils of the Lake Chad Region

In general there are four distinct soil situations as related to agricultural production. First are the sandy soils of the dunes which are unflooded and where agriculture relies on rainfall. These soils are generally acidic and contain little organic matter. Rainfall permitting, millet is cultivated and livestock is grazed. In the flood recession zone of the lake there are sand islands where doum palms are the dominant vegetation. Millet is also grown here and these islands are important sources of forage as the lake waters recede. Second are the soils of the polders. These soils are fine textured and rich in organic matter. They have generally good physical properties and excellent fertility. They do however pose some difficulties due to shrinking and swelling on drying and wetting and with salinization. Traditional management calls for periodic flooding of polders to flush out the salts. Third are the recessional lake bottom soils which are similar to the soils of the polders but are more frequently flooded and have more organic matter. Typical profiles show evidence of reducing conditions associated with flooded soils, and there is considerable deep cracking on drying. Fourth are the wadi soils. In general these soils have good physical characteristics and are fairly fertile. However salinization is a major problem because of low

rainfall and no opportunity to flush these soils with lake water (more detailed descriptions of the soils of the Lake Chad regions are given in Appendix A1).

2.02 Ethnographic Information

The outstanding social factor of the Lake Region is its current ethnic diversity. Not to recognize this would be folly. Ethnic groups vary among themselves in language and social organization, in political power stemming from the historical past, population size, and in economic orientations and adjustment to the same general ecosystem. Where there have been asymmetric inter-group relationships, with one society subordinate to another, as in the case of the Haddad and Kanembou, acculturation has been largely a one-way process, with the former having to learn to speak the language of the dominant Kanembou, the lingua franca of the area along with Arabic.

The Kanembou comprise the largest ethnic group of Kanem Prefecture and extend southward into the northern part of Chari-Baguirmi and Lac Prefectures. They speak arabic as well as their own Saharan language. They have intermarried extensively with their various neighbors, with the exception of the Haddad, who remain in caste-like isolation, their Islamic ties notwithstanding.

It is the Kanembou, incidentally, who have been seen by recent planners of modern polder development as the major labor source in the variously proposed farming schemes. Cultivators of millet on the sand dunes, and of maize, wheat, sorghum, melons and some vegetables on more heavily watered lands. The use of the shadoof in the wadis permits a greater variety of cultivated crops and indeed, their use of the wadis may reflect their later arrival in the Lake Region. They rely heavily on cattle, which are daily driven to forage in the environs of the villages, fertilizing sand dunes where penicillum millet will be planted at the onset of the rains.

One of the oldest, if not politically dominant, inhabitants of Lake Chad's islands are the Bouduma. Their economic life has taken several turns over time and the caprice of climatic changes. Traditionally cattle herders, they shifted to less desirable fishing after losing their pastures more than two decades ago. The recent drought and its severe effect on the lake's fish resource, has meant a return to dependence on livestock and farming, with millet and maize the major crops, as well as some wheat grown in polders. During the dry season, the herds are moved some distance from their communities located on islands and the northern shore of the lake. Most of the year, in "normal" times, the islands would be used for pasture.

Like the Bouduma, the Kouri (who refer to themselves as Yedina) engage in some fishing when this is feasible, but they are primarily farmers and cattle herders. The same staples -- wheat, millet and maize -- are grown on the islands where they reside, along with some vegetables.

There are other, lesser ethnic groups, in varying proportions of the Lake Region's population. There are the ubiquitous Fulani. There are the Kanuri, sometime invaders from the west, who played an important role in the formation of the Sultanates, active vestiges of which still are to be reckoned with. The Haddad, artisans and sometime fishermen, have already been noted. The camel-herding Toubou, who refer to themselves as Teda or Daza, depending on the Saharan dialect used (Area Handbook for Chad, HRAF, p. 48) have normally

lived in well-defined areas, their nomadic or semi-nomadic life notwithstanding. Their clans claim traditional rights to specific wells, pastures and wadis. Similarly, specific date trees and gardens, where these are grown, may fall under Toubou claim. Traditionally, these may not be used by other without prior transaction which may involve some payment.

More significant in number are those who seasonally move with their herds to different pastures and wells or other water outlets. These groups have a permanent residence that they occupy during the rainy season, but some rights of ownership prevail for date trees, water sources, and pastures located in the semi-arid zone which they consider their territory. As in all other cases we have noted, or will later mention in this report, the West African adage prevails that "There is no land without an owner."

2.03 Land Use Patterns

It is obvious that the lake shore environment and the wadis beyond have been both a site of permanent settlement and temporary refuge for centuries. The land use patterns show important linkages among fishing, cultivating, and herding. Population distribution is tied to lake flood and recession cycles and rainfall patterns. Two periods of the intense drought during the past 15 years have led to increased influx and settlement of people and herds, modifying more "normal" patterns.

The lake area is the dry season forage reserve. Animals migrate to rainy season pasture as early as possible, stay until either water, forage or both are in short supply, and then return to the lake area. Sometime during the rainy season herders move out of the lake recession lands to their northern home ranges and wadis. They stay to grow a wheat crop from October through March before moving their herds to the lake again. The movements to and from the lake seem to be timed to avoid pests and disease and to take advantage of forage made available by flood recession, while permitting the home range vegetation to regenerate. The current drought has led to distress sales of stock, longer camping in the lake area, migrations even further south, and herder relocation to wadis. On a south-north transect, herds feeding on fairly unpalatable shrubs indicates that the range capital has deteriorated significantly. More information on land use under the current drought along with a cropping calendar is given in appendix A-1.

2.04 Land and Water Rights

War and then drought accelerated the southerly movement of displaced persons to Lake Chad, both to its adjacent areas now enlarged by receding waters and more widely, the wadis that are unevenly scattered throughout the lake region. Others have migrated to Bahr el Ghazal, that long sandy depression east of Lake Chad that runs in a southwest-mortheasterly direction and receives some overflow during the flood stage of the lake.

Refugees arrived in these areas in large numbers, leaving devastated fields and decimated herds behind them. While their dire situation has been accepted thus far by the permanent residents and those migratory groups like the Kreda Toubou, who lay claim to many of Bahr el Ghazal's wadis and pasture lands, a considerable readjustment in land use is taking place in favorable farming locations as a consequence of relocation. The current benign accommodations to the new, heavy in-migration may prove to be temporary, especially

in view of the lake's recession and the impact of this development on the entire basin.

The existence of a plentiful resource seldom creates inter-group problems. With its increasing rarity, however, new relations of interdependency may be developed. This possibility is clearly seen in the symbiotic relationships developed by migratory herders like the Fulani and the sedentary farmers with whom they annually and habitually camp and exchange services. Alternatively, there has been control by one group and payment by another. The history of the region is littered with reports of periodic conflict over water rights.

In times of drastic water shortage, humans, like plants and animals, suffer from water stress and compete for its acquisition. The process is more than one stemming from biological stress. Socio-economic and traditional juridicial parameters come into play. Conflicts can arise between different traditional concepts of property rights, now exacerbated by a nationalizing polity that claims eminent domain for itself, obliterating all traditional or customary rights. Especially when the enactment has not been made clear to the national population nor means established to prepare for a satisfactory and mutually agreed upon transition, a new arena for dissention is created.

2.1 The Lake Chad Polders Project

The northeastern shore of Lake Chad has historically been the major wheat production zone in Chad. The area's potential for increased wheat production led to the creation of SEMABLE, basically a state extension and marketing organization. SEMABLE was apparently organized to obtain a supply of wheat for the Grands Moulins du Tchad, the milling company in N'Djamena. SEMABLE proved not to be a very effective competitor for wheat on the local marketplace during years when production was low and prices were high in neighboring Niger and Nigeria.

The need for a reliable supply of wheat to N'Djamena led to the transformation of SEMABLE into SODELAC (Societe de Developpement de la Region du Lac). The latter was charged with overall development of natural resources in the Lake region. Its first priority was wheat production. Its broader roles included the creation of a regional pole for economic development and, eventually, the establishment of an agroindustrial base.

The first and critical step in the overall process was to be the elaboration of a full control irrigation technology that would permit intensified use of the highly fertile polders. An IFAD/IBRD mission identified the Guini, Berim, and Mawdi polders as the preferred site in 1968. In 1969 a FAC/FAO study led to the construction of a 50 ha experiment station at the Guini polder at Matafo. Feasibility studies were done with French financing in 1971/72. Financing agreements were made in 1975 between Chad and FAC, RGRD, and AFDB. Construction began in 1976 only to be bolted in 1979 by the outbreak of civil war. Construction was essentially completed in the Guini polder (350 ha command area), about 20% completed in the Benein polder (850 ha), and not begun in the Mamdi polder (1800 ha).

The irrigation system constructed was dependent on lake surface for irrigation. Surface water was seen as the least costly option as long-term records showed that pumping would be required only one year out of four to meet

irrigation requirements. Also, the high quality of the lake water would reduce the salinization hazard. The principal concern of the original designers appeared to be the construction of a system that would provide adequate drainage needed for salt management and not interfere with mechanized crop operations.

However, from the time the research station at Matafo was constructed pumping was necessary every year. In addition, the recent series of drought years have drawn lake levels below the 100 year low water mark for 8 years out of the past twelve. Lake Chad has shrunk revealing a natural sand barrier which prevents water from flowing to the Guini intake until the lake reaches the 280 meter elevation contour. Also, the initial financial rate of return calculations were based on the assumption that agricultural products could be shipped on the lake by relatively inexpensive water transport between N'Djamena and Bol. Since the start of the construction phase of the project, the lake has not been navigable to Bol.

While 250 hectares of land was developed for irrigation, wheat and cotton were produced for only two years by small holders. Yields for the cotton crop in 1972 ranged from 2.9 t/ha to 4.6 t/ha with an average of 3.6 t/ha (ACET, 1973). The date of planting wheat was pushed into a nonoptimal range due to the large cotton harvest. Wheat yields averaged about 2 t/ha with a few farmers producing up to 4.0 to 5.0 t/ha. Estimates in 1973 were that small holders would have to pay SODELAC about 25% of their production to reimburse production costs. However the official prices that SODELAC was offering were below local market prices.

Since 1983 there have been a series of studies investigating the potential rehabilitation and/or redesign of the polders. These have ranged from full to partial rehabilitation of existing structures, the conjunctive use of groundwater for gravity irrigation using the same distribution networks, to groundwater pumping water to center pivots. All have duly noted that the problems of water supply, high operating costs, and isolation (transportation costs) introduce large elements of risk. The IBRD Supervising Mission of February 1984 recommended that less costly alternatives for meeting regional food needs be studied rather than rehabilitating the Bol polders. This irrigation review team agrees with that conclusion.

2.11 Irrigation Potential and Recommendations

The IBRD Supervision Mission (1984) pointed out that about 6,500 ha of land was cultivated in traditional polders. They recommended that improvement of production in these areas be studied. However, as the most balanced study to date indicates, the lowered lake level, evolution of soil under its new moisture regime, and the major change in socioeconomic conditions apply to both the improved and traditional polders (Aviron-Violet, 1985). Lowered capital resource availability and the priority given to food self sufficiency have also changed the givens behind the original project design. These modifications based on the team's field observations and conclusions, suggest a series of actions that might be undertaken to improve crop production.

1. Make better use of existing resources in the polder and recessional lands. Using the results of the earlier agronomic experimentation, higher yielding varieties of wheat and maize should be reintroduced to the area. Wheat varieties Penjama 62 and Dambata K38 might be obtained from

Mexico. Former local varieties Massor and Baul should be identified and purified for trial and distribution for March plantings. For June plantings the varieties X101 (Jamaica), NCB (Mgevia) and X105A (Jamaica) should be obtained for trial and reintroduction.

2. Hydrological investigations combined with soil studies need to be undertaken to characterize the groundwater resources and their linkage to surface water flows. Concurrent with small-scale tests of improved groundwater extraction methods, work needs to be done to determine soil and water management strategies for years when surface water flood recession lands and cause ground water tables to rise and for years when lake levels lead to soil subsidence and cracking.

3. Improvements to traditional polders to make flooding and draining operate without destruction of sand dunes should be studied. An important element in any such effort should be a low-cost method of removing drainage water and perhaps reclamation of saline soils in the polders.

4. Examination of the use of low-lift pumps that could be mounted and removed from shallow tubewells in the recession zone to provide end of season water security to crops planted as lake waters recede.

5. At this point none of the rehabilitation programs proposed for the Guini and Berim perimeters appear to be within the reach of small holders. Should Lake Chad regain its higher water levels, opportunistic use of the existing irrigation infrastructure in the Guini perimeter should be considered using the main canals and the water-tight portions of the PVC pipe system. Earthworks could be constructed by farmers in areas with damaged PVC secondaries.

2.2 Mao and the Wadi Zone

Mao, the capitol of the Kanem region (prefecture), is located 225 kilometers north of NDjamena and 100 kilometers to the northeast of Bol. Mao lies at the extreme northern edge of the rainfed cropping zone. It is also within what might be characterized as the wadi zone, the area in which interdune depressions provide the most secure source of crop production.

The peoples of the wadi zone carry out a range of economic activities. Rainfed and irrigated crop production, herding and trade are probably the three most important contributors to household income in normal times. Both war and a sustained drought have severely dislocated local economies. Sedentarized people have become dependent on emergency food aid to a greater or lesser extent. Herders have moved their livestock to the Lake Chad area or further south.

The wadi landscape is characterized by dune systems which run NW to SE across the area. In the Mao area dunes are high with relatively steep slopes to the interdune depressions. Salinization of the depressions is a problem limiting intensive use of the soils in the depressions. The hydrological dynamics of the wadi's are similar to those of the polder area but with much lower inflows from the surrounding dunes and, perhaps, with less of an influence of groundwater flow from Lake Chad. The dune soils vary considerably between Mao and the Bahr el Ghazal. From west to east clay content increases to the point that significant runoff appears to occur from the lower dune

slopes to the wadi basins. Intergrade soils of loamy sands appear at the foot of the slopes of the dunes. The depressions have soils that range from sandy loams to sandy clays with organic matter levels probably between 1 and 3%. Surface horizons in the wadi's change to deep, lacustrive deposits of white platy clays probably high in kaolimite. Salinization and sand invasion appear to be the two major management problems of the soils.

Date palms dominate the cropping systems of the wadi's. Irrigated wheat, millet, sorghum, vegetables, spices and condiments round out the cropping pattern. The low rainfall of the rainy season may permit one crop of bulrush millet to be grown on the intergrade sandy soils of the lower and middle slopes of the dunes.

2.21 Climate and Seasons

Figure 3 gives climatic data and the cropping calendar of an intensively cultivated wadi near Mao. Potential evaporation excedes rainfall in every month of the year. Wheat is grown during the cool season to mature before the Harmattan. The Harmattan is a hot monsonal wind blowing southwest off the Sahara Desert around February or March. Two irrigated bulrush millet crops and an irrigated dura sorghum crop round out the cereal rotation. The climate is arid with only marginal potential for rainfed agriculture and soils which make rainwater collection and conservation impractical. In this type of environment rainfed crop production is a supplement to irrigated production and other economic activities. The rainfed forage resource is key to maintaining herds.

2.22 Water Resources

Irrigation is essential to crop production and groundwater is essential to irrigation. The groundwater table in the Mao area fluctuates on a seasonal basis between three and five meters. Depth to groundwater increases to both the east and the west of Mao according to available groundwater maps and inspection of some wells. Towards the Bahr el Ghogal groundwater level rises again. Water yields will vary considerably, but in the Mao area appear to be between three and four cubic meters per hour. Characterizations of the linkage between the groundwater table and Lake Chad have not been made. While it is generally known that there are three major aquifers at near, medium and deep distances, their local yields are not known.

2.23 Irrigation Activities

Irrigation in the wadi zone is limited to shadoof extraction from hand dug shallow wells. Water is conveyed over short elevated dead head sections to field ditches which fill small basins. There is great variation in irrigation system layout and operation, but the best farmers have very little to learn about irrigation.

The cropping pattern shown in figure 4 was taken from farmers working on a quarter hectare holding in a wadi near Mao. Fields were divided into 1m x 1m net area basins and well leveled. Crops were planted more densely along the bottom of the basin ridges to take advantage of border effects on light, soil, and water availability. The farmers had a system of crop coefficients for each of their crops. They used heights on the side of the individual basins to indicate needed water applications at each stage of crop growth. Ba-

sin filling procedures were very precise, each basin being filled over a thirty second period with a constant flow of about two liters per second in the field ditches. Field sections were irrigated at two day intervals.

All fields visited did not operate with the same efficiency. A vegetable and date holding next to Mao showed poor basin layout on a steeply sloped field with excess field ditch velocities and much wasted space. The difference appeared to be that the latter system was owned by a merchant who used mainly hired labor to irrigate and produce crops.

Salt accumulation was apparent along the ridges separating basins. There was no visible buildup in the basins themselves. Water applications of 50 mm at seeding to over 100 mm at peak requirements should ensure that an adequate leaching factor is applied.

2.24 Land Tenure and Distribution

Land within wadis is assigned by a land chief. Once assigned it is held and can be inherited. Holdings tend to be fragmented within a wadi. In similar settings in the Sobel the owners of the date palms are also owners of the land.

Land rights extend up the slope of the dunes where millet is cultivated. Where no wadis exist usufract rights are reportedly easy to obtain for high risk rainfed dune land.

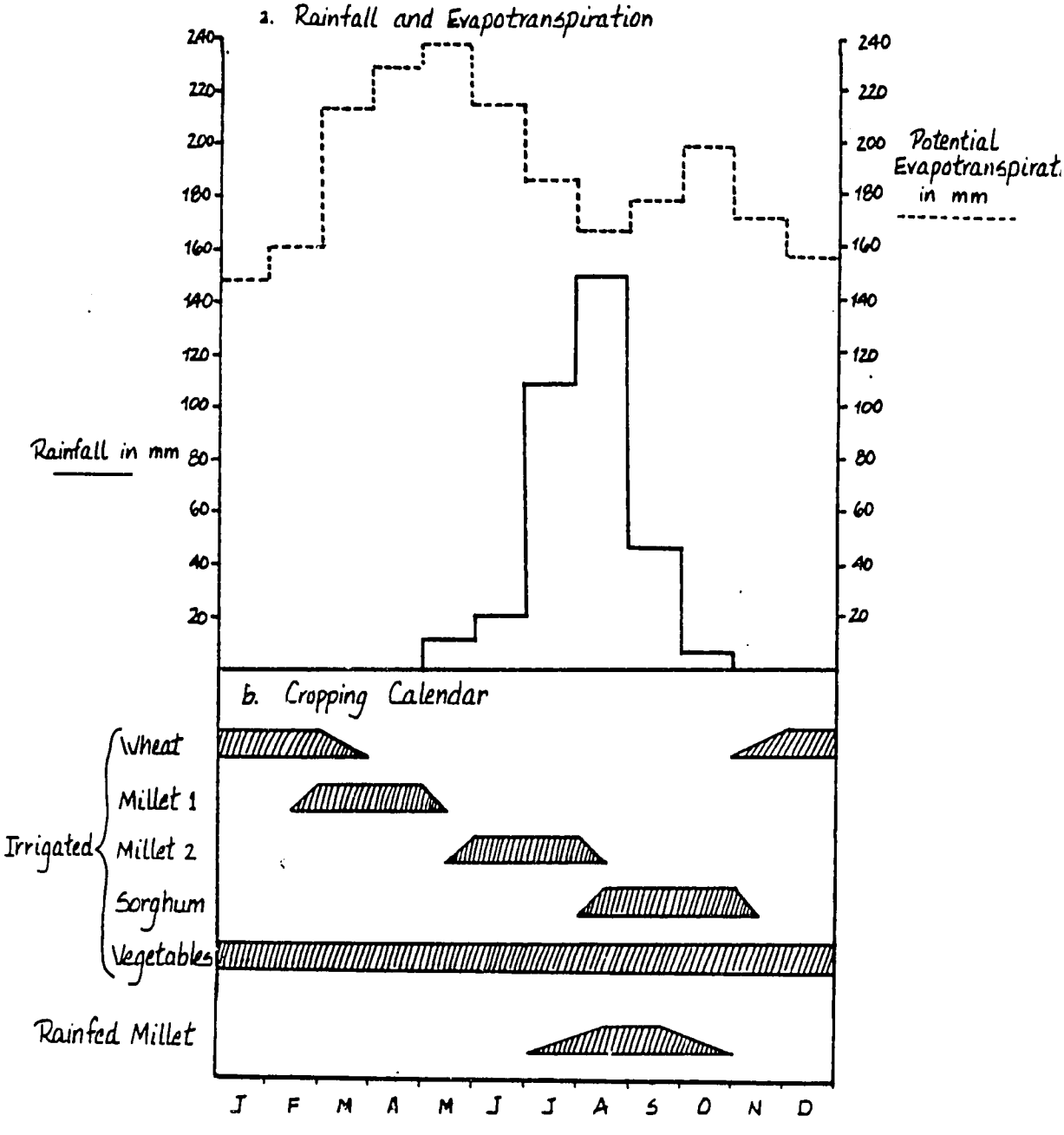
No information of allocation of grazing rights was obtained.

2.25 Irrigation Issues and Constraints

The primary irrigation issue in the wadi zone is whether irrigation can be sustained in existing sites and expanded to new ones. Water availability, cost of extraction, water quality and management to avoid salinization are all important to successful and continued use of the wadis. Elsewhere in the Sahel, the most readily accessible wadis and oases have degraded as intensity of use increased. Salinization has been a major problem as the same water supply is spread over a larger surface area, reducing leaching quantities of water applied per unit surface area. Date palms deteriorate as water is diverted to more intensive annual crop production. In drought conditions, sand dunes loose vegetative cover and begin to fill in the interdune depressions. Occasionally, deeper wells are dug and equipped with pumps to rehabilitate date palm stands and permit more intensive annual cropping, e.g., the Ator region in Mauritania. The issues thus become economic and logistic in nature. Will the increase in production pay for more expensive water and the support services needed to keep pumps and motors running? Also, the reliability of the supply of water from deeper levels needs to be determined before pumping programs are initiated.

Labor availability appears to be a constraint to improved irrigation. The drought has led some family members to migrate over longer periods to time with their herds or to seek employment in towns. Labor costs range from about 750 FCFA to 1000 FCFA per day (approximately 1.75 to 2.10 U.S.). Where family labor is not available, most cereal crops would not provide sufficient returns to permit extensive use of hired labor. In a more general framework, the

Figure 4. Rainfall and Evapotranspiration and Cropping Calendar at Mao



Sources: Hargreaves, George H. 1977. World Water for Agriculture and farmer interviews

important issue is how the drought has affected household patterns of activity -- farming, herding, trading, etc. -- and seasonal and permanent outmigration.

An added constraint to irrigated agriculture in the wadis is the scarcity of local traditional varieties of wheat, millet, and sorghum during the drought because seeds have been used for food. Current seed supplies are coming from Niger, Nigeria and Cameron food grain stocks. Some are adapted, and others probably not. The lack of pure adapted varieties is likely to result in underutilization of available water, soil and labor resources over the next few years.

2.26 Irrigation Potential and Recommendations

The irrigation potential of wadis is limited by the availability and cost of water supply, a salinity hazard, and a sand invasion hazard. These constraints combine to make the wadis relatively fragile environments the intensified use of which carries with it an absolute need for monitoring soil and water supplies and the overall health of the wadi, e.g., date and doum palm vigor.

Ultimately, if larger populations are to be supported a thorough understanding of groundwater resources and their renewal will be needed. In the near term, a hydrological study should be done to determine the depth, availability, costs, and sustainability of deeper groundwater resources.

At a more operational level labor saving techniques for water extraction from the existing shallow wells should be studied by the PVOs and ONDR. Improved shadoof design and construction, low lift hand pumps, and possibly motorpumps could be tried with a view to evaluating their costs and returns in labor freed to pursue other cultural operations. VITA or Appropriate Technology International are among the organizations which would be able to provide support for this work.

The extent of wadi area and van salinized wadi area within the zone is not known. A plammetric study of the location and size of wadis, perhaps based on recent Landsat imagery, would help log the framework for better planning and monitoring of irrigation development. Such a study would also provide the physical framework for investigations of the dynamics of use of wadis by families and their livestock. As similar areas exist throughout the Sahel a CILSS-sponsored effort may be appropriate to inventory existing wadis in Chad and their current use.

There is a need to restock the wadis with adapted crop varieties. It would seem that a major contribution of PVOs operating in the wadis on relief efforts would be to inventory the names and the characteristics of previously used local varieties of wheat, millet, and sorghum. A link to the FAO seeds project should enable the acquisition of pure varieties of local or improved types which could be multiplied under irrigation in the wadis. Any projection USAID seed effort under the umbrella PVO initiative's project could be involved in this effort.

2.3 Middle Valley of the Chari River

The Middle Valley of the Chari River is located in the southern part of the Sahelian zone. The Chari river, which overflows its banks far less

frequently than the nearby Logone, is a source of water for irrigation. A number of small scale irrigation schemes have been installed along the banks of the river beginning about 1970. For all of these schemes irrigation water is pumped from the river (both from floating pump sets and from mobile and semi-permanent stations on the banks) and delivered by gravity flow in unlined canals to 10 to 25 hectare irrigation perimeters.

These perimeters have been developed by a number of different agencies including: (1) CANAM (th N'Djamena Market Gardening and Fruitgrowing Cooperative). This was a 300 acre project in 1979 which had declined to 84 hectares in 1984. The emphasis in this scheme has been to grow vegetables for the market in N'Djamena; (2) the Chari Irrigation Areas (PIC) run by the National Rural Development Agency (ONDR) which has been developing irrigation perimeters on the banks of the Chari river since 1974. The emphasis in these perimeters has been on rice. Recently these efforts have received assistance from CARE/CHAD and are scheduled to obtain World Bank funding starting this year; (3) GARED, a private volunteer organization which has established irrigated vegetable projects around Bougoumene, 80 kilometers south of N'Djamena. A fuller discussion of the projects in Middle Valley of the Chari River is given in Appendix A-4.

2.31 Goals and Progress

The various irrigation schemes in the Chari River's Middle Valley have at least two underlying goals: (a) to increase production and land productivity through irrigation and intensive farming methods and (b) to increase the income of farmers by emphasizing profitable crop enterprises.

Progress reports of the several agencies supporting the irrigation systems invariably reflect enthusiasm about the number of meters of ditches laid out or the quality of the water distribution boxes constructed. The numbers of persons involved in a food-for-work activity will be dutifully recorded and reported and inferences about success or failure drawn from such figures.

Questions have been raised about the success of the various systems during the period up to 1979, when many operations ceased to function. The current situation provides at least equally valuable basis for comment. The general observations of the Club du Sahel published in 1984 are immediately relevant: "It has not been possible to convert production systems because not enough attention has been paid to social fabric when imposing technical solutions." (CILSS: Proposals for a Revised Strategy for Drought Control and Development in the Sahel, Paris, November 1984, p. 14.)

What attention, indeed, has been given to that "social fabric?" Any sensitivity to the cultural milieux in which the perimeters were introduced was limited, at best, to several broad factors intruding on local situations.

2.32 Land Use Issues

The state has already announced that all land falls within the public domain, and that it is now the property of the national government. Are farmers in the various communities aware of this federal position? Is it acceptable? How "legal" now are traditional concepts of property which, even if they are in harmony with one another in a multi-ethnic community, are at odds with the national position. Aware or not, the installation of an irrigation

scheme -- even when presumably discussed fully and collegially between agency and community leaders -- is an intervention involving at least partial expropriation of community lands and personal (i.e., family) rights to their use. That it could at the same time effectively usurp the power of local leadership and ignore local modes of community decision-making is also a not unreasonable presumption.

The conciliatory rhetoric of establishing preliminary agreements between extension personnel or even PVOs on the the one hand and villagers notwithstanding, those civil servants in negotiation are perceived as "government," an outside force traditionally best avoided by a peasantry. Those non-nationals representing private voluntary organizations, despite their modesty in tone, dress and demeanor, are perceived as "powerful."

Perceptions are not readily changed by fiat, or good intentions, or unilateral assurances. In sum, the goals of irrigation agriculture's innovators, even when couched in "participatory" language, may be quite distant from local social realities.

The introduction of the irrigation perimeters ruptured existing farming systems, required new patterns of behavior in family activities, and assumed a cooperative spirit to be extant or readily developed in communties with disparate ethnic groups, with new arrived persons not yet integrated into those communities or identifying with these communities.

The introduction of irrigated farming ignored the extant farming and cropping systems, the local values attached to these, and assumed that farmers - people living on the brink of subsistence -- would risk their family's well-being by giving top propriety to the demands of irrigation. Reckoning with the existing calendar of agricultural activities, a prerequisite of any anticipated farming intervention, seldom occurred.

2.33 Production

The production data available from the several perimeters is at best very scant and incomplete. It is difficult to determine if increased production (if this indeed did occur) is significnatly great to pay water fees, cost of purchased inputs, transportation -- let alone provide an observable and worthwhile gain in the farmer's terms.

Government and PVO personnel despair about farmer attitudes and indifference, complain about lack of cooperation among themselves, let alone cooperation with outside "mangement." They experience a gamut of unfulfilled goals: recommended practices have not been carried out; "traditional" (and therefore "undesirable") practices have not been dropped by villagers; and adequate maintenance of the systems is seldom found over time and without external insistance.

The CILSS "Proposals for a Revised Strategy," which calls for "giving rural population responsibility" is more easily pronounced than developed as a function model. The several recommendations are sound; many are stimulating. How to transform these into actions consonant with the underlying philosophy of the "Proposals" will require creative thinking, not only by donors and technical personnel, but by and with people from the rural groups themselves.

2.34 Summary and Recommendations

In summary then, for the most part these perimeter projects have had at best only mixed success. In many instances there have been problems stemming from the high infiltration rates of the sandy soils, i.e., high water pumping requirements with associated high costs as well as rapid deterioration of the irrigation canals. In many of the rice perimeters, adequate drainage has been a problem. Production costs have been high enough that in some cases farmers have left the schemes because there was no economic incentive to remain. In part, this was caused by marketing problems that include low prices, lack of transportation, and inadequate storage facilities for perishable commodities. Additional problems have occurred from farmers being thrown off the schemes because of low yields and from a failure to provide for farmer organizations that are consistent with the indigenous social structure and that are motivated to supply the cooperation necessary to manage the irrigation water, distribute inputs, deal with marketing issues and so on.

In the opinion of the irrigation team, these perimeter projects are excellent case studies from which additional lessons could be learned that could be useful in designing new projects. The team recommends that the socio-cultural studies being suggested for the more immediate Lake Chad area also be carried out for the Chari river valley. It seems clear that there is much to be learned about designing schemes that are in tune with local institutions. The team also expects that the long term irrigation specialist would assist the PVOs in addressing some of the technical questions that arise in the operation of the physical works and in developing a means of sharing the lessons learned between the government and donor agencies. Additional recommendations relevant to PVO operations are given on pages 39 and 40 of this report.

2.4 CASIER B

Casier B is an irrigated rice perimeter 4 kilometers north of Bongor along the banks of the Logone river. The project was constructed by the Tiawanese in the late 1960's and then reworked by the Chinese (PRC) in the 1970's. The soils are generally sandy clay and silt. Infiltration rates range from moderately high to high. Water is pumped from the river and design calls for 495 net irrigated double cropped rice hectares with full water control and another 300 hectares net area with partial or supplemental irrigation for a rainy season rice crop.

Water is rotated between six secondary canals and distributed to 33 area blocks which are partioned into quarter hectare plots. Individual farmers operate between one and three plots. The rice is transplanted and serious problems arise in scheduling water deliveries with the various husbandry activities over the season. See Appendix A-5 for a fuller project description and notes on current plans and operation.

2.41 Issues in Irrigation and Water Management

Early project management considered the project to be a training and demonstration exercise, presupposing a support infrastructure and societal organization that would continue to provide inputs, external management and financing without demanding smallholder resource commitments. Postwar rehabilitation efforts have started to catch up with deferred maintenance problems on the headworks and conveyance structures. BADEA (Arab Bank for Economic Deve-

lopment in Africa) and FAO, with some contributions by the World Food Organization and CARE/Chad, will support a two year project to complete rehabilitation and provide technical assistance for project operations.

The key issue is whether or not a rehabilited perimeter with an improved operations and maintenance capacity will lead to an economically viable rice production perimeter. The major comparisons should be between returns to investment in the rehabilitated and extended irrigation scheme and a similar level of investment to improve rainfed rice or other cereal crop production in the area. The team believes that it will take a few years of steady operation of the system to enable this evaluation to be made.

The BADEA/FAO project will invest $4,115,000 in Casier B from 1984-85 through 1986. An additional $50,000 of works assistance will be provided by World Food Organization and CARE/Chad. Including $752,000 for technical assistance costs, $547,000 will be invested in capital improvements and $2.9 million in operating costs over three years. It is expected that two irrigated rice crops under full control and one partially controlled crop will be grown with first year yields of 5.5 T/ha (full control rainy season), 4.5 T/ha (full control dry season), and 3.5 to 3.8 T/ha (partial control rainy season). The current operations problems (water duty, rotation, land preparation bottleneck, cropping calendar) suggest that these yields are probably optimistic.

At some point cultivation will have to temporarily be suspended to permit improved operations to be phased into the system. This observation implies that some farmers will suffer some crop loss to permit parcels in a block to come under unified management. There are no signs that current management is influenced in any positive way by participating farmers. Any new management structure needs to pay careful attention to assisting the creation of farmer organization at the block level if water management and crop scheduling is to improve. While the BADEA/FAO project recommends a repayment equivalent to one ton of paddy per hectare per crop, the 1982-83 crop year gave production costs -- without water costs, salaries, pesticides, maintenance and amortization -- of 180,000 FCFA per hectare. Given this the suggested level of repayment may be unsustainable. Farmer involvement in management of the scheme beginning at the block level may enable advances to be made to improve efficiency of capital use through better irrigation operations and agronomic practices.

2.42 Potential for Medium-scale Full Control Irrigation, Mixed Systems: Recommendations

Casier B is the only existing medium-scale, full control irrigation system in Chad. It has never been managed to develop and test an operations and maintenance approach to support unsubsidized rice production that requires full farmer engagement in water management, crop production decisions, and systems maintenance. The team recommends that USAID should consider allocating some of the recommended water management engineer's time to promoting a careful monitoring of the BADEA/FAO-supported Casier B rehabilitation project (see Appendix A, Part 5). USAID should not get directly involved in supporting Casier B operations or similar projects until sufficient experience is gained to permit the evaluation of relative returns from full-control irrigated and rainfed rice production. If a sustainable O&M model is developed, replicability of the experience will be directly tied to modifications of existing agreements with Cameroon on pumping from the Logone River. These

agreements were drawn up because the Sermry Irrigation Scheme in Cameroon is directly across the river from Casier B. The agreement is meant to assure that there will be an equitable distribution of river water between the two country's projects. The BADEA/FAO proposal to extend the partially-controlled flooding sections of the scheme suggests that the international agreement is a constraint to expansion of full-control systems.

Some specific recommendations to affect current operations in Casier B are:

1. Examine the possibility of reducing pumping costs by rehabilitating the lower lift Taiwanese pumping stations.

2. Scheme officials should request a Chinese-reading mechanic to assist to document parts lists of the existing investory and work with the proposed technical assistance team to create a machinery maintenance capacity.

3. Explore the use of animal traction for tillage and weeding operations.

4. Reconstitute the seed multiplication program.

5. Test rattoon and oversowing techniques to gain turnaround time between crops (fertilization and thinning trials).

6. Explore alternative uses for canal seepage as an option to lining the main canal with concrete.

7. A water-management distribution model should be developed to evaluate and develop water distribution which maximizes the net benefits from irrigation. This would involve block-by-block crop operations and an irrigation plan coordinated with rotational water deliveries among the secondary canals

2.5 Abeche (The Ouaddai Region)

The Ouaddai region of Chad has been especially hard hit by the drought of the last two years. This region in eastern Chad is a gently sloping alluvial terrace with occasional hillocks and rock outcrops. The area is covered with a network of watercourses and wadis. The dominating feature of the environment is short but high intensity rainstorms which fall during a three month rainy season in the north (July through September) and a five month season (mid-May through mid-October) in the south. Storm runoff flows rapidly through the highly errodable water courses sometimes causing flooding. Annual rainfall averages around 450 mm (with a range of 360 to 700 mm). The soils vary from dune sands to heavy clay vertisoles. Agricultural production includes rainfed millet on the sand-dunes close to the villages, sorghum (berberbe) on the lowlying vertisoles and vegetables in and around the wadis. (A more detailed description of the area is given in Appendix A-5).

2.51 Irrigation Experience

Historically water resource development has been to provide potable water for human use and watering holes for the herds of goats and of cattle belonging to the nomadic people who transit across the region. For the latter, over the last decade, the government has constructed a number of "hafirs" which is

a small tank built into the bed of a wadi together with a dyke directing small streams into the tank while allowing part of the heavier flows to run outside of it. These dykes are made of packed earth, sometimes buttressed with blocks of granite. Seven recent attempts to impound water for irrigation by constructing dykes across the waterways have been disappointing as all of the dykes have been washed away during flash floods caused by high intensity rainfall from thunderstorms.

In response to the current drought, refugees resettled in the wadis have been assisted in developing wells for small-scale hand irrigation. They have been provided with food, hand tools, and seeds. Because the watertable in the region stands around four to six meters, irrigation using the traditional shadoof is not practical and farmers have turned to the "calebasse". This is simply a gourd tied to a rope which is lowered into the well and retrieved by hand. Only small acreages can be irrigated by a single farm family using this method.

2.52 Irrigation Potential and Recommendations

As in the other regions of the Sahelian zone, there is a potential role for irrigation in the development of the agriculture economy, however the stock of water resources does not appear to be as abundant nor as available as in the vicinity of Lake Chad. The particular circumstances of high intensity rainfall, highly erodible soils, and a limited shallow groundwater resource combine to make it difficult to achieve low cost irrigation capacity. The experience to date indicates that if irrigation is to contribute to food security and increased incomes to area farmers, irrigation system design will have to be more closely in tune with the hydrology of the region.

Given that there are on-going projects under AFRICARE to exploit the potential run-off, USAID assistance to irrigation in the region should likely be channeled through that agency. At this time the greatest need appears to be an assessment of the physical environment, including rainfall, hydrology, and soils, and the design of water impoundment structures which are able to withstand the intensity of the run-off within reasonable limits of probability. The potential for using off-stream storage either by itself or in association with an impoundment or dam across a water course should also be considered. These analyses should include a careful comparison of benefits in terms of increased crop production against the increased costs of building more substantial structures than have been built so far. An analysis should also be carried out to assess the ground water potential of the wadi areas and to develop a system for monitoring the affects of the wells that have already gone into production on the groundwater resources. The studies called for here should not be added on as another dimension to similar studies recommedned for other areas in the Sahelian zone. The uniqueness of the area and the current stage of development in the region recommend this a separate activity.

The reconnaissance studies suggested above would require the services of a two man team of a hydrologist and an irrigation project design engineer for a period of one month. It is expected that this team would work closely with both the Chadian government and with PVOs in the area. It would be important to include the experiences of both professional workers including the Swiss and other donors and of long term residents in the analysis.

If the above analysis suggests a continued investment in irrigation in the area, then additional studies should be carried out to determine the most appropriate means of integrating irrigation into the indigenous agricultural system. This analysis would include labor requirements, farm organizations for on-farm water management, indigenous land and water rights institutions and markets especially for perishable vegetable crops. The results of such studies would be important for planning a series of small-scale impoundment projects. Water distribution networks as well as water scheduling could be influenced by the findings.

One very strong caveat must be made in regards to all of the above, and that is careful consideration must be made of the potential human health hazards found associated with stagnant water. These are water borne intestinal diseases, malaria, schistosomiosis, and bilharzia among others.

2.6 Conclusions and Recommendations for the Sahelian Zone: Some Technical Issues

What follows are a series of technical recommendations related to the development of irrigated agriculture in the area of Lake Chad and of Abeche in the Sahelian region of the country. Additional supportive evidence for these recommendations can be found in Appendix A.

2.61 Recommendations on System Development

The irrigation team recommends that phased feasibility studies be commissioned to test the economic and technical viability of the following types of irrigation interventions in the Sahelian Zone. Phased feasibility studies are meant to identify sets of likely viable alternatives reducing the choices that later design teams would have to deal with, and ultimately deciding if further studies project development is appropriate..

1. Studies should be undertaken to develop workable irrigation systems for both supplemental as well as dry season irrigation in the Sahelian Zone encompassing the recession zone of Lake Chad, the polder area and related wadis, the Chari River Valley and the Ouaddai Region. Such systems may be mostly portable and of low cost to allow for the necessity of moving them in response to changes in the level of the lake. They may for instance, incorporate floating pumps on the lake with some portable piping systems. The very gentle slope of the lake basin may make this economically feasible. Shallow bore holes with hand-powered or fuel-driven pumps with portable piping might be appropriate. Special attention needs to be given to the repair and maintenance of any motor-driven pumping systems preferably in the private sector.

   The first step in this design recommendation would be to secure the services of a two-man team of an irrigation engineer and an irrigation economist to develop some preliminary designs and cost estimates. The total time required would be from six weeks to three months. This activity would be complementary to the recommendation on page 38, on obtaining a water management/small systems engineering specialist.

2. Dependent upon, and concurrent with the hydrologic survey recommended on page 21, a study of the economics of shallow tube wells (up to 120 meters) with a variety of distribution systems including border furrows, small basins, mini-sprinklers, bubblers and so forth with various combinations of, for example, open channels and PVC pipe, dependent on soil situations, should be carried out. The objective of this study would be to determine under what conditions, if any, of water availability, soils, and cropping systems in the Lake Chad region of the Sahel, that shallow tube wells might be suitable. The most promising areas for the application of this type of irrigation technology may, in the first instance, be identified by reference to Carte de Planification Pour l'Exploitation des Eaux Souterraine de l'Afrique Sahelienne. This map and the accompanying study were prepared by the Bureau de Recherches Geologiques et Minieres, Fonds d'Aide Cooperation fe la Republique Francaise, 1975. The information suggests that groundwater may be economically accessible in a broad area in the Sahelian zone to the north and east of Lake Chad.

   Furthermore, this study must include an economic analysis of the cost of developing indigenous repair and maintenance systems. The analysis should recognize the increasing cost of repairs and the difficulty of maintenance, especially under Chadian conditions, with increased distance from the major urban centers.

3. The construction of small tanks/impoundments to supply supplemental irrigation to upland crops especially in more low-lying areas where water naturally tends to accumulate. Sites would be chosen on the basis of topography, soils, and local cropping patterns. Water for irrigation, dependent on circumstances, might be available by gravity flow, hand pumping, or small diesel pump units. It is not likely that such impoundments would be sufficiently large to store sufficient water for multiple cropping. Work currently underway in the Abeche area by the Swiss may provide some important guidelines and experience for these studies. The most promising areas for this type of activity from a technical and topographical viewpoint is outside the Lake Chad area in the Ouaddai Biltine region. It is extremely important, in evaluating the potential of this type of intervention, to be aware of and account for the health hazards (primarily malaria, schistosomiasis and contaminated drinking water) that most often accompany stagnant groundwater.

4. At the present time there is some interest in the suitability of centerpivot irrigation systems for use with smallholder agriculture in Africa. To date there are no examples of this type of irrigation. Theoretically, however, the adoption of centerpivots to smallholder irrigation holds promise of (1) lower per unit area irrigation development costs ($2000 to $2500/acre), (2) a lessened bureaucratic system for managing water distribution, (3) lower organizational costs to be borne by small-scale cultivators because user organizations are not required to distribute water, (4) increased flexibility of farmers to respond to market prices because there is less need to coordinate husbandry activities over multiple owners, and (5) even decreased competition between cultivators for limited water supplies. Centerpivots are not practical for growing all types of crops and for use in every environmental condition. However, it may be instructive, maintenance and operations issues notwithstanding, to cost-out

a number of hypothetical systems for selected environments assuming deep-wells, major rivers or Lake Chad as the source of water.

For all these studies it is essential that they include an economic nalysis that is based upon a solid knowledge of input quantities, and costs nd estimates of output prices for the typical cropping patterns of the area. urthermore, it is critical that any labor constraints required either for rrigation or general crop production, be assessed. In spite of a general nterest in small-scale irrigation systems, there appears to be almost no inormation on the economics of crop production. In the current situation of rought and real and threatened famine, it is appropriate to assume that the pportunity cost of farm labor is at or near zero. However, if irrigation evelopment is to prove a viable investment over time, it must be able to proide a financial return to the operator that is greater than costs including he value of his labor. Also, in spite of a general recognition that the ahel region has a relatively low population density, there are instances of mbitious plans for the development of irrigation perimeters and associated ropping patterns with labor requirements which would likely greatly exceed abor availability. For example the team heard reports of plans to introduce ransplanted rice in small irrigated rice perimieter projects being planned by erman designers. The intense labor requirement of this husbandry practice is ell known.

All of the studies suggested here should include and respond to the inormation on irrigation communities which is covered in the recommendation on age 32. This will enable any design team to speculate on irrigation interentions which take advantage of indigenous systems of land and water rights nd of patterns of cooperation. By this approach it may be possible to avoid onflicts between water users which typically lengthen the time, at considerole cost, required to develop the full potential of irrigated agriculture.

.62 Recommendation on Groundwater Survey

The irrigation team recommends that a survey of groundwater resources at ll levels in the region of the Chadian portion of the conventional Lake Chad asin be undertaken. The Chadian portion of the conventional Lake Chad Basin s the area within Chad which falls within approximately 100 miles of the avrage level of Lake Chad. This is roughly the area which is at one time or nother comes under the direct influence of the flood water of the lake. This urvey should be coordinated with other groundwater studies which may be unerway in the country including (1) the test drilling of the Germans in the uaddai Biltine region who are searching for groundwater for domestic and ivestock uses, and (2) the exploratory drilling of ESSO. This is presently eing carried out in the southern Saharian zone but in-country company repreentatives have expressed a willingness to help track down some thirty drilling logs from earlier exploratory activities in the Sahelian zone. These ogs could be studied for information on goundwater.

This survey should attempt to establish the relationship between groundater levels, rainfall, and the level of Lake Chad. The first step would be or a hydrologist to define the scope and dimension of this survey. This ould be a two to four week study effort.

It is essential, as with other study recommendations in this report that he survey activity be coordinated with the appropriate Chadian institutions.

The International Office of Studies and Program (BIEP), the Office of Livestock and Village Water Supply and Genie Rural would all very likely have interest in this type of activity.

In fact, a more detailed hydrologic survey than is now available would be invaluable for all of the country. It is not recommended that USAID undertake such an ambitious project. However, through the activities recommended here, USAID may encourage other donors to be more active in this critical area.

2.63 Recommendation on Monitoring Groundwater

The irrigation team suggests that concurrent with the present rapid expansion of irrigated agriculture in wadi areas, that assistance be given to the development of a system of monitoring well levels and drawdown and water quality. This is important for avoiding salinity problems and for planning an appropriate intensity of development of wadi irrigation.

The wadi and oasis areas found in the Sahelian Zone of the country are especially fragile environments. Their rich soils have historically been irrigated using the traditional shadoof. Irrigation is necessary in practically all seasons and year-round cropping is the rule. Many wadis, not farmed within recent times, but which traditionally provided rainy season grazing have been recently settled. This has often been with the use of the food for work program run by PVOs, with immigrants (often pastoral people) who have moved in because of the current drought.

The rapid increase in the number of traditional shallow wells (two to three meters deep) and shadoofs could have drastic impacts in fragile wadi areas by reducing application quantities and raising the risk of increasing soil salinity. The new settlers, many of whom are pastoral peoples, cannot be expected to be as sensitive to soil water relationships as the traditional wadi farmers who have accumulated centuries of irrigation experience. The first step in this activity would be for a team of two persons, a hydrologist and water management specialist to develop a program for a wadi groundwater monitoring survey procedure and to identify coordination mechanisms within the Chadian Government. An obvious point for initiating coordination is through the recently formed BIEP. (This institution is discussed more thoroughly on page 38 4.11 of this report.) The Office Nationale Hydrolique Pastorale et Villageoise and Genie Rural should also be consulted and activities be coordinated.

2.64 Recommendation on Pilot Intervention

The Team recommends that U.S. AID sponsor pilot irrigation development interventions (projects) to test different designs for developing irrigation in the polders and wadis. It is obvious from past development experiences that project designers are unfamiliar with workable irrigation system designs for dealing with these unique environments. Thus, while phased feasibility studies are in order as mentioned in the recommendation on page 29, it is important that, before any projects based on such studies are developed, that the economic, social and technical viability upon which they are based be adequately tested.

In order to utilize the data derived from monitoring well levels and water quality in the developing and developed wadis and to better manage them, (see recommendation on page 31) pilot wadis should be selected and studied. Ideally wadis (and polders) selected for such studies should be unsettled initially. Development can then be controlled and scheduled to test different rates and intensities of development and the overall effects in the water resource, etc.

The preliminary design of these pilot studies can be part of the responsibility of the phased feasibility study team's activities if, in addition, an agronomist and hydrologist were available to assist in developing the designs.

2.7 Recommendations on Community Studies

What follows are recommendations to assure that socio/cultural circumstances are integrated into the development of irrigation within the country. Experience so far clearly shows that this type of information can have a high payoff by increasing total production and by reducing the time required for projects to reach their full production potential.

It is the recommended that a study be conducted of existing and potential irrigation communities which will: (1) identify and delineate farming systems, social organizations and patterns of cooperation, and (2) identify potential areas of conflict because of ethnic and/or sedentary farming/herding activities and their effect on land and water rights and use and on market access. Potential irrigation communities are those in relatively uninhabited wadis and along rivers, such as the Logone, where irrigation has not yet been developed.

This study should ideally be carried out by a 5 person group comprised of a senior anthropologist with experience in the Sahel region of Africa to act as team leader and two teams of two persons, each with an agricultural economist with a background in agronomy. It should be possible to complete this study within a six to eight month period.

This study should maintain a farming systems perspective. The findings should be made available to, and would be invaluable for, the PVOs in developing their country programs.

The irrigation team recommends that in these above studies there should be priorities, according to geographical areas as follows: (1) The wadi areas of the north and central Lake Chad region. These areas are both an underexploited resource and in some places coming under intense development, (2) the traditional polder areas of the central region, and (3) the area of recession agriculture around Lake Chad. These areas are also under intense pressure from recent immigations of people from other regions.

These recommendations should be carried out concomitant with the other recommendations of this report.

PART III - THE SUDANIAN ZONE

In the Sahelian Zone, there is little question that water management and irrigation are a critical element in the agriculture of the region. In the Sudanian Zone, however, investment in irrigation must be compared with the alternatives: (1) investment in the improvement of rainfed agriculture and (2) investment in the development of market access primarily through improved roads and transportation systems.

3.1 General Assessment

There is not sufficient data to carry out a financial or economic analysis of the relative economics of these investment alternatives. The irrigation schemes which have been built are not sufficiently documented and managed closely enough to their potential to allow for definitive judgements. What is unmistakeable, however, is the relatively high natural fertility status of the soils, a traditional use of animal power for carrying out agricultural operations and a rainfall quantity which allows for harvesting of a crop in all but the driest years. Given all of this, and the current level of crop husbandry, varietal status of the principle crops and so forth, improvement in rainfed agriculture in the Sudanian Zone appears, in the team's opinion, to hold considerable potential for increasing agricultural production.

This is not to say that there is not a role for irrigation, especially supplemental irrigation in the south, but in the opinion of the team members, this is a second order of development priority at this time.

The irrigation team does not recommend USAID investment in irrigation development at this time in the southern, i.e. Sudanian region of the country. Here investment irrigation must be compared with the investment alternatives of the development of rainfed agriculture and of market access primarily through improved roads and transportation systems. It is also the opinion of the irrigation team that agricultural development in the Sahelian Zone is not a substitute for (and conversely) development in the Sudanian Zone. Circumstances of the existence of population centers, pattern of farming, trading and social interaction, mitigate against such tradeoffs. The discussions which follow are specific to the irrigation project sites that were visited by the team and which are located in the Sudanian zone. For each of the sites there are a number of suggestions as to activities that members of the team thought might contribute to project success.

3.2 Sategui-Deressia

This 11.000 hectare supplemental irrigation scheme for lowland rice begun in 1974 is located on the east bank of the Logone river just north of the town of Lai. The project is designed both to provide improved drainage during high river flood stage and supplemental irrigation water when the river is at lower levels. Water is only available to the scheme by gravity flow after river waters have risen above the intake level of the main canal. The project includes a rice mill, feeder roads, and a research station. The project soils are generally light textured sandy clay with moderate to very high infiltration rates. Project plans called for yield increases of about 1.4 metric tons per acre and further benefits from an increase in the quality of rice milled by the project rice mill. In 1984 the World Bank reformulated the project to induce some rehabilitation of canals and the rice mill, provision of extension

management and engineering services, provision of buildings and of applied research and seed multiplication services.

3.21 Recent Operations

In 1984, 1500 hectares of paddy were planted in the project area but because of the drought and accompanying low river flow there was no harvest.

At the time of the site visit in 1985, some 75 hectares of IRAT 144 for seed were being planted in an area near the project intake from the river. Some portion of this seed farm can be irrigated by river pumping in the event of a continuation of the drought. Planting in the project area was behind schedule because of the unavailability of seeds.

One of the more striking features of the scheme is the relative lightness of the soils, being far sandier than is typical for rice cultivation. It is only the flooding of the river which can be expected to provide the water necessary to mature a rice crop. The importance of this flooding is emphasized by the fact that under current agreements with Cameroon, Logone pumping to supplement the river flood is not possible.

What has been learned from the operation of this scheme to date is that in very dry years, such as the current drought, there is not sufficient water available through the gravity canal system to mature a short-season rice crop. At the other end of the spectrum, it is not totally certain that, in a very rainy year with high river flood levels, that it will be possible to provide sufficient drainage across the scheme to prevent damage to the rice crop. This will be especially the case if relatively short stemmed varieties such as IR-46 are being grown.

3.22 Management Options

Clearly, in the opinion of the irrigation team, at the present time the most critical element in the operation of the Sategui-Deressia scheme is the development of a complete management system which is in tune with the capacity of the irrigation works to control water, the soils and their high infiltration rates, the labor resources of the region and the need of the farmers for credit and extension services. Some of the management options which might be considered are (1) cutting more drains to allow the farmer to block and drain based on their individual requirements, (2) the use of a herbicide such as "roundup" to help avoid staggered planting and variable water depth control problems, (3) using rice varieties that are sufficiently long stemmed to rise above flood water, (4) constructing a third major drain on the catchment reservoir, (5) investigating the suitability of a combination of practices such as ridging to exclude water, growing a short season millet or sorghum on the ridge tops and then interplant rice on the ridge sides, and (6) investigating the suitability of shallow wells for early and/or late season supplemental irrigation.

3.23 Conclusions and Recommendations

The rice irrigation scheme which is currently in operation at Lai is not under best management. As noted, this is due to a variety of factors including the disruptions due to the war, the current drought which left the gravityfed river water scheme at Lai without water for the past three years, a lack

of management experience and skills, difficulties with crop husbandry practices, inexperience with scheduling husbandry operation and irrigation schedules and so on.

It is the recommendation of the irrigation team that USAID through its interactions and relations with other donors work to secure expatriate management expertise to help the Chadian agencies responsible for managing irrigation systems such as SODELAS and gain experience with the operation of rice irrigation schemes. This should include on-site training of Chadian personnel. This recommendation also applies to the medium scale schemes in the Sahelian region around Bongor. It is important that the Chadians working in irrigation be given the opportunity to learn by doing and working with international experts. This, practically speaking, means that Chadian institutions should be involved. This increases the likelihood that the expertise gained will be available for managing irrigation systems in the country.

These systems, as the now stand and with the existing level of management, could not likely be turned over to the Chadian private sector for operation. There is no evidence that they are financially viable however they may yet prove to be viable from a social point of view.

3.3 Rice Operations at Moundou

The cultivation of lowland rice has traditionally been associated with the agriculture of the southern region of the country. Most often its cultivation has relied on water from the flooding of the rivers in the region. As is often the case under such circumstances, many of the flood plain soils are relatively light with higher infiltration rates then are typically associated with rice soils, flood waters are difficult to control and rice often has to be grown in "deep water", and adequate drainage patterns are difficult to establish. These are usually not considered to be ideal rice environments. The Chadian government, with international assistance, has undertaken a "rice operation" in the area around Moundou. Both rainfed and irrigated rice schemes are included.

The rainfed projects are 24 hectare parcels which are provided with dykes to protect against excessive flooding. Typical rice bunds divide the fields and the individual farm operating units are .5 hectares. Experience to date has been that these rainfed perimeter schemes are not effective in dry years such as 1983 and 1984. These projects are an outgrowth of earlier projects in which individual fields were from 100 to 180 hectares. These efforts suffered from poor field layout, soil problems, units too large to be handled by the existing farm communities, and little interest on the part of the cultivators. In addition there was considerable difficulty with fishermen cutting the dykes as fish captured from flood waters is an important economic activity in the region.

3.31 Small Perimeter Scheme

The irrigated rice perimeter schemes water supplied from diesel pumps floated on the river are new to the region. Twenty of these perimeters, each about 20 hectares, are in the planning stages. The perimeters will be enclosed behind flood oarriers and field irrigation will be from unlined canals. Water is to be pumped through above-ground PVC pipe to the high point from where it will flow by gravity to the rest of the scheme. Initially pump

maintenance and repair and operation is to be carried out by two expatriate volunteers with a pick-up truck and six assistants with motorcycles. (See Appendix B-2 for further details on the scheme.)

Under current plans these projects are expected to be ultimately self-supporting including the creation of a replacement fund which will be used to expand the schemes into new areas. These expectations are dependent on single crop yields of seven tons per hectare and on the smooth operation of a government marketing system which will be set up as part of the overall project. Government (ONDR) will provide inputs on credit. Marketing will be through a marketing board who will extract loan payments in kind, make initial partial payment to farmers at harvest time and final payment after the grain has been sold in the private sector. The procedure is designed in part to protect cultivators from typically low prices at harvest time and allow them to benefit from higher prices later in the season.

Based on the available evidence, it does not seem that these projects will achieve their objectives without first overcoming great difficulties. There is no history of rice yields in the region at the levels which have been used for planning purposes and which are necessary if the project is to be financially attractive both to farmers and to government. Experience elsewhere in Africa has shown that operating floating pump sets on rivers is a difficult undertaking at best and that a considerable gestation period is required before such operations achieve some level of stability.

3.32 Recommendation

In the opinion of the irrigation team USAID should not become involved in this type of irrigation scheme in the south at this time except as they might provide Chadian operators of the scheme the opportunity to travel to other countries, such as Senagal, and to other parts of Chad (such as the middle valley of the Chari River) where such systems have been in operation for some time and where they could learn from the experiences to date. Given that other donor agencies (for example Africare and GARED) are experimenting with these types of systems elsewhere in the country, USAID might act to coordinate efforts so that all parties could learn from each others' successes and failures. This could be part of the assignment of the long term irrigation specialist. (See the recommendation on page 38.)

PART IV - DEVELOPING CHADIAN CAPACITY TO DESIGN AND INTEGRATE SMALL SCALE IRRIGATION SYSTEMS INTO THE AGRICULTURAL ECONOMY OF THE NATION

The irrigation assessment team attempted to evaluate the structure of and associations between the government agencies which have responsibilities for the design, construction, operation and monitoring of irrigation schemes within the country. The team met with representatives of the following agencies: (1) Genie Rural, (2) Office National pour le Developpment Rural (ONDR), (3) Societe de Developpment du Lac (SODELAC), (4) Office National Hydrolique Pastorale et Villageoise, (5) Bureau Inter-Ministeriel d'etudes et programmation (BIEP), (6) Centre d'Etude de Formation et de Documentation (SAFED), and (7) Office de la Mise en valeur du Sategui-Deressia (OMVS).

Through conversations with senior government officials, the team accessed the current quantity of trained manpower available to work in the various dimensions of irrigation development and inquired about the country capacity to train such manpower. The following recommendations address that issue and are considered to be critical complimentary activities for carrying out most of the other recommendations of this report.

4.1 Recommendations on Training

The irrigation team recommends that USAID work closely with the Chadian government to develop a country capacity to identify, design and monitor smallscale irrigation systems. The features of this program should include both short and long term training:

1. Training to the M.S. level of ten irrigation engineers who would specialize in on-site design of small-scale irrigation systems so that systems can be adjusted at the time of construction to the great diversity of water resource soil and topographical features that are typical of the Chadian countryside. The training/experience of the Chadian students must include irrigation, community and farming systems studies as well as the engineering dimensions. Five of these students should attend the Institute Agronomique et Veterinaire Hassan II in Rabat, Morocco. The language of instruction here is French and Arabic and the program is internationally recognized. The other five should be sent to various Western U.S. universities and the University of Jordan in Amman. (The language of instruction here is English and Arabic. There are individuals in Chad formally trained in these languages, for Arabic in religious schools and in Nigeria for English.)

2. Development of a country capacity to carry out on-site design of system rehabilitation. This type of rehabilitation approach requires that engineers systematically utilize farmer experience with the irrigation system to effect improvements. This capacity might be created (1) by incorporating the concept into the M.S. training program and (2) by development of a training program for the Chadian government including parastatal organizations which would encompass:

   a. Short courses in irrigation, preferably in African institutions and/or given in Chad by the Utah University International Irrigation Center.

b. Systematic in-service training for extension and technical personnel concerned with irrigation activities. This training might be offered through the long term irrigation specialist and by PVO organizations.

Concurrent with the recommended training program and supportive of the development of this capacity within the Chadian government, USAID should provide a water management specialist trained in small system irrigation engineering for at least a three year period. This person would not be a part of the AID staff, but would be placed within another agency (perhaps BIEP). This individual would:

1. Assist Chadian agencies including Genie Rural, ONDR, SODELAC and SAFED in developing small-scale irrigation system plans and design and in establishing a training capacity.

2. Provide ready support to private voluntary organizations who are currently experiencing considerable difficulty in the selection, design and operation of small-scale irrigation systems.

3. Provide necessary support to the irrigation community study teams (See recommendation No. 5, page xviii).

4. Provide support to the AID Agricultural Development Officer in developing a USAID irrigation program.

5. Provide support and follow up for any groundwater study team and monitor activities (See recommendation No. 6, page xviii).

6. Document the Chadian irrigation experience for possible application across the Sahelian region of Africa.

4.11 Assignment of Water Management Specialist

The agency to which the long term irrigation specialist might be assigned, Bureau Inter-Ministerial d'etudes et Programmation (BIEP) is relatively new and was slow getting underway. It has responsibility for coordinating some 17 bureaus, all of which have some responsibilities related to agriculture. It also appears to have gained support from donor groups (FAO for example) and expatriate staff are being made available.

A clearinghouse and coordinating agency for development activities seems appropriate given the current dispersion of roles across ministries and bureaus. In order to be effective, however, there must be cooperation and acceptance by those being coordinated. The strength of acceptance of the BIEP role by other agencies was difficult to determine. However there are signs that the agency has gained recognition within the establishment and that their function is viewed as important for accelerating the development process.

4.2 Agency Needs

It is apparent to all observers, including the Chadian government that the capacity to identify, design, develop, and manage irrigation systems is limited in all of the agencies that share that responsibility. The heavy demands of the emergency situation created by the drought coming on the heels of

a civil war and the invasion by Lybia, have strained the capacity of government. There has been a substantial loss of trained manpower and many workers are over-committed. Much agency effort in recent months has gone into attempting to secure donor assistance for rehabilitating established projects or for completing projects interrupted by political events.

As already noted, no single agency is responsible for irrigation development. Rather irrigation is more often managed as one of the set of activities associated with agricultural and rural development. For example, SODELAC, a parastatal, deals with rural development activities in the region of Lake Chad and ONDR, a quasi-government agency, works with agricultural development in both the North and the South. Both have irrigation works under their charge but SODELAC, for example, is also concerned with such things as, wheat production, livestock production, and inland fisheries. This organization has seventeen or so extension agents operating in the Lake Chad region.

Another agency, Genie Rural, in the Ministry of Agriculture is responsible, among other things, for providing irrigation design work and has engineers on the staff. The Office National Hydrolique Pastorale et Villageoise deals with groundwater and has been involved in hydrologic surveys.

It appears to the team that some donor agencies preferred to avoid working with Government given the alternative of working through PVOs. In part this is because o the expectation that the PVOs, with their trained and experienced man-power, are currently in a relatively stronger position to oversee some types of development activiti s. Project benefits are anticipated to be generated more quickly, an especially important consideration given the drought situation. In addition, there is some feeling that when working within the government framework, project funds may be used to secure lost operating capital such as buildings, office equipment, and transport capacity.

4.21 Working with the Chadian Government: The Role of PVOs

In the short run, the policy of relying heavily on the PVOs may be sound given the shortage of trained manpower in Government, and the need to make rapid headway in developing the agricultural economy. The payoff can be substantial, especially if the PVO staffs have more technical personnel and support and, if there is an active counterpart training component to PVO operated projects. Although there is some on-the-job training, the irrigation team was not aware of any active structured counterpart training dimension of the PVO projects which it visited and suggests that USAID should be especially sensitive to requiring a training component for the PVO projects which it supports.

Irrespective of short-run gains, for the long run, it would seem essential to contribute to the development of human capital by working directly with government agencies such as Genie Rural, SODELAC, O.N.D.R., BIEP and SAFED. Such involvement could include training programs (see 4.1), policy dialogues (4.5), and the assignment of long term specialists.

4.3 Strengthening the Contribution of the PVOs

The PVOs (private volunteer organizations) have played an important part in the response to the recent drought. They have been at the forefront of relief efforts, identifying needs and responding with solutions. They have

played a critical role in organizing the food for work program and in providing operational capacity in the field. They have also shown some capacity to conceptualize longer term solutions to the problem of agricultural development. Examples of this are the attempts of Africare and CARE to operate small scale irrigation perimeter projects and especially of GARED to run what are essentially small scale integrated agricultural development projects paying attention to not only production, but to input supplies, marketing, and credit issues as well.

The PVOs, under their present staffing seem most suited to responding to immediate crises and to problem identification. Their organizational skills and field experience serve them well in these areas. They seem less able, at least to date, in mobilizing the skills necessary to solve the technical problems, as they arise, associated with agricultural project interventions. In many instances the expertise required is specific and technical while their field personnel tend to be generalists and sometimes more process orientated. The latter skills are indeed necessary but generally are not sufficient for successful project implimentation. When technical expertise is used it tends to be short term and not in a good position to provide follow through assistance.

The agricultural development projects which have been undertaken to date by the PVOs, if viewed as pilot projects, may prove to be invaluable as models for development. However this will require a mechanism for capturing and evaluating their experiences and an improved capacity to solve project problems as they arise. It has been noted time and time again that the development process is one of continual adjustment to changing circumstances and new information as a project moves along. The successful projects are those that most quickly adjust to these changes.

One possible role for the PVOs, after the immediate relief needs have been met, is to serve as operators of pilot projects. They might for example be associated with the irrigation interventions that are recommended by the studies called for in this report (see especially pages 31 and 32). However, to be effective in this, it is strongly suggested that they or USAID would need to supply readily available, in-country technical expertise to help move the projects along. The long term water management specialist (see page 39) could be of some assistance in this. In addition, more short time specialists will also be required; and PVOs should be required to demonstrate their capacity to supply the technical expertise that will be needed.

4.4 Recommendation on Assembling Published Documents

Although some effort has been made by WMS II to develop a bibliography, a body of materials available only in Europe are not included. It is recommended that the literature on institutional and human resources in irrigation and water resources management for agricultural production purposes be accumulated, reviewed, synthesized and brought to bear on current and longer term irrigation, rehabilitation and development problems in Chad. This work needs to be a multilateral effort. WMS II could work with the Sahel programs to explore the potential for a Club du Sahel/CILSS initiative to include French, Dutch and other European institutions in the information gathering and analysis process. Outputs would include:

(1) answers to various technical questions, e.g. crop varieties that have been tested, aquifer characteristics, soils analysis, etc.

(2) identification of public institutions and individuals capable of providing support to field studies of water resources.

(3) orientation of irrigation strategies according to natural resource potential and constraints.

4.5 Developing a Policy Dialogue

There are numerous references in this text to conflicts, real and potential, over water and especially land rights. The government policy of taking land ownership and sometimes attempting to achieve production goals through a system of penalties, has not been effective. Other policies, including popular participation in decision making and providing economic incentives, should give better results.

USAID should establish a dialogue with the Government of Chad on the development of land-rights and water use policies which are more congruous with the socio-economic circumstances of a given agricultural system (farming system). Such issues as length and conditions of tenure and procedures for determining irrigation are always important areas of policy debate. It is important that workable policies be developed and in place in order to insure a smooth and reasonably rapid rate of irrigation project development. To this end AID should work to establish relations with the Ministry of Agriculture and, as soon as appropriate, provide the services of a consultant with special expertise in Chadian/African land tenure systems and irrigation water charges. A systematic procedure for establishing not only the costs of supplying irrigation water, but also the returns to irrigated agriculture, is a prerequisite for establishing water rates which provide for amortization of project costs and at the same time are not a disincentive to cultivator participation in a project. This consultant must be capable of suggesting alternative policies for providing economic incentives, through both government and the private sector for achieving both production and distribution (equity) goals. Popular participation would be an expected dimension of the policy formation process and of program implementation. This activity should be concomitant with the other recommendations for developing a capacity for the incorporation of irrigation into the existing farming systems.

APPENDIX A - THE SAHELIAN ZONE

Part 1 - Bol and the Northeastern Shore of Lake Chad

Part 2 - Lake Chad Community Vignettes: Karal

Part 3 - Lake Chad Community Vignettes: Doum Doum

Part 4 - The Middle Valley of the Chari River: Pumpsets on Smal Perimeters

Part 5 - The Bongor Area Casier B

Part 6 - The Ouaddai Region (Abeche)

APPENDIX A-Part 1

A1.0 BOL AND THE NORTHEASTERN SHORE OF LAKE CHAD

The area surrounding Bol in the Lake Prefecture has been the site of an unusual irrigation initiative in an essentially unique environmental setting in Africa. The landscape is dominated by Lake Chad and the formative influence of its historic and geologic phases of expansion and regression.

A1.1 Soils

The sandy soils of the dunes are unflooded and have rainfed water regimes. They are generally acidic and contain little organic matter. Where rainfall permits, bulrush millet is cultivated and livestock is grazed. The dune sands are deposited on older sands more richly endowed with organic matter. A layer of calcium carbonate accumulation is found below the sands. All of the above rest on lake bed clay deposits.

On the lower slopes of the dunes, intergrade soils appear which contain more clay and organic matter. Occasionally flooded and subject to groundwater flow from the dunes, these areas usually support a ring of date and doum palms and spiny shrubs.

The floor of the polder is covered by hydromorphic soils formed under alternating flooding and drying regimes. In general, the surface horizon has a fine texture, rich in organic matter and diatomaceous clays. The surface is similar to a loamy mulch with transitions to a zone of carbonate accumulation and a deeper horizon of fissured clay in prismatic sheets, until the groundwater table is reached and the clays swell. While the dominant clay mineral is montmorillonite, these soils are little evolved. Apart from the characteristic shrinking, swelling and microrelief of montmorillonitic soils, they do not present the management difficulties of consolidated, evolved vertisols.

These soils have excellent fertility characteristics and good physical properties. Their major management constraint is salinization or natronisation, the accumulation of sodium bicarbonate salts through evaporation of water after damming of the polder and through capillary rise and accumulations of salts from the shallow groundwater table. Traditional management included periodic flooding of polders to flush salts from the polder.

Several studies suggest that salinity is linked to salt transport from the lake via groundwater flows (MacDonald, 1985; ORSTOM, 1969). The dynamics of the situation are not well understood and probably vary with distance from the lake, dune recharge of groundwater, soil materials and their distribution, groundwater communication with deeper aquifers, and subsurface flows.

Following the lake into the flood recession zone brings one into a landscape where dunes become sand islands surrounded by wide and shallow clay and silt plains. The sand islands are low and have little land that is totally free from flooding or saturating groundwater. Doum palms dominate the sand island vegetation. Some millet production takes place in the sandy soil, but these areas are also important sources of forage as lake waters recede.

The recessional lake bottom soils are similar to the polder soils. However, they are more frequently flooded and show greater accumulations of non-decomposed and partially decomposed organic matter. Strong gleying at shallow depth is apparent with traces of iron oxide accumulation along plant roots. Upon drying, deep fissuring occurs resulting in a strong microrelief.

North of the polder zone, soils have been more greatly affected by the alternating patterns of clay and sand deposition. Dunes are higher and occupy a greater portion of the land area. Slopes to the interdune depressions are greater. The wadi soils show more heterogeneity at the surface and at lower horizons. Profiles revealed by wells show a sand layer at 1.5 to 2.0 meters that may represent a series of alternating sand and clay lenses residing on more ancient lakebed deposits. Natronization appears to be a greater problem in these wadis than in the polder area, probably due to longer periods of high evaporation demand, lower rainfall, and no possibility of flushing salts with lake water.

While the wadi soils are fertile, less of their area is available for cultivation than in the polders due to the salinity problem. Organic matter levels are lower than those found in the polder zone. Figure A-1 schematically summarizes the variation in soils across the three environments.

A1.2 Ethnographic Observations

Constant movements of peoples from the north and east have converged on Lake Chad and its surrounding wadis since at least the eigth century. At that time, as today, the growing desertification of the Saharan borders impelled a search for other, greener pastures such as the wadis and oases leading to Lake Chad and its huge expanse of water.

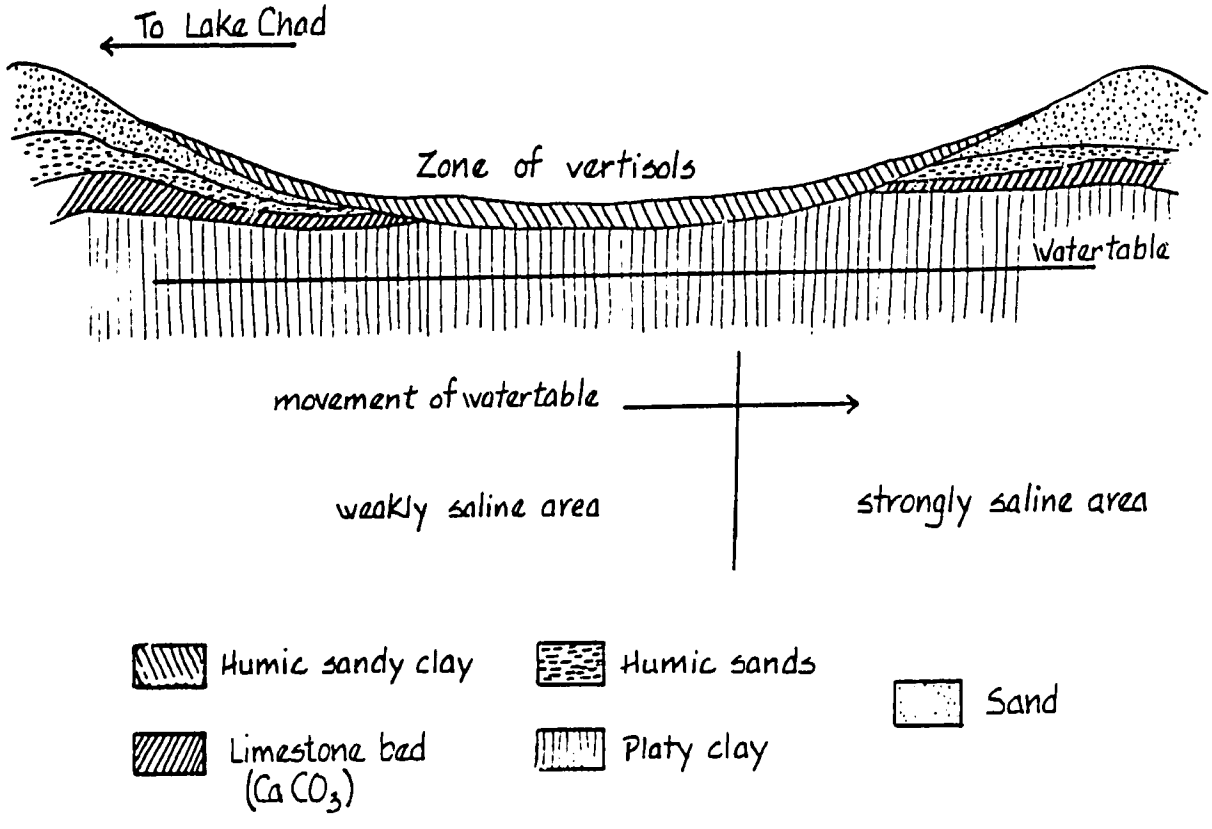
Lake Chad itself, with its litoral and hundreds of islands, offered the potential of pasture and arable land. Hence, over time the Lake Region has been a magnet attracting a mix of ethnic groups which, in turn, have shaped the history and socio-economic configuration that now prevails. Some have and do practice transhumances, others have been sedentary, farming and raising cattle along with some donkeys, sheep and goats. Still others have farmed and fished, selling their catch in the commercial market stimulated by nearby, recently established international borders.

It is not possible here to present more than a brief ethnographic sketch of all the societies that reside in the Lake Chad region. We extrapolate only those socio-cultural facets of Lake Chad's traditional ethnic group life that may be immediately relevant to the several tasks of the Irrigation Team.

The settled population of the northeastern shore, because of the drought, has had to alter their economic activities. Shallow water fishing around Bol is currently nonexistent. The retreat of lake waters has led some families to establish temporary quarters at 30 or more kilometers from Bol to grow the recessional maize crop.

In some areas to the northwest of Bol, farmers indicated that they have stopped recessional crop production in order to concentrate their energies on irrigated production in the wadis and dried polders. Unless exchange mechanisms with herders are operating, the small stock of settled farmers is probably

Figure A-1 East-West Section of a Polder and Wadi near Bol
(from a report by Cheverry)



exerting greater pressure on a range resource already in retrogression. Distress sales of stock have also occurred among sedentary farmers.

There is also greater human use of standing vegetation. SODELAC personnel indicated that many more doum palms were being used for shadoof timbers and for food (the doum fruit being harvested, dried, and ground for flour).

The effects of the drought on human settlement, seasonal migration, and herd and crop management might be considered as a function of distance of home or resident settlements from the Lake. Villages at the level of Bol still have access to polders with a shallow groundwater table. They have greater difficulty reaching recessional lake lands. The drought has reduced rainfed crop production on the dunes. There has probably been a net reduction in labor availability due to the time required to travel to recessional lands, despite reductions in labor requirements for rainfed crops and herding. More intense use of groundwater resources is made in the polders.

In villages north of the Bol there may be a concentration of production activities in the wadis as recession cultivation has been abandoned. No information was obtained on outmigration of people or coping strategies for small stock management. Even with intensified irrigated production in the wadis, it is difficult to see how these populations could support themselves without a successful rainfed millet crop or food aid.

Still further north irrigation activities in wadis have probably suffered a net loss of labor to the lake area and other regions. Outmigration has probably been significant.

A1.3 Cropping Systems

Figure A-2 presents rainfall, evapotranspiration, seasonal fluctuations in lake levels, and a cereals crop calendar for the northeastern shore at the level of Bol. Figure A-3 gives a schematic overview of the spatial organization of crop production activities. Long-term (47 year) average rainfall is 312 mm with annual reference crop evapotranspiration of 2,293 mm (Sir H.M. MacDonald and Partners, Ltd., 1985). The six to seven month dry season is characterized by an initial cool period which permits wheat production, if crop maturity occurs before the advent of the hot and dry harmattan winds in March and April.

In the setting of the sand island archipelago around Bol, the concept of farm size is a fluid one because of the varying availability of recessional lands. Only small fields of millet were observed, with none of the hedged fields that usually characterize Sahelian holdings. The polder areas that have remained dry over the past few years are sites of 0.2 to 0.4 hectare holdings, irrigated by shadoofs. Table 1 gives the estimates of previous studies on holding sizes, assumed cropping patterns and labor requirements.

Figure A-2 Rainfall, Evapotranspiration, Lake Levels, and Cropping Calendar at Bol

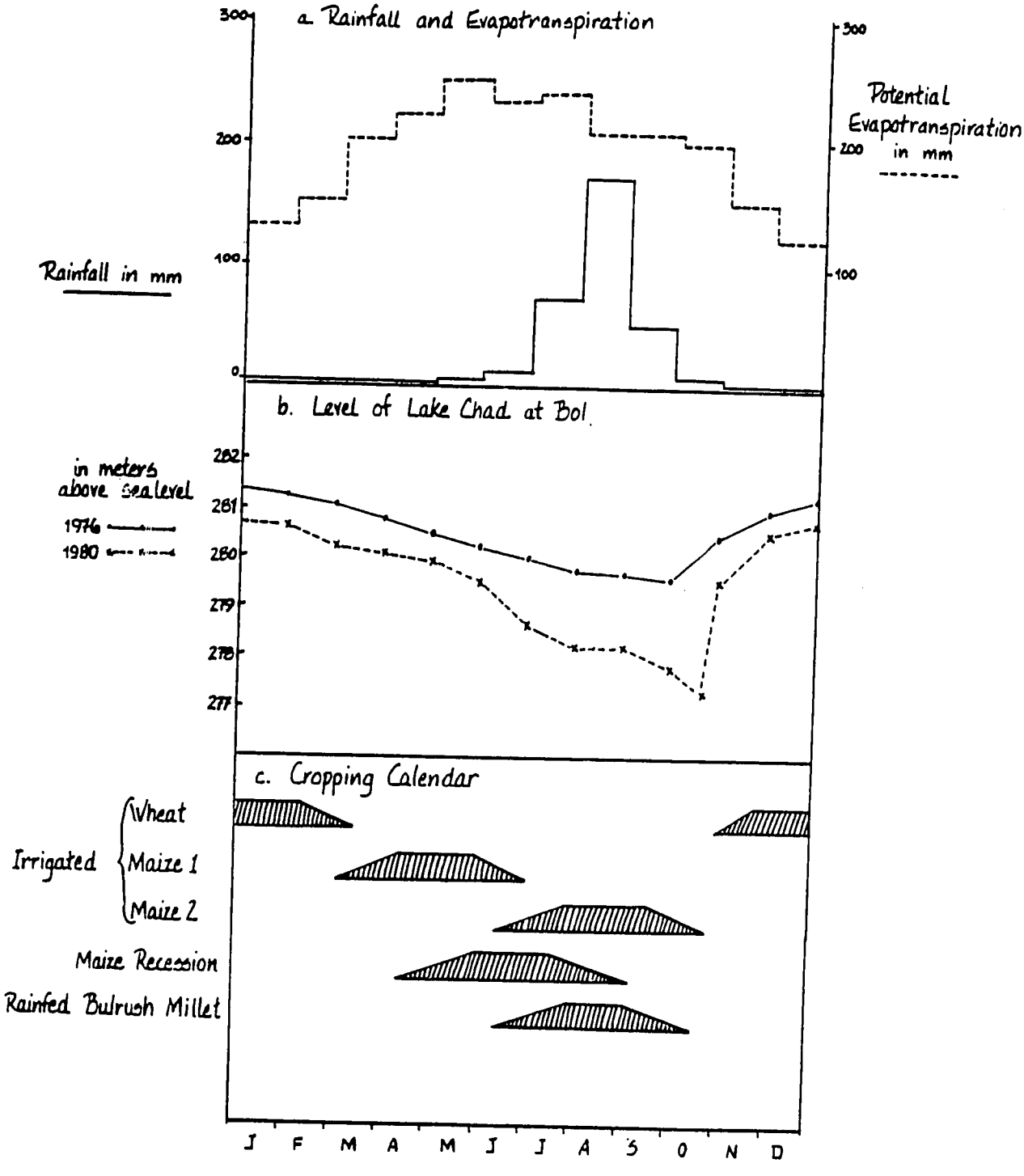
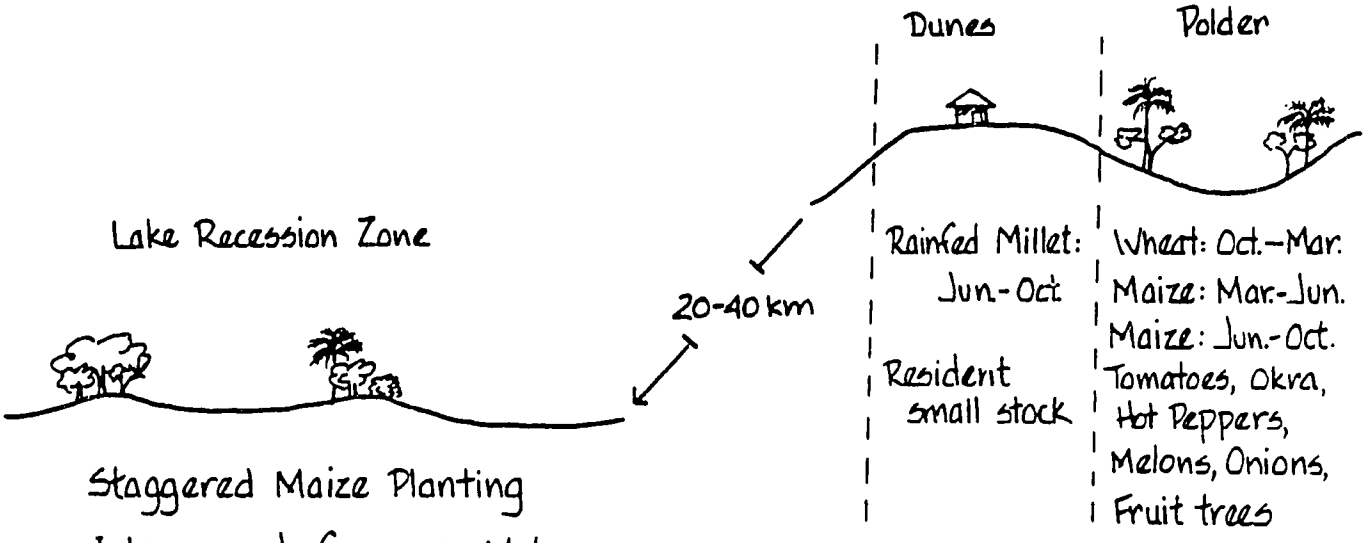


Figure A-3 Spatial Organization of Crop Production in the Bol Area. 1985.



Staggered Maize Planting
Intercropped Cowpeas, Melons.
Patches of Okra, Cassava

Zone of large stock - cattle and camels - as well as transhumant small stock

TABLE A-1. Estimates of Holding Size, Cropping Pattern and Labor Requirements

Holding Size	Cropping Pattern	Labor Requirement (work days)	Source
A. 3.75 ha	3 ha rainfed millet	225	Sir M. MacDonald, 1985
	0.75 ha naturally subirrigated or supplementally irrigated maize	132	
	Total	357	
B. 0.46 ha Polder	Wheat, Maize, Vegetables	N/A	UNSO, 1983
N/A Dune	Bulrush millet	N/A	
C. 1.0 ha Polder	Wheat, Maize	238	IBRD, 1974
1.3 ha Dune	Bulrush Millet	N/A	
.1 ha Polder Garden	Vegetables	N/A	

Land distribution is determined by a traditional land chief or Chef du Canton, and more recently in the polders, through joint consultation between SODELAC (Lake Region Development Authorities) and the land chief. Polder land developed behind 70 sand dunes since the beginning of this century contains about 12,500 hectares of cultivable land. UNSO (1983) estimated that about 6,500 hectares were being used for production by 14,100 families. Broken dams, salinization and reduced lake levels were given as the cause of the underexploitation of this resource despite the 24% growth in population estimated to have occurred since 1979.

Marketing is dominated by private traders and the farmers. In the sixties and seventies, SEMABLE and its successor SODELAC attempted to gain control of the wheat market without success. Official prices and marketing organizations could not compete with traders within Chad and from Nigeria and Niger. Market prices for cereals on a kilogram basis in Bol during early July (1985) were: maize 240 CFA ($0.56); millet 400 CFA ($0.94); rice 370 CFA ($0.75); and wheat ($0.56). These prices reflect the scarcity of cereals due to crop failure in 1984.

Crop yield estimates vary widely. Maize yields have been reported from 0.5 T/ha to 2.5 T/ha (MacDonald, 1985; UNSO, 1983). Wheat yields of 1 to 2 T/ha (UNSO, 1983) and millet yields of 600 kg/ha (MacDonald, 1985) have been cited. There has apparently been no study of production from farmers' fields that would enable better estimates to be made of traditional yields, production and incomes. However, some rough ranking of the variability of yields across the three production zones of Figure A-3 can be attempted.

The irrigated wheat crop in normal years should probably have the highest yield stability. Groundwater resources are at their highest levels during the growing season while evapotranspiration demand is lowest. Bird damage late in the growing cycle and high temperature and wind damage during the harmattan period would be the key complicating factors, both partially under the control of farmers through allocations of bird scaring labor and planting dates of the irrigated maize crops.

The first irrigated maize crop is planted during the March/April period of hot, dry winds. There is probably wind damage and moisture stress during stand establishment. Once established, however, day/night temperature regimes and regular irrigations should produce good growth. The chief problem as the milk and dough stages are reached would again be bird damage.

The second irrigated maize crop is also established under difficult conditions. Groundwater tables would be declining, and high devapotranspiration rates prevail. Despite frequent irrigations most stands showed moderate to severe moisture stress. Up to 15% of some stands had foliage and growth points damaged by a rodent similar to an agout. Bird damage before harvest is also a problem. Very few signs of rust and brown leaf spotting were seen. In normal years the second maize crop should benefit from the summar rainfall through some leaching of any accumulated salts and from groundwater flow from the dunes. Since granivorous birds would have millet, wild grass seed, and maize as feed, bird damage to this crop may be proportionately less than the earlier crop.

Plant populations of irrigated maize fields visited ranged from 15,000 to 25,000 plants/hectare. The reason for such low populations in irrigated fields may relate to estimations of risk in water supply, the current short supply of seeds, littlt local experience in maintaining salt balance in fields, etiolation of plants at higher densities, and so on. The reason behind this phenomenon should be found, because it runs contrary to expectations that plant density would be high to take advantage of high soil fertility, good insulation, and an easily extractable irrigation water resource.

Small areas within the two irrigated maize crops are intercropped with cowpeas, beans, melons, and occasionally sweet potatoes. During the cool dry season tomatoes are grown with succeeding warmer season crops of hot peppers, okra, roselle, eggplant and various cucumbers.

During the site visit in July, only a few rainfed millet fields were encountered and those were located close to towns and villages. About five to seven seeds were planted in each hill at about 1 m to 1 m spacings. Dry seeding is practiced in some areas, probably to take advantage of the nitrogen flush that occurs during the first rains. At the rainfall level of Bol, dry seeding probably leads to replanting if early rains are irregular.

Large areas of recessional maize production were visited about 35 kilometers south of Bol. Planting dates were staggered. Some fields had already been harvested while others were still at the milk stage. Both flint and semi-dent varieties were seen, all with yellow grains. Most plants produced two full ears per plant. There were large variations in plant and ear height. Stands seemed fairly disease free with only a low degree of sheath rust and minor amounts of leaf spot. Plant populations ranged from 14,000 to 25,000 plants/hectare. Weeds did not seem to be a problem.

These cropping systems in the three production zones of dunes, polders and lake recession lands are tightly linked through labor requirements. Management of production is a complex affair in time and space. Under drought conditions dependence shifts from rainfed to irrigated and recessional production with probable net losses in labor availability as longer distances to recession lands have to be covered. Under higher rainfall conditions and higher lake levels, more effort can be devoted to rainfed and polder production. Recession land availability patterns would shift, perhaps becoming less important in surface area, but also permitting more intensive management and protection from both livestock and birds.

A1.4 Water Resources

Surface, groundwater, and rainfall provide water to the northeast shore. Rainfall's contribution to soil moisture is central to the millet crop and natural forage production. It also is a contribution to the groundwater flows moving from the dunes into the polder soils. No estimates of flows from the dunes have been made. While probably small in volume relative to other flows, dune water supports the fringe of date and doum palms that rings polders and wadis and undoubtedly contributes to the leaching or dilution of salts on the intermediate slopes of the polders.

The dominant element of the hydrological cycle of the region is Lake Chad. Three major phenomena are linked to the lake. The first is surface flow which affects polders through inundations when polder dams are open, through recharge of the shallow groundwater table when polder dams are closed, and which determines the surface area available for recessional agriculture. The second major phenomenon is groundwater flow from the lake to the uppermost groundwater table in polder and wadi areas. The northern extent of these flows in Chad is not known. The third major phenomenon is lake and lake-influenced recharge of the partially perched groundwater table extending to about 70 m below the surface.

Variability in surface flows has been a major problem in the development of modern, gravity fed irrigation systems. Over the years and seasons Lake Chad varies in size from 2,500 km^2 to 23,000 km^2. The order of magnitude swings in surface water availability have confounded all estimations of economic returns from intensified and larger scale irrigation. The recent period of declining lake surface area has also affected smallholder management of traditional polders towards increased groundwater extraction.

While there have been reconnaissance studies of groundwater development costs and water quality, very little is known of sustainable recharge rates and interannual and seasonal variations in water quality (MacDonald, 1985; Dalien-ORSTOM, 1969). A few pumping tests have shown water yields from 70 meter wells to range from 50 liters/second to 250 liters/second. (MacDonald, 1985)

Lake water quality is good at about 135 parts per million of total salts (IBRD, 1974). Groundwater salinity varies seasonally and spatially. Reports give values of from 325 ppm to 5600 ppm of total salts. There are no monitoring programs for surface or groundwater quality and only lake area measurements are made to guage water volumes.

A1.5 Irrigation and Water Management Activities

Three irrigation activities have been undertaken in the Bol area:
- traditional shadoof irrigation from shallow open wells into small basins;
- small pump assisted irrigations from trenches cut to intercept groundwater flows from adjoining dunes and elsewhere; and,
- the Lake Chad Polders Project to develop gravity flow irrigation systems from surface water flows into these polders near Bol.

A1.6 Shadoof Irrigation

The shadoofs seen were drawing water from wells of about 2.5 meters deep reenforced with woven branches. Water is drawn in a shallow pan and dumped into a small basin protected by woven mats. The splash basin empties a short elevated dead head canal which provides the drop to a series of small basins connected by field ditches. Basins range in dimension from 1.0 m x 1.0 m to 1.7 m x 0.8 m. Rough measurements showed well storage to be about 2.5 m^3 which along with recharge during the pumping interval could be emptied in about one hour's time. Farmer reports of well recharge notes varied from two to four hours. Farmers were applying about 50 mm of water to each basin on a five day rotation for maize and okra. About forty 1.4 m^2 basins could be irrigated from a full well or two such sections in a day or a net irrigated surface area per day per well of 112 m^2. A five to six day rotation would permit 560 m^2 to be irrigated by each shadoof.

Well development costs were given by SODELAC personnel as 10,000 CFA per well. With a rough average of three shadoofs per holding this is a 30,000 CFA investment cost spread over a three year well lifespan. If a wheat-maize-maize cropping schedule were maintained over the full 0.2 hectare holding and about 119 labor days per crop were used the IBRD (1984) opportunity labor cost of 300 FCFA/day would imply a labor cost of 21,420 FCFA. Seed costs may be evaluated at peak market prices in Bol (1985) of: Wheat 80 kg/ha x 0.2 ha x 240 CFA/kg = 3,840; Maize[1] 15 kg/ha x 0.2 ha x 240 CFA/kg = 720; Maize[2] 15 kg/ha x 0.2 ha x 240 CFA/kg = 720; for a total of 5.280 FCFA per .2 ha holding.

Table A-2 gives an estimate of crop income.

TABLE A-2. Estimate of Crop Income

Cost Category	Cost/Year FCFA/0.2 ha	Crop	Estimated Yield	Production	Market Value
Shadoof + Well	10,000	Wheat	2 t/ha	400 kg	96,000
Seed Costs	5,280	Maize	1 t/ha	200 kg	48,000
Labor	21,420	Maize	1 t/ha	200 kg	48,000

A. Total Cost	36,700 FCFA	D. Maximum Gross Income	192,000 FCFA
B. Cereal Unit Value	240 FCFA	E. Maximum Net Income (D-A)	155,300 FCFA
C. Kgs. Cereal Needed (A/B)	153 kg	F. Subsistence Requirement/HH 4 people/HH x 150 kg/person/yr	600 kg
		G. Surplus and Seed	200 kg

Table A-2 should be taken as an order of magnitude estimate. The actual cropping pattern is probably not as intensive. Less than 0.2 hectare is cropped and labor, yields and prices will vary considerably across holdings, seasons, and years.

A1.7 Pump Assisted Irrigation from Trenches

Two sites were visited where three to four meter deep trenches had been dug at the intersection between dunes and polders to intercept groundwater flows. Small 1.5 to 2.25 HP gasoline motorpumps were used to irrigated cereals and vegetables. At one location a reservoir well lined with empty oil barrels was used to improve storage capacity for pumping. It was not possible to estimate recharge rates, water use or production and income.

APPENDIX A-Part 2

LAKE CHAD COMMUNITY VIGNETTES: KARAL

Karal is a political center, populated predominantly by Chadian Arabs, located on the southern border of Lake Chad, 120 kilometers north of N'Djamena. Prior to 1965, the village was located at the lake's edge -- so close that its residents would have to construct dikes to avoid flooding. Since then, the lake's surface began to withdraw and currently its shore is about 27 kilometers away from Karal.

The community contains two political headquarters. The compound of the sultanate established since pre-colonial times controls an area of approximately 100 square kilometers, containing villages of various sizes. Each village has its chef du terre, or boulama, responsible for smooth social and political life, adjudicating local disputes and assigning areas for farm use according to family size and based on a pattern of usufruct rights. The Sultan intervenes only in the event of disputes.

Karal also contains the regional office of the Lake Chad Basin Commission, a multinational organization, comprised of countries bordering Lake Chad, that has a number of regional development functions, with a current emphasis on development of livestock and livestock vaccination programs.

Six markets within the area absorb the small-scale products that move into them and are trans-shipped to Nigeria and Cameroon to obtain better prices. Toward these countries flow the packed, smoked fish caught in the lake's waters, and natron gathered from its beds. These countries offer larger markets at better prices than can be obtained in Chad.

Maize and other agricultural products move actively through the markets. Donkeys and camels are used for moving bulk materials to and from local communities at a distance of 30-60 kilometers. For more distant sales, trucks carry the sorghum, groundnuts, sweet potatoes and sugar cane to N'Djamena despite the poor condition of the connecting roads. Their availability is an asset for producers because since the drought and decline in the lake level they no longer having access to a waterway. Price discounting when the trucker acts as intermediate buyer and perishing of vegetables during the prolonged delays of the rainy season are liabilities.

A2.1 Impact of Lake Chad's Withdrawal

The lack of ready accessibility to the lake has seriously limited fishing activities, both those for home consumption as well as for processing and sale. For those emphasizing fishing and fish processing as an alternative, there has necessarily been greater emphasis on farming, livestock herding and increasing the search for wage labor. Basically, for most there has been a shift in the character of subsistence living. The health consequences of diminishing of protein and iodine from a diet with fish as a major component is yet to be determined.

Lake withdrawal and decline and unpredictability of rainfall has had deterious effects on herding and farming. For those who engage in the former, transhumance rather than reliance on local pastures alone is increasingly practiced. Herds now have to be moved to different locations as much as 100-200 kilometers and remain there for longer periods. Removal of part of the family labor force for a protracted time seriously affects the cycle of agricultural work.

Lack of local pasture and sources of feed, and lack of adequate animal disease control has resulted in decimation of Karal's local livestock population which is now largely reduced to goats. Most cattle are given to the care of the nomadic Fulani and their owners check on the status of these periodically with those to whom they have entrusted the animals.

A2.2 Emphasis on Agriculture

With the depletion of fish and animal resources, families necessarily look to the land as the main basis for support. The increase in farm activity, accentuated by an influx of displaced persons also hunting for arable areas, has created new land pressures.

Control of the land is seen as falling within the province of the Sultanate. Through its chefs du terre, or boulemas, recession land is allocated according to individual household need and the usual pattern of usufruct right obtains. But with lake withdrawal, distribution of the land resource has required greater care: smaller allocations are provided to facilitate a more equitable distribution. Land areas, then, vary in size from 1 to 3 hectares. Equity may be a consideration for the subsistence or near-subsistence level. Nevertheless, there are signs of stratification: those few with financial resources to hire labor may operate farms up to 40 hectares. In effect, the recession cultivators have cut themselves off from participating in the socio-economic life of the village by their choice of this cultivation technology. Occasionally these farmers may obtain small areas in the recession land and hire someone else to prepare the seedbed, do the planting and even the weeding.

The distribution of irrigable land is more structured. ONDR's representative in Karal allots holdings according to family size and economic capability. A household obtains about 35 ares, half of which is to be used for vegetable production and the remainder for maize. Since labor requirements will be intensive, only those who have the means to undertake successful operation obtain the land.

In late 1982 the ONDR agent in Karal organized 320 families into groups of about 25 families per group to develop several natural depressions around 10 to 12 kilometers from Karal. Each group cut a channel from the edge of the lake to its depressions. One channel visited by the team during the 1982-83 season was 4.5 kilometers long. The same channel was about 10 kilometers long the the 1983-84 season. At that point 520 families were organized for this effort in the Karal area. By the 1984-85 season, 825 families had organized. By that time, however, the lake edge had moved too far away to dig a channel by hand. Moreover, the level of the lake had dropped too much to flood the depressions by gravity. A low lift pump would have been needed.

CARE/CHAD provided food for work and hand tools for member families to work on the canal. Some machine tools were made available. The canal the team visited was about one meter deep and 1.5 meters wide. It had filled in with drifting sand to the point where the exact dimensions were difficult to estimate.

Each of the 25 families in a given depression was allotted 36 ares for vegetable cultivation. Each family cultivated its area on an individual basis. The entire group collectively cultivated 1 hectare of cereals and 1 hectare of vegetables to establish a revolving fund with which to meet group expenses such as purchase of tools to dig the canal and to provide meals for workers. The total area thus served is 20 hectares.

With the canal, water would flood the depression in September. As it receded in November, people would plant rapidly maturing maize and some vegetables. They kept planting with the receding waters until April or May when the waters were spent. They would plant a rainy season crop of maize and sorghum in June to harvest in September or October. Enough moisture remained in the soil from the recession of the lake for the dry season crops.

A2.3 Cropping Patterns

There is a three-cycle growing season in each of the three land use patterns. Most of the crops grown are similar in each cropping pattern.

As the lake waters withdraw, farmers plant early and late maturing varieties of maize in the moist, fertile soil. Both are usually planted at the same time in the first week of April, with the early variety grown for cash and family consumption. It exploits the available moisture content of the soil and may not require any rainfall. It is short statured and yields approximately between 400-600 kg/ha. The late maturing variety is harvested around the end of October. It often reaches the tasseling stage before any significant rainfall starts.

The late maturing variety attracts many pests, with birds causing the greatest damage. It requires harvesting soon after ripening. After harvest, this variety occupies nearly 80% of the area market and some of it is shipped to markets farther in the country's interior.

Tomatoes, sweet potatoes, okra, pepper, watermelon and some squash are grown, with the first three occupying the greatest portion of land. These are intended for the market and generate the greatest income. Tomatoes are shipped by trucks to N'Djamena, where the demand is greatest. Packed into boxes, they are carefully transported during the night to reach the market for early morning sale.

Sweet potatoes are less subject to damage and rotting and usually can wait 2-5 days prior to shipping. Some farmers try to sell them locally first then send the remainder on to N'Djamena.

Okra can be sold fresh for local as well as external market sale. When dried, it is sacked and shipped to Nigeria, and south to N'Djamena and beyond, even reaching Sarh and Moundou. Other shipments reach Abeche.

Although the crops are diverse, dry fields are 80% vegetable, two-thirds of which is okra. A biennial okra variety survives harsh dry conditions better than any other plant but manioc. Okra and manioc adapt better to sub-optimal conditions and provide the greatest return per unit area. Maize is grown but only after enough income is generated to hire some labor to help irrigate.

Berebere, dura sorghum, is grown at the end of the rainy season in more clayey soils.

A2.4 Dryland farming

Dryland farming is carried out by those who have stayed behind in Karal rather than follow the lake to areas 25 kilometers away. Even though plots are not as large as those in the recessional and ONDR irrigation areas, huge areas are not worked. Where possible, shallow wells are dug, 2 to 5 meters in depth, to provide a supplementary water supply. Shadoof and meter-square depressions are the key components of this irrigation mode.

At the present time people in the Karal area are interested in systems that improve their ability to use ground water. The most important limiting factor in both the natural depressions and the shallow wells is the quantity and quality of water people can draw from the ground.

APPENDIX A-Part 3

LAKE CHAD COMMUNITY VIGNETTES: DOUM-DOUM

Located on what is known as the Eastern Archipelago of Lake Chad is a concentration of locally developed polders and scattered villages, linked to the administrative center of Doum-doum. Fifteen kilometers to the northwest of the town is the village of Iriri, populated primarily by Kanembou, along with some Toubou, most of whom are recently arrived displaced persons. Simultaneously, the village has been the scene of farm families leaving the area because of drought. They had followed the shoreline of the receding lake waters and become discouraged, only to return to the vicinity. At the same time, Toubou suffering extreme drought and decimated herds elsewhere, were attracted by the respite of pursuing subsistence agriculture.

The polder at Iriri had been developed in 1956. Building dams with local materials across the necks between islands, the villagers were able to cut the flow of water and create a large polder. From 1966 to 1968 the local construction was rebuilt with World Food Program assistance but since 1980, the lake surface has been too low to permit direct use. Only 50 hectares are currently under cultivation.

The soils of the Iriri area now under cultivation are dark in color and clayey in nature. There is a plowing layer of 30-40 cm. in depth, rich in organic matter. Below it lies an unconsolidated layer with a small amount of iron oxide. It is on these soils that farm operations are carried out by individual households, using the traditional shadoof to obtain water.

Whether the shadoof has seen long use in the area or is a recent innovation is not clear. Polder cultivation had permitted planting directly in the moist soils. Two to three years of cultivation were possible before breaking open the dams to permit inundation and regeneration of farmland. Shadoof cultivation was begun in Iriri polder in 1973, following the severe drought of the preceding years. Now more than 200 shadoofs in the polder provide the water for the 50 hectares under cultivation. About 100 households are involved.

Each household has its own well or wells, each with its own shadoof. Water is drawn from a depth of two to three meters and then carried to various locations in the fields, then either poured directly on the plants or distributed to them by small ditches leading to 1-1 1/2 meter basins. All family members capable of work assist in the digging of the well and the installation of the shadoof. This phase of farming requires the most labor and every effort is made to complete it successfully. Male members prepare the land and develop the irrigation system; planting is done by both males and females and later, it is the women and children who will weed and guard the ripening plants from pilferers or animal pests.

After the shadoof and its irrigation system is operating, the head of the household moves on to other activities -- planting penicillary millet in the dunes at the onset of the rainy season, spending more time tending or marketing small animals, or engaging in small-scale commerce or labor in Nigeria. Other men follow the receding waters of the lake with the family's livestock. Regardless of the activities, they return to the village to participate in the harvest of the irrigated crops.

In principle, rights to cultivate the Iriri polder are held by villagers in the environs. The village chief determines the area within his jurisdiction which may be used by a family requesting land for cultivation. The assigned land remains with a family so long as the latter utilizes it. Thus the practice of usufruct rights prevails; plots cannot be bought or sold, but rights can be passed on from generation to generation. No payment as such for cultivation rights will have been made, but offering is made to the village head of a few kilograms of grain at harvest time. It was claimed by villagers that no outsiders had come in recent years to request cultivation right in the Iriri polder.

The convenience of ready access to the polder and clearly established historical rights of tenure are major factors deterring the core of families in the village from following the lake's recession.

A3.1 Cropping Patterns

Multiple cropping prevails as a general mode of farming, but there appears to be no distinct, systematic pattern of vegetable production. Most of the growing areas are given over to maize, with a smaller portion devoted to crops such as sweet potatoes, okra, cayenne pepper, cucumber, tomatoes and some watermelon. Some wheat and manioc are grown and like the other crops, chiefly for home consumption.

A3.2 Growing Calendar

Wheat is sown in the polder in November, when the water table rises close to the surface because of the high level of the lake, to develop during the cold months of the year. It is harvested by the end of February and immediately thereafter, the fields are cleared and a seedbed for maize is established.

By late March or early April, the maize is seeded, to be harvested by the end of July. During the same period, vegetables are grown on a smaller portion of the field.

About the middle of July, some of the family members move to the adjacent dunes where millet is planted. Most of this will be consumed by the household but any surplus may be sold.

During the second hald of July, after the rains have begun, corn seed soaked overnight is planted in moist holes in the polder. After planting, the corn will be irrigated every three days, depending on the rainfall regime. With an increase in rainfall, irrigation activity will lessen. The maize is harvested by the end of September and the field cleared again for wheat production. The cycle is then repeated.

The village of Fatou is located in a polder close to Iriri and it is there that the Toubou have come from the drought-stricken Moussoro area. Some relatives had come to Iriri during the drought beginning in 1968. Those who came at that time have adopted shadoof irrigation. More recent arrivals have followed the lake for recessional agriculture. Some have dug wells, constructed shadoof and cultivating maize and vegetables. Others are growing millet on dunes some distance from the village. They have a few goats and camels. The latter graze without a herder, but the goats are watched more closely to avoid crop damage.

The Iriri-Fatou setting reveals four differential patterns of coping with the environment. Those with least experience need time, let alone motivation, to embrace the shadoof technology. Discouragement with it on polder cultivation finds recessional agriculture an easier solution. Whether the herders will remain in the polder, continuing a sedentary economic mode, after the drought's end, is open to question. Certainly, some of their kinsmen had done this after the previous drought that ran into the 1970s.

APPENDIX A-Part 4

The Middle Valley of the Chari River: Pumpsets on Small Perimeters

The Chari River plays an important role in Chad's agricultural economy. It is a significant source of irrigation water throughout the year, not only during the long, dry season but also when the rains are insufficient in accrued volume to maintain crops.

A4.1 General Description

Over most of its length, the middle valley of the Chari River is characterized by a well-defined main river channel. Unlike the nearby Logone River, it has very few extensive floodplain areas. The river banks overlook the stream from a height of between 6 to 15 meters and usually take the form of an irregular sandy shoulder, with a steep drop to the river. Outwards from this shoulder, the ground slopes gently downwards until it reaches, especially to the north of Mogroum, mudflats. These are flooded during the winter by rainfall or overflows from the Chari which drain off eastwards to the Logone.

For the most part, the soils found along the banks of the Chari form a topographical series of: (1) leached tropical ferriferous soils, very sandy, permeable and of low fertility; (2) emergent brown soils of slightly higher fertility; and (3) waterlogged soils with some agricultural value, reserved for a rainy season rice crop because they are frequently or permanently under water. In other areas are found (1) "naga" soils which are highly saline on top, infertile and difficult to work; (2) clay soils that are rich but very hard to work without the use of heavy machinery and (3) recent alluvial deposits which are poorly structured and are occasionally irrigated by shadoof during the dry season.

A4.2 Population Groups

The regions crossed by the Chari are quite sparsely populated, but with greater concentration along the river itself, partly due to the existence of the N'Djamena-Sarh-Bangui "highway" with a junction at Guelengdeng leading to Bongor and the south-west of the country.

Formerly a relatively deserted region (Tsetse fly infestation was no doubt a contributory factor), the Chari valley, especially on the Left Bank, has in the last few decades become a resettlement area, mainly for the Sara and Massa peoples from the south of Chad. This influx was interrupted, and to some extent reversed between 1979 and 1982, but there are currently signs of its being renewed now that there is a greater feeling of security in the region.

The oldest settlers, Baguirmi and some nomadic Fulani peoples (whose village farms are prominent on the right bank) were gradually joined by various other groups, mainly the Sara and the Massa, but also many Moloui, Marba, Bornou and Haoussa families, themselves divided into sub-groups. Apart from the Fulani semi-nomadic tribe, and the Bornou and Haoussa peoples attracted by trading, all these groups practiced fixed rainfed crop farming as their main occupation, and keep livestock as a capital reserve.

Some of the villages are made up of different ethnic groups (in such cases the village headman is usually a Baguirmi), and others comprise only the members of a single ethnic group (this is typical of the resettlement colonies, such as the Massa village of Madoubou).

The customs, behavior, and social organization of the different communities may contrast sharply, depending not only on ethnic origin but also on the particular history of each village (date and conditions of arrival in the region). A primary factor that distinguishes them is religion. The Baguirmi, Bornou, Haoussa, Moloui and Foulbe are Moslems, with remnants of animist traditions (less pronounced among the Baguirmi). This shared religious linkage makes for easier relations between the groups. Their common use of Arabic, the lingua franca of all the Chari River groups, also helps. The remaining groups are animist, but with various degrees of Christian influence. The existence of a local mission house often contributes to solidarity and enterprise in the village community.

Group differences are reflected in crop preferences: red sorghum by the Massa, pearl millet by the Baguirmi, pearl millet plus rapia sorghum by the Bornou, and so on. The Massa and Baguirmi menfolk have taken up fishing, but this is not regarded as a specific occupation.

Participation by the women in farm work is another aspect of ethnic differentiation. The Bornou women do very little in the fields, and their Baguirmi sisters are content to tend small plots of groundnut and okra. The Massa, Sara and Marba women not only cultivate herbs and spices, but also actively assist the men in the open fields and sometimes may tend their own small cotton plot.

A4.3 Climate

There are three distinct seasons in the Chari river valley, a rainy season from May-June to September-October, a cool, dry season from October to February, and a hot dry season from March to May. The mean annual rainfall varies between 620 mm at N'Djamena and 960 mm at Bousso and 740 mm at Guelengdeng, with a rainy season from four to six months. August is the wettest month of the year throughout the Chari River zone. The annual variation in total rainfall is very great, as illustrated by the severe droughts in 1972-73 and 1983-84.

The highest temperatures are recorded in March-April (41°C) and the lowest in January (14°C).

Potential evapotranspiration measured by the Turc method varies between 3.8 mm/day in August, and 7.3 mm/day at Bousso and 7.6 mm/day at N'Djamena in February and March. The annual PET is 2,060 mm at N'Djamena and 1,860 mm at Bousso.

A4.4 Non-Irrigated Farming Systems

The region's staple crops are sorghum and millet, followed by groundnut and sesame. Cotton is only grown upstream of Mogroum, on the left bank. Berbere sorghum is grown in areas where flooding is very extensive, particularly downstream towards N'Djamena. Other crops are farmed on only a limited scale. Companion crops take up about 15 percent of the total farmed area.

In the areas where it is cultivated, cotton accounts for nearly 25 percent of the planted area, with 54 percent taken up by the millet-sorghum crop. The average area farmed per active person is about 1.4 hectares. Animal-drawn implements are relatively common in the cotton-growing areas, 1 team for every 5 farms, but are used only for plowing. Hand-carts are rarely seen.

Most farming activity is concentrated between sowing in June and harvesting from September to October, or December to February for cotton. The exceptions to this are berbere sorghum, sown in August, transplanted in October, and harvested late March, and the few irrigated crops watered by gourd or shadoof.

We lack data concerning other farmer activities, but livestock and fishing are known to be important. Also wood and charcoal are sold prominently along the Guelendeng-N'Djamena highway.

Between growing seasons, people occupy themselves with repairs of their dwellings. This can be very time-consuming, taking 45 to 60 days of work. Younger men often leave the villages during the dry season to work elsewhere for daily wages.

A4.5 Irrigation

A number of irrigation developments have been carried out since 1970. In all of these irrigation water is pumped from the river and delivered by gravity in mostly unlined canals to small unit areas (10 to 25 hectares) given over to a villge community.

There have been several different schemes:

(a) The irrigated gardens run by the CAMAN (French acronym for the N'Djamena Market Gardening and Fruitgrowing Cooperative), initiated with technical assistance from FAO, covered 300 ha in 1979 and produced 2,000 tons of vegetables. Production dropped to only 64 ha in 83-84, and yields per unit area declined dramatically.

(b) The Chari Irrigation Areas (acronym PIC). Since 1974, the ONDR (National Rural Development Agency) has been developing village irrigation areas on the Chari River, with the assistance of the Rural Works Administration in design and site installation. This scheme differs from the CAMAN operations in that it places less emphasis on truck farming for the N'Djamena market.

Initial funding from FAC after the 1972/73 drought allowed setting up the first pilot areas and the completion of an identification study which identified 100 to 130 potential sites, going as far south as Sarh. Subsequent financing was granted by the World Bank. When work was suspended in 1979, 14 areas had been established, covering a total of 350 hectares, along with a logistic support unit of Guelendeng. However, only 50 ha were effectively under cultivation. Following resumption of activity, 10 areas were put back into working order in 1984, and 67 hectares were planted.

ONDR now received assistance from CARE/CHAD, funded by USAID. Financing by the World Bank is due to be resumed in October 1985, when two additional support units to supplement the existing one will be set up at Mailao and Bousso.

In addition, two rice areas have been established on the banks of the Logone River, under separate supervision by the ONDR. The whole of the latter's activities directed to village irrigation schemes in the Sahelian region are shortly to be centralized, except for a refugee resettlement scheme covering three sites at Asso, owing to its unique character, which will be managed independently.

(c) The Horticultural and Rural Development Center at Bougoumene. Financed and administered by GARED, a private volunteer organization, the Center's principal achievement to date has been the establishment of irrigated garden allowments along a 20 km stretch of the banks of the Chari, focusing on Bougoumene, 80 km south of N'Djamena.

A special feature of this activity is the importance it places on giving prior training to a number of young farmers who will subsequently form the nuclei managing the producer associations GARED plans to create. The training period is extensive.

Since 1984, GARED has been receiving support from CARE/CHAD, financed by USAID, in connection with project implementation and rehabilitation. By October 1985, it is expected that ten projects, including six entirely new ones, will be under cultivation.

The Center is also conducting a scheme to promote the use of animal-drawn implements on rainfed farms.

A4.6 Project Configurations

As a general rule, the irrigation system is powered by:

(a) a pumpset comprising an air-cooled Diesel engine in direct transmission to a centrifugal pump. The installed capacity is about 10 CV for the garden crop projects and 20 CV for the PIC schemes (1 and 2 pistons respectively). On the whole, each scheme has standardized its equipment with a view to simplifying maintenance.

The pumpsets are set up on concrete slabs placed on the slopes of the river bank. Most of them are shifted over a season so as to maintain an acceptable suction height of not more than 5 or 6 meters and to remain above the flood line. In 1984, some 10-CV sets were installed on floating platforms.

The piping used on the PIC projects consists of 4-inch aluminum sectional tubes. In the garden projects, flexible piping is sometimes employed.

(b) The distribution network in unlined canals and brickwork flow-control boxes with metal gate-valves.

Field-level irrigation is usually done by the furrow systsem (furrows spacing of 10-15 m), compatible with the high soil permeability, or for rice, through shallow basins measuring about 100 m^2.

In general the canal networks follow the natural shape of the land and drainage systems have not been provided. In some of the garden projects, buried pipes have been installed.

Some project areas are bordered by windbreaks. Protection against animal intrusion, like thorn hedges and fences, is common but usually ineffective.

Water losses from the canals is another problem due to the very sandy texture of the riverbank soils, which also leads to rapid deterioration of irrigation structures. Various technical solutions have been tried, including (1) rigid plastic gutter-pipes (AFRICARE projects); (2) aluminum foil linings (PIC); and (3) lining with brought-in clay (CARE/CHAD).

In general there are real difficulties with heavy losses occurring in the canals, but also in many cases, with faulty design.

The area that can be irrigated by a given pumpset depends directly on the discharge rate, and thus on the lift height. It therefore varies from one site to another, with the height of the banks above the water level ranging from 6 to more than 12 meters. It also depends on the level of peak demand, which varies considerably from one season to the next and to a lesser extent on fluctuations in the water level in the river. Consequently, the area effectively cultivated in conjunction with a 20-CV pumpset varies according to the season and the site between 5 and 15 hectares. It should be possible to improve on this performance, but the norm of 30 hectares sometimes quoted would appear to be unrealistically high.

A4.7 Irrigated Farming Systems

Different kinds of crops are grown, depending not only on the season and the type of soil, but also on which project we consider: the CAMAN and CHAR schemes concentrate on garden produce, and the others on field crops. PIC schemes have the following pattern:

	Light soils	Heavy soils
Rainy season	sorghum, cotton, groundnuts	rice
Cool dry season	vegetables	corn
Hot dry season	okra, pimento	rice

In practice, the growing of three consecutive crops on the same parcel on land requires very strict observance of the cropping calendar, (which seldom occurs).

Wheat growing in the cool dry season on light soils was abandoned following some negative trials. Failure was due mainly to the inability to develop an effective water distribution system.

As a general rule, the organization of water fees does not appear to be effective and leads to water wastage. A new system has been introduced by CARE/CHAD at Mailao, where irrigation water is provided on demand and the water is paid for on the basis of volume supplied. By contrast, the PIC schemes charge a fixed rate per acre of 500 F for the rainy season, then 1,100 F for each of the two dry seasons. This system was applied for the first time (and not without difficulty) in 1984, and the charge includes a component to be put aside as provision for equipment renewal. Collection success has been uneven.

The amount and quality of the seed supplied to the farmers varies with the crop and project. They are often both inadequate. Fertilizer is also available through the schemes. On the PIC schemes, the norms applied per crop are 50 kg/ha urea and 150 kg/ha NPKSB. The latter is in fact the type generally recommended by the ONDR for rainfed cotton growing. It is not the best option for the specific needs of other crops under irrigation.

The yields recorded are lower than would be expected from irrigated crops:

Summary Estimate of Selected Crop Returns

	Production Costs (water dues plus fertilizer) FF/ha	Yield t/ha	Farmgate price FF/kg	Gross Profit FF/ha
Rainy season				
rice	77,500	4	150	600,000
sorghum	77,500	0.9	150	135,000
cotton	77,500	1.6		
Cool dry season				
tomatoes	137,500	25	80	2000,000
onions	137,500	15	500	7500,000
pimento	137,500	2	600	1200,000
gombo	137,500	4	350	1400,000

NB - The above figures are purely indicative, being subject to caution on account of highly variable markets and the unusual climatic conditions in 1984.

A4.8 Constraints Affecting Village Irrigation Schemes

The existence of a large and easily accessible water supply, together with the interest displayed by the farmers are factors which favor the rapid development of irrigated farming in the Chari Middle Valley region.

However, the poor results obtained so far suggests major constraints which must be dealt with. For example the soil characteristics are a major limiting factor. The lightness of the riverside soils and their high permeability leads to heavy water losses both in the canals and after field delivery, thus limiting the area which can be irrigated and increasing pumping costs. In addition their actual fertility is low and likely to deteriorate with irrigation, through leaching. In addition to this the earthwork canals are easily damaged, so that maintaining them places a heavy workload on the farmers and makes it especially difficult to organize group activities.

Projects on more clayey soils in the low-lying areas avoid these difficulties, at least to the same degree, but limit the wet-season crop option to rice, which gives poor returns unless an effective drainage system can be introduced.

APPENDIX A-Part 5

THE BONGOR AREA - CASIER B

Bongor is located in the Mayo-Kebbi Prefecture 320 km south of N'Djamena along the bank of the Logone River which forms the border with Cameroon.

The Logone River floods into the Bongor depression which eventually drains into the Ba-Illi River to rejoin the Chari. The river begins to rise in the May-June period reaching its peak in October. The groundwater table fluctuates between three and five meters apart from the periods when the flood plain is inundated.

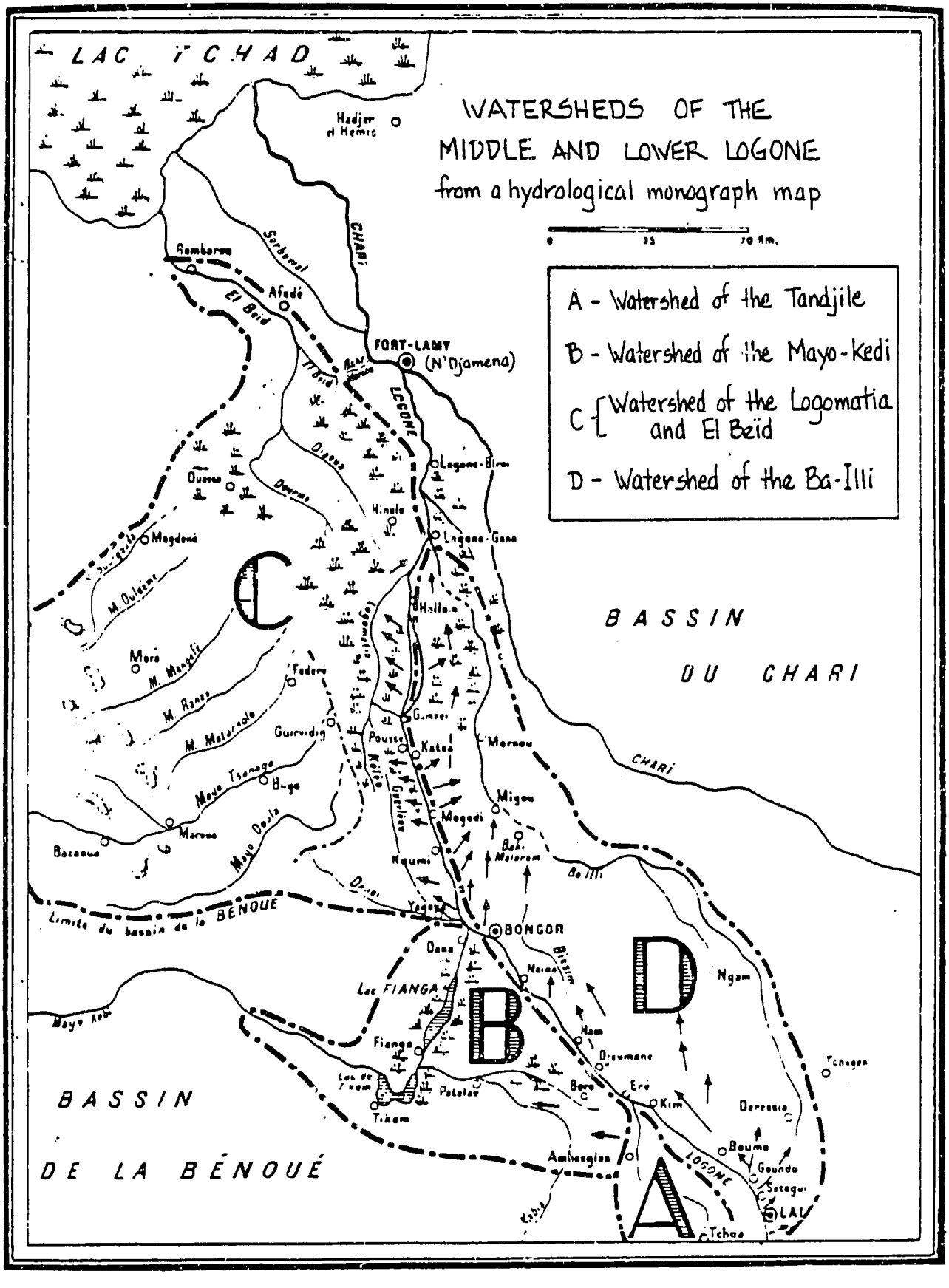
A single rainy season crop or a short-cycle cereal crop and a full season crop are possible. Due to the extensive nature of the floodplains only rice is grown in most of the hydromorphic flooded soils. Maize, sorghum, beans, melons, and other crops are grown on the sandy ridges where villages are located.

Irrigation Activities

Two casiers or irrigation perimeters have been built around Bongor. One built during the 1950's is about 40 kilometers north of Bongor. This is a partially controlled flooding scheme called Casier A. Four kilometers north of Bongor a Taiwanese Rice Missions constructed Casier B in the late 1960's. Due to time constraints only Casier B was visited although both casiers were overflown in a small plane and discussions were held with technicians of DPA (Division de Production Agricole). This organization is responsible for the management of Casiers A, B, and C.

It is composed of two main sections. One is a 495 hectare net irrigated area with full water control. The second section contains 300 hectares net area that is rainfed with some supplemental irrigation. The drainage system of Casier B's full control system feeds into a reservoir at the top end of the rainfed system. An overflow channel from the river permits supplemental irrigation of the second section when the river level floods a natural sill in the river bank. The rainfed system is laid out so that additional pumping capacity would permit year round irrigation on the second section.

The full control section of Casier B receives water from a pumping station on the Logone River. There are in fact two pumping stations with separate intakes and stilling basins. The first station was installed by the Taiwanese in the late 1960's. It consists of a concrete shared and gated intake of classical design on the river. A concrete pumping station leads to a sunken stilling basin with an overflow spillway into the main canal. It was abandoned by the PRC team that took the project over in 1973. The second pumping station has an unshared intake canal of about 40 meters length which leads to a steel frame and zinc sheet pumping shed. Five pumps in parallel feed into a stilling basin and the conrete lined dead head canal. The PRC station has a pumping head at least one meter higher than the Taiwanese station. The PRC rice mission also constructed the second section of the project, the 300 hectares which are known as the "new development" (nouvelle amenagement).


WATERSHEDS OF THE
MIDDLE AND LOWER LOGONE
from a hydrological monograph map
0 35 70 Km.
A - Watershed of the Tandjile
B - Watershed of the Mayo-Kedi
C - Watershed of the Logomatia and El Beïd
D - Watershed of the Ba-Illi
LAC TCHAD
Hadjer el Hamis
Sarh
CHARI
Bambara
Afadé
El Beïd
FORT-LAMY
(N'Djamena)
LOGONE
Logone-Birni
Logone-Gana
Ouaou
Magdemé
M. Oulgéme
Mora
M. Mangelé
M. Ranza
M. Matarcale
Guirvidig
Federe
Pouss
Katea
Gumsei
Mersou
Mogodi
Migou
Kaumi
Yagoua
Maya Tsanaga
Buga
Maroua
Maya Dasla
Bazaoua
Limite du bassin de la BENOUE
BONGOR
Dana
Lac FIANGA
Fianga
Lac de Tikem
Tikem
Patalao
Maya Kebi
BASSIN
DE LA BÉNOUÉ
BASSIN
DU CHARI
Ba Illi
Ngam
Tchagan
Dreumane
Bere
Ere
Kim
Derressia
Baume
Gaundo
Sarague
LAI
Tchao
Ambasgiao
A
B
C
D

The 700 m dead head sections of the main canal feeds into the main earthen canal. Water flows to six secondary canals 1,500 m in length and a system of tertiary canals and field ditches. The smallest water management unit is the block. The 33 blocks are each divided into quarter hectare squares (carres) distributed to farmers.

The 300 hectare section with partial water control receives water from two sources. The drains of the full control area empty into a storage reservoir between the two sections. A natural flood channel has been diked and equipped with valves to fill the basin during peak flows of the river and to deliver water to secondary canals. The new development is divided into 20 blocks of 15 hectares, each subdivided into quarter hectare plots.

A5.2 Soils

At the edge of the river bank and to the interior flood plain, the soils are primarily recent silt and clay deposits that have evolved under different degrees of waterlogging and flooding. These soils are often lightly covered or mixed with sandy alluviums. Vertisols form near the base of the landscape alternating with silty soils deposited by overflow channels and seasonal streams and with unflooded sandy ridges. Casier B is located on two major soils. One is a sandy clay alluvial soil with good organic matter content at the surface with a transition to a gleyed clay subhorizon. Under natural conditions the entire soil horizon is subject to seasonal waterlogging. The second is a sandy clay alluvial soil with gleying throughout and the same flooding regime. Higher points in the relief contain a mixture of the preceding soils and coarser sands which have higher infiltration rates. The soils should have a moderate fertility level, although the rainy season rice crop was showing signs of nitrogen deficiency.

A5.3 Development Costs

The total development costs of Casier B are not known. No records from the Taiwanese or the PRC period are available. A recent report lists operating costs at 50 to 60 million francs CFA or about $120,000 to $140,000 during the period of the Chinese rice mission (UNDP/FAO, 1983. "Projet de Relance du Casier B"). Production figures are not available but the following table summarizes approximate aid to operating costs and surface area cultivated.

A5.4 Organization and Water Distribution

Rotation among the six secondary canals is attempted. DPA personnel estimate that two to three days (48 hours) of pumping is required to irrigate along one secondary canal. Assuming an output of 80% of pump rated capacity of 792 m^3/hr, three pumps working 48 hours, and 50% system efficiency, each irrigation round would apply about 50 mm of water. One round would take 12 to 18 days. No rotations among blocks occurs. Since transplanting is spread over six weeks time within a single block some of the quarter hectare plots in any one block are always receiving more water or less water than they require. The poor organization of transplanting dates and water deliveries is related

TABLE 1. BONGOR CASIER B OPERATING COSTS AND SURFACE AREA

Production Year	External Financial Contributions FCFA	Funding Organization	Surface Area Cultivated (ha) Irrigated	Rainfed
1979-80 (2)	2,500,000	PRC	455	276
1980-81 (1)	7,000,000	Equipe Sahel	350	300
1981-82 (2)	20,600,000	Equipe Sahel	500	300
1982-83 (1)	1,000,000	Ministry of Agriculture	275	300
1983-84 (1)	-0-	0	0	300
1984-85 (2)			438	300

Notes: (0), (1), (2) = 0, 1, or 2 irrigated crops per year.

Sources: UNDP/FAO. 1983. "Projet de Relance de la Riziculture dans le Casier B de Bongor, DPA, Chef de Secteur Bongor.

Table 2 provides information on the 1984-85 dry season production costs.

TABLE 2. DRY SEASON IRRIGATED RICE PRODUCTION COSTS 1984-85

ITEM	QUANTITY	COST CFA	UNIT COST CFA
Diesel Fuel	56,000 liters		
Gasoline	2,400 liters		
Oil	2,900 liters		
Fertilizer			
NPNSB	1,673 bags (50 kg)	9,201,500	5,500/kg
Urea	500 bags (50 kg)	2,750,000	5,500/kg
Pesticides			
HCH	2,500	12,500,000	5,000/kg
Fenthion	120 liters	1,200,000	10,000/l
Seeds IR 46 (Semry)	40 T	20,000,000	400/kg

to a complex of factors including failures in the supply chain for fuel and seed, and lack of sufficient labor or traction power for land preparation. There is no master operation nor maintenance (O&M) plan for the project.

Farmers are organized by block. Each block is cultivated by farmers from the same residential quarter in Bongor. There are 12 residential quarters in the town. A single farmer may have from one to three quarter hectare plots in the full control section. According to DPA officials the full 800 hectares of Casier B is cultivated by 1500 families. No information on size of holdings was available.

A5.5 Project Operation and Returns

The sector chief of Casier B estimated yields of 4 T/ha over the 400 hectare area harvested in June, 1984. At the local market price of 150 CFA/kg this is a gross return per acre of 240 million CFA ($656,000 where $1 = 425 FCFA). Valuations at the official price of 60 FCFA would give a gross return of 96 million CFA. It should be noted that the operating costs above exclude CARE/Chad supported rehabilitation of pumps and repair of canals and the salaries and labor costs paid by the Government of Chad.

Farmer payments for water, inputs, and other services were first introduced in 1980-81. Previously, the Chinese rice teams treated the project as a demonstration and training site. Farmers had to produce a minimum yield of 560 kg/carre (2,240 kg/ha) to remain on the scheme, but they made no payments. Table 3 presents the repayment history since the 1979-80 season.

Table 3. FARMER PAYMENT OF OPERATING COSTS

Year	Surface Area Cultivated Irrigated	Surface Area Cultivated Rainfed	Farmer Repayment Rate FCFA/ha	Total Estimated Repayment Obligations	Amount Collected FCFA (4)(5)
1979-80	455	276	0	0	0
1980-81	350	300	6,000 (1)	2,100,000	2,076,300
1981-82	500	300	0	0	0
1982-83	275	300	22,400 (2)	5,152,000	5,151,825
1983-84 (3)	0	300	0	0	0
1984-85	438	N/A	120,000 (4)	48,000,000 (4)	28,800,000 (4)(5)

(1) 1,500 FCFA/0.25 ha-carre.
(2) 5,600 FCFA/0.25 ha-carre.
(3) No production on the irrigated perimeter.
(4) Repayments made in kind at the rate of 500 kg/0.25 ha or 2 tons/ha valued at official price of 60 FCFA/kg. If 150 FCFA/kg market price were applied the three columns would change to 300,000 FCFA, 120 million FCFA, and 72 million FCFA, respectively.
(5) Repayment period for 1984-85 not yet finished.

Source: FAO 1983. "Relance de la Riziculture dans le Casier B de Bongor."

The FAO report written to permit financing of the rehabilitation of Casier B reports that the poor management of Casier B in 1982-83 led farmers to avoid prepayment of operating expenses in 1983-84. No irrigated production took place, but 650 tons of rice were produced on the rainfed sections. For the rainfed section DPA has adopted a formula of 125% repayment in kind of the quantity of seed received, usually 20 kg/carre. The total seed reimbursement per carre would be 24 kg/carre or 1,440 CFA/carre. No decision had been made about repayment of other inputs or operating costs for the rainfed crop or the rainy season irrigated rice crop.

A5.6 The Current (1985) Crop

Seedling nurseries were started in December for the 1984-85 dry season crop. Transplanting was done up to the end of January and later. Major constraints were inadequate power to plow the land and late arrival of seeds. Much land was probably prepared by hand. The variety grown was IR 46 from the Semry scheme in Cameroon. Harvest started in early June and was essentially complete by the first week in July, although some plots were still being harvested on July 17. Average yields were reported at 4.0 to 4.5 T/ha, with the range extending from 640 kg/ha to 8 T/ha.

Of the irrigated sections, 27 parcels were taken away from farmers due to low yields ascribed to poor management. When land is repossessed (no lease hold agreements exist), DPA sends notification to the prefect of Bongor who in turn notifies the Chef de Quartier concerned. The Chef de Quartier thus decides with DPA to whom the parcel will be redistributed. This system is not always followed as both government officials and merchants have plots (most have multiple plots).

Land preparation for the rainy season crop was proceeding in a very patchy manner in both the full control and partial control sections. Nine walking tractors were in operating condition permitting three plots a day to be tilled. Seventy-five days would be required to plow only the full control section. An additional 45 days would be needed to complete the partial contr sections. Faced with this problem DPA has asked farmers to prepare their lan by hand plowing. All farmers in the full control system will hand hoe their land even though most of the area is covered by a dense volunteer crop from last seed or a ratoon crop that has been growing from three to five weeks. Seedling beds were being prepared at the time of the team's visit. The late planting will push the crop into the cool season slowing maturity and pushing the main harvest into late November or early December.

Discussion with one farmer yielded the following information on labor us per hectare:

Labor Requirements for Irrigation Rice - 1985

Hand hoeing	32 work days
Seedling bed	1 work day
Transplanting	16 work days
Weeding (2 times)	48 work days
Irrigations	forgot, opened drains 4 times
Bird Scaring	60 work days
Harvesting	16 work days
Threshing	24 work days
TOTAL	197 work days and irrigation time

Estimation from a single informant.

During the 1984-85 dry season an average of 25 kg. of 19-12-12-S-B and 25 kg. of urea were applied per quarter hectare, half the dose recommended by the Chinese. Labor requirements would be minimal if fertilizer were applied at land preparation and weeding.

APPENDIX A-Part 6

The Ouaddai Region (Abeche)

The Ouaddai region of Eastern Chad has experienced two consecutive dry years (1983 and 1984) a combination that resulted in almost a total failure of the 1984 crop. Crop failure and the influx to the Abeche area of distressed populations from the region, even more severely affected by the two-year drought, has highlighted the potential importance of developing the alluvial terraces in the wadi lands, where there is occasional flooding and some groundwater resources.

A6.1 Physical Features of the Region

The region lies mainly on the crystalline Ouaddai Piedmont, a large and gently-sloping plain (gradient of one percent) with occasional hillocks and granite or sandstone outcrops.

The outstanding feature, especially in an area around Abeche, is a very close network of watercourses carved out by torrential torrents following the convective rainstorms which account for virtually all of the regions's rainfall.

Many of the watercourses have a narrow but clearly indented, U-shaped bed with a bottom lining of washed sand in their higher reaches.

In the flat zones, wadis converge to form alluvial terraces made up of recent flood-borne soils, which are poorly developed, of varying textures and are moderately fertile. They are subject to flooding from thunderstorms. Down the middle of these terraces are drainage courses between one and two meters deep.

The lowest-lying parts of the landform are very extensive, poorly drained hollows, which lie to one or both sides of a wadi. There are two different types of these hydromorphous zones dependent on the nature of the soils.

1. In some cases, "black clay depression" soils which are very compact lower down and sometimes have an accentuated micro-relief. They are difficult to till and are usually left uncultivated;
2. Clay depression soils which overlie ancient clays. These are more elaborately structured and more fertile. They are used for recession sorghum ("berbere").

The emergent zones are represented mainly by:

1. The piedmont or clay soils, poorly drained with a shallow high moisture retaining horizon. They are used for seasonal grazing by the nomadic herds which cross the region.
2. Dune ranges formed by wind-borne or alluvial sand. These tropical ferruginous soils are used to grow rainfed crops.

A6.2 Climate

The climate of the region is classified as saharo-sahelian in the northern part (Abeche and Adre areas) and sudano-sahelian in the South (Amdam, Gozbeida). The inter-annual rainfall mean varies between 300 and 700 mm. A measure of between season rainfall variability at Abeche is shown in Table A6-1 which gives seasonal rainfall probabilities over a 30 year period (1936-65).

TABLE A6-1. ANNUAL RAINFALL PROBABILITY AT ABECHE

	9/10	4/5	1/2	1/5	1/10
mm/year	360	390	450	590	700

The rainy season in the North lasts 3 months (July to September) and, in the South, from 5 to 6 months (May to October). Maximum monthly precipitation is in August in both regions.

TABLE A6-2. MONTHLY RAINFALL AT ABECHE AND AMDAM

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Abeche mm	-	-	-	1	21	32	130	231	61	12	-	-	495
N° days (1936-65)	-	-	-	0.5	3	5	11	16	7	1	-	-	44
Adam mm	-	-	2	3	24	54	199	273	125	21	-	-	701
N° days	-	-	0.1	0.1	5	6	12	14	8	2	-	-	44

Rain occurs from violent local thunderstorms. The ten-year maximum storm at Abeche is estimated as 95mm (50mm for the 1-in-2-year cycle). The run-off from those storms causes a number of stream overflows in a typical year (sometimes only one, and more rarely none at all, as in 83-84). The annual average number of overflow days is around fifteen, with the wadis themselves being watered fewer than 30 days each year.

Evapotranspiration, as measured by the Piche meter, averages 10mm per day. Monthly averages are given in Table A6-3.

TABLE A6-3. DAILY AVERAGE EVAPOTRANSPIRATION AT ABECHE

	J	F	M	A	M	J	J	A	S	O	N	D
mm/day	12	14	14	14	12	10	6	3	5	10	12	11

Monthly average, maximum and minimum temperatures temperatures recorded at Abeche are shown in Table A6-4.

TABLE A6-4. DAILY AVERAGE EVAPOTRANSPIRATION AT ABECHE

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Max	36	37	40	42	41	39	35	32	35	38	37	35	37
Mean	25	27	31	33	33	32	28	26	28	29	28	26	29
Min	16	18	22	24	25	24	22	21	20	20	19	16	21

Based on 1935-1965 data.

In summary, there are three distinct seasons in the Ouaddai region: (1) a cool dry season from October/November to February, (2) a hot dry season from March to May/June, and (3) a rainy season from June/July to September/October. The cropping calendar generally follows this same seasonal pattern, except as conditions are amended by the wadi's water regime. Finger millet, and maize are grown on the sand-dunes in June through September close to the villages. On the verisols, sorghum is planted in September and harvested in November/December. On the alluvial terraces sorghum, gombo, and cucumber are grown from June through September, tomatoes from July to November (planted out to accompany sorghum in August, when the latter crop is earring), garlic from September to February and onions from October to March.

The crops grown late in the rainy season and early in the cool dry season are planted on areas where flooding has been sufficient to permit the soil to store an adequate reserve of available moisture. These areas vary according to the year's rainfall.

Those crops planted on the wadi edges late in the cool dry season (garlic) and early in the hot dry season (onions) require irrigation. Irrigation water is from shallow wells.

A6.3 Irrigation and Water Management Measures

Wells have been bored and diversions constructed to control water flow to supply water for human and livestock consumption, but there is no long tradition of irrigation works.

The water development works which have been undertaken by the government have been mainly directed at establishing permanent watering points for roving livestock herds. The most typical of these is the "hafir", consisting of a tank sunk into a wadi together with a dyke directing small streams into the tank while allowing part of the heavier flows to run outside it. These dykes are made of packed earth, sometimes buttressed with blocks of granite (rip rap).

In addition to building up a water reserve for the use of livestock, these structures can also help the alluvial water table to develop thus, improving the well yields and/or enabling planting, depending on particular site characteristics.

In the past decade or so there has been interest as to whether or not these structures could be used to provide irrigation, either by causing floodwaters to spread over contiguous areas or by providing a source of water.

In the Abeche region, two of these hafirs were built by the Department of Rural Engineering in 1974 (at Dougouri and Batouma) and, although some problems have been encountered, they are still in service.

Another water-control structure (at Facha) built in the same year, comprising an earthwork dam in U formation with a central waste-weir, was destroyed during its first rainy season when a breach occurred close to the weir.

All of these works were constructed under a Ouaddi Rural Development Project financed by the United Nations development aid program. In 1984, after the war, a similar project was set up by AFRICARE called the Abeche Rural Development Project and financed by USAID with participation of the PAM Food for Work program.

This operation, in addition to seed distribution and reforestation activities, included rehabilitation and improvement of the three existing hafirs together with the construction of two new ones at Tire and Kicedji. The project also provided for the building of eight cemented rock channel dikes.

These structures are installed on an alluvial terrace in a position where they dam the central drainage channel. They have a threefold purpose: (1) to increase both the area inundated by the wadi floods and the duration of flooding, (2) to raise the level of the alluvial water table, and (3) to create a small water reserve upstream of the dam. During the rainy season of their first year (1984), seven of these structures were destroyed by floods.

The remaining dyke (at Ouere) worked satisfactorily in 1984 and, in addition to increasing the area available for sorghum/tomato cropping, made it possible to establish on the edge of the drainage channel, a crop of irrigated hot dry season onions.

However, this structure failed during the first rainstorms in 1985. Nevertheless, the Ouere dam provides a model for structures of this type, once due allowance has been made for the causes of its failure.

A6.4 Irrigation from Wells

The regional administration is conducting a wadi development operation in connection with a program for the assistance and rehabilitation of displaced persons. The local authorities (District and Village headmen) take in refugees and allocate land to them. A large number of these refugees have been resettled in the Sabaar Wadi area, with the aim of growing dry-season crops irrigated from wells. The settler families have been granted assistance in the form of food and small tools, together with seed and technical support from the ONDR agency.

The wells are about six metres deep in a water table whose static level is about four metres. In these conditions, the shadoof is impractical and farmers use the calibash which is a gourd tied onto a rope. Use of this primitive irrigation method severely restricts the area which any one family is able to irrigate. In fact, this form of irrigation is mainly used by merchant classes, who employ hired workers and can make a profit by selling their produce outside the region.

There are reports of one of these merchants using a small gasoline-powered pumpset (probably two CV rating) which he had installed over a brick-lined permanent well. The area irrigated covers 0.25 ha and it was said that the yield of the well was sufficient to enable uninterrupted pumpage without notably affecting the level of the water table.

A6.5 Natural Resources (Water and Land)

The wadis offer two possibilities for increasing crop production: (1) the water retained in the soil from the periodic flooding can be used to grow crops on the alluvial terraces; (2) the shallow water table, under the alluvial terraces, replenished by the periodic wadi floods, can be used to irrigate dry-season crops. This is most attractive where there are sandy soils which are highly permeable and tend towards more efficient ground water storage. This results in high well yields owing to their excellent transfer capability.

A reconnaissance survey of the natural resources of the region published in an ONDR mission report dated April 1985 covered 2,200 hectares distributed over 16 different sites. However this survey does not provide sufficient data on ground water and soil characteristics for project planning at any of the sites.

A6.6 Potentials for Development

The clay soils in the hollows are attractive because of their relatively high fertility and good moisture retaining characteristics. However, their poor workability and drainage imply that their use in intensive farming would require a complex package of agricultural practices including the provision of drainage systems and high levels of power for field operation. Currently these soils are well used for sorghum ("berbere") production. Local farming practices may perhaps be improved upon through flood-control and drainage works.

The alluvial water tables of the wadis are not an abundant resource. The closeness to bedrock means that aquifers exist only as small isolated pockets. Their capacity to provide water for human and livestock consumption is limited. In fact some of the wells run dry at the end of the dry season, and even earlier following a poor rainy season. Many of the best wells draw on aquifers that are replenished by seepage from the wadi water tables. There is some possibility that springs close to the base of the mountain could be sufficiently active to sustain intensive cropping.

Overall knowledge of the wadi water regimes is inadequate. However, hydrometric surveys carried out by ORSTOM in a few small catchment basins (Kadjemeur - 245 km^2 and Safoya - 345 km^2 are examples) provide some information.

For the heaviest floods, the runoff coefficient measured approximately 25 percent. The specific flow-rate eatimated for the ten-year flood high is between 0.15 and 0.30 $m^3/s/km^2$.

The quantities of solid matter carried were found to vary between 0.3 and 2.0 m^3/km^2, and the frontal wave velocity between 1.3 and 3 km.p.h. These data illustrate how violent the floods can be.

In the larger catchment basins, the specific flow-rate is much lower owing to the damping effect of the flood terraces (0.15 litre/s/km^2 for the Am Nabak basin covering 5,600 km^2).

A6.7 Conclusions

Practical experience in both irrigation and flood control is limited. In two small areas, irrigation using the hafir dike systems is in service and there was one season of operation of the dam at Ouere. Seven rock-cement channel dykes and one earthwork dam have all been washed out and there has been one season of irrigated farming using well resources in wadi areas.

The resettlement of displaced persons in some of the wadis was an emergency operation and not an organized pilot scheme. Nevertheless, it has provided some experience which should be captured to provide future directions.

The failure of the irrigation dams shows the difficulty of this type of project. A number of lessons have been learned to date which can be useful for guiding further efforts. A major constraint is quite clearly the violence of the floods. The repeated failures show that sites must be selected more carefully. Structures need to be more robust which will increase costs. The maintenance requirement following actual construction is also a major item to be considered.

The hafirs are watering points for livestock. The land area that can be irrigated using their water surplus is limited. Intensive exploitation of the water tables, whose replenishment is enhanced by the presence of a hafir, is a limited opportunity since significant lowering of their levels would have adverse effects on the hafir itself. In addition, the hafirs constitute a special health risk in the Ouaddai region, where bilharsiosis is endemic.

Utilization of the wadi shallow aquafer for irrigation presents a number of difficulties. First the present depth of the water tables is too great for elementary irrigation devices such as the shadoof. The traditional method of hauling up water with gourds attached to ropes and carrying it to the fields, is a time-consuming operation which severely limits the area which any one farmer can practically irrigate. Second, well-holes bored using traditional practices have to be redone each year after damage from the heavy floods. This, and the maintenance operations which have to be carried out throughout the irrigation season, places a heavy work load on the farmers. Third, the capacity of the alluvial water tables is not really known, and may be a limiting factor on the area which can be irrigated.

High transportation costs both to and within the region increase the cost of bringing in materials and inputs, and of delivering produce to outside markets. During the rainy season, many areas are virtually inaccessible.

During the dry season, the very poor roads place considerable strain on vehicles. There is considerable scope for rain-fed and flood-watered crops in years of normal rainfall. This together with stock-breeding possiblities, unless irrigated agriculture gives higher returns in these years, may result in irrigation structures suffering from lack of maintenance and repair over long periods. This tendency is further accentuated by the fact that typically farmers' activity is scattered over land for rain-fed crops, the wadi flood terraces, and the grazing areas used for livestock herds. These activities are frequently remote from each other and from the home village.

The region is traditionally used by large numbers of nomadic stockmen as a grazing area. This inevitably raises the familiar land use conflicts between the farmers and graziers. Even though a common religion and basic language help to keep the conflict within bounds, this is a factor which any development project must account for.

Ouaddai Province has suffered much from the internal strife in Chad. The state of the official machinery is particularly poor, and this may handicap regional-scale development schemes for some years to come. The records of physical (hydrology, climatology, soild research) and economic (demography, agricultural production) parameters have either been dispersed or destroyed altogether.

APPENDIX B - THE SUDANIAN ZONE

Part 1- Project Sategui-Deressia

Part 2 - Moundou: The "Rice Operation" in Southern Chad

APPENDIX B-Part 2

Project Sategui-Deressia

B1.0 Sategui-Deressia Irrigation Project is in the Prefecture of Tandjile and comes under the Office de Mise en Valeur de Sategui-Deressia (OMVSD). It is located on the Sategui-Deressia Plain on the east bank of the Logone River. The plain floods during so called normal years permitting the cultivation of a single wet season rice crop.

The wet season in the region is from May to early October. The other months of the year are dry. Annual rainfall averages 1,080 mm but as elsewhere in the country, the distribution is erratic. Average rainfall in the region from 1950 through 1975 and is given in Table B-1. For the period 1950-75 average total rainfall during the May through October growing season was 1,034 mil and pan evaporation was 770 mil.

TABLE B-1. Rainfall and Evaporation at Sategui-Deressia

	Average Rainfall (mm)	Average Monthly Evaporation (mm)
January	0	185
February	0	205
March	9.5	251
April	34.2	231
May	96.0	186
June	139.0	131
July	228.3	96
August	297.0	94
September	216.0	96
October	57.6	167
November	1.8	196
December	0	181
TOTAL	1,079	2,019

Based on 25 year averages (1950-1975).

B1.1 Project Description

The project is located at Lai in the Logone Valley. Some 55,000 hectares of paddy (rainfed, both with and without flood inundation) is grown in this valley. This project, six years under construction, was designed (74-79) to improve flood water control on 11,000 hectares of rice land -- 4,000 hectares with irrigation and 7,000 with earlier flooding. Earlier flooding would permit more timely planting of the rice crop.

The project was planned with the following features: (1) construction of two gravity irrigated polders totaling 4,000 hectares, (2) construction of 102

kilometers of feeder roads, (3) rehabilitation of an agricultural research station and (4) construction of a rice mill with a 4 ton/hour capacity and with associated housing and office buildings. Funds were also provided for planning a second phase of the project.

The irrigation works are a main canal to convey water to a compensation basin which is used to control the water supply to each of the two polders and to provide early water for planting to the project area outside of the polders. Irrigation water is distributed to independent blocks within the polders by primary and secondary canal networks. Gated pipe culverts permit discharge of water at high river flood stage.

As originally planned all project costs, both capital and recurrent costs were to be recovered by a harvest levy of 10% of gross paddy production for farmers on the polders and by profits from operation of the rice mill.

Polder M was planned to be divided into seven independent blocks by dikes giving a total cultivable area of 1,750 hectares. Land leveling was planned for 650 hectares. Here fields are grouped into 14 hectare units (700 X 200 M) and supplied by field ditches from the secondary canals through simple gated structures. Water level control is at a depth of 10 to 20 cm.

On the other unleveled blocks contour bunds were originally planned to control water at a depth of 30 cm in some places and 60 cm in others. Discharge to these fields is from gated structures. A system of collector drains are provided.

Polder D was planned to be divided into 14 independent blocks totaling 2,100 hectares of cultivable land. No land leveling was used and contour bunds were to divide the blocks into 30 cm and 60 cm water depth zones. Blocks are irrigated by controlled flooding through gated offtakes.

By 1979 construction had been completed for a combined total of 2,920 hectares on both polders. Rough land leveling had only been carried out on a small portion of the originally planned 650 hectares, however, on the recommendations of SATEC, changes were made to have shorter dike intervals to avoid the 60 cm. water depth zones and to have barriers in the canal to permit drainage of the storage basin. A recommended pilot area to permit drainage of the storage basin was never completed.

Initially the project seems to have been viewed as a pilot project. Funding was provided for second stage studies thus leaving the door open for replication of a successfully implemented project. However, in 1976 the project was revised. The net irrigated area was increased to 5,000 hectares, road construction was reduced and the second stage studies were eliminated.

Project activities came to a halt in 1979 due to the civil war. In 1984 a World Bank mission reformulated the project to include the following: construction and rehabilitation of polders already developed, construction of 70 kilometers of feeder roads, provision of extension services, rehabilitation of a rice mill, village warehouses, and other buildings, provision of management and engineering services and applied research and seed multiplication services.

B1.2 Soils

The project soils are generally light textured, sandy clay which is subject to periodic flooding.

B1.3 Land Rights

Rights to cultivate land are based on the custom of allocating a plot of land (usually around 1.5 hectares) to each family member reaching the age of eighteen. Family farms (average family size - 4.8 persons) average 4.5 hectares and seventy-five percent of the farms in 1975 were in the range of two to ten hectares.

Traditionally the "land chief" is in charge of land allocation and the "village chief" is the administrative head of the village. Typically, after about ten years of continuous cultivation, land is abandoned by the user, automatically reverts to the village, lies fallow, and is subsequently reallocated. Land not cultivated because of death or illness is reallocated.

As originally planned the project was to have a minimum disruption on traditional land allocation practices although the OMVSD would allocate any unused land. The current practice of removing cultivators from the scheme who either fail to repay their fertilizer, seed and water charges or who have low yields suggests that OMVSD has taken a stronger hand in the distribution of land rights.

B1.4 Husbandry

Traditionally soil harrowing and plowing for the rice crop is carried out by ox-drawn implements in June, and seed is broadcast. Weeding, requiring about 35 person days per hectare, was considered in the mid-seventies to be a major constraint to expanding the area under cultivation. The irrigation team saw many rice fields with very heavy weed infestations during their visit.

Labor inputs, based on 1975 estimates are shown in Table B-2. In 1985, some confirmation of the low plowing input was obtained through interviews with farmers and on observing how easy it was to plow these very sandy soils.

TABLE B-2. PER HECTARE ESTIMATES OF LABOR INPUTS FOR PADDY SATEGUI-DERESSIA

	Man Days	Women Days	Mixed Women/Men	Oxen Days
Plowing and Harrowing	3			3
Broadcasting		6		
Weeding			35	
Harvesting			23	
Threshing and Winnowing		20		
TOTAL	3	26	58	3
GRAND TOTAL			90	

B1.5 Farm Income

The principle source of farm income in the project area is the rice crop. Farmers also derive income from cattle, vegetables grown on high ground around the villages and fishing in the Logone River. Pre-project yields were estimated at .9 T/ha. The project was expected to increase yields to an average of 2.5 T/ha. In 1977-78 the SATEC study estimated that yields outside the project were 1.8 T/ha. and 2.5 T/ha. in the project area.

In 1975, it was estimated that the total cost to the farmer/hectare for seeds, fertilizers, hand tools, ploughs, carts, and custom threshing to be 10,185 CFA (15,330 CFA at the real rather than subsidized fertilizer price). This gave a return to land and labor (farm family income), with yields of 2.5 T/ha., of 74,290 CFA (70,860 CFA without fertilizer subsidy) for a two hectare holding within the project area. A comparison of farm family income between 1975 and 1985 is shown in Table B-3.

TABLE B-3. COMPARISON OF 1975 AND 1985
COSTS OF PRODUCTION FOR PADDY AT SATEGUI-DERESSIA

	1975 CFA	1985[1] CFA
Water Charges		2,500
Seed Premiums[2]		900
Hand tools	300	534
Oxen	1,350	2,106
Plough	250	445
Custom Threshing	800	1,425
Cart for Transport	200	356
Seeds		4,500
Subsidized Fertilizer	7,785	6,000
Unsubsidized Fertilizer	(+5,145)	(+5,000)[3]
Costs exclusive of land and family labor	10,185	18,766
Costs exclusive of land and family labor--unsubsidized fertilizer	15,330	23,766

[1]1985 prices for inputs except seed and fertilizer inflated from 1975 prices on the basis of percent change in foreign exchange rate, July 1985. Fertilizer is at current market prices and seed at official prices.

[2]Farmers are asked to repay seed loans at 120% of quantity of seed supplied. Here the premium is calculated at the official 1985 paddy price of CFA/kg. The charge would be 2250 CFA if calculated using the unofficial parallel market price of 1150 CFA.

[3]Based on a price of 100 kg of urea of 11,000 CFA/ha+.

It seems likely, given the income estimates shown in Table B-4, that there is sufficient incentive under current prices to attract farmers to participate in the scheme. At the same time, however, it is worth noting that a farmer off the project with a two hectare holding and an average yield of 1.7 tons of paddy, purchasing seeds and selling his crop at unofficial parallel market prices, can anticipate a return all other factors the same of 493,884 CFA. It is also worth considering that the primary difference between project and non-project area yields may be the difference in levels of fertilizer application. Differences in input level could exist because of fertilizer being available on credit only through the project or because the project provides some insurance through water control, against crop failure. This decrease in risk may promote increased levels of fertilizer application.

TABLE B-4. 1985 FARM FAMILY INCOME FROM SATEGUI-DERES IA[2]

	Subsidized Fertilizer	Unsubsidized Fertilizer
Official Price	262,468	252,468
Official Parallel Market Price	462,468	452,468
Unofficial Parallel Market Price	702,468	692,468

[2]Based on previous crop average yields of 2.5 T/ha and a two hectare holding.

B1.6 Marketing

A rice mill (4 MT/hour) was planned and built as part of the original project. To date the mill has been in operation a total of some 29 days. Reportedly the mill is basically intact and awaits only modest repairs and a harvested crop. Economic analysis of the project in its original form projected an increase in the quality and hence value of the milled rice which would result from the presence of a modern rice mill as an important benefit from the total project. In 1975, the average per ton value gain was expected to be 3150 CFA. At 1983 prices, the same performance from the mill would have generated benefits of approximately 15,840 CFA/ton

APPENDIX B-Part 2

MOUNDOU: THE "RICE OPERATION" IN SOUTHERN CHAD

B2.1 General Features of the Scheme

In 1984 efforts at developing rice production in Southern Chad, were co-ordinated under the ONDR Sub-directorate based at Moundou. There are two principle components of these efforts: 1) rainfed rice projects which involved building bunds and providing for drainage, and 2) establishment of small village-level irrigated rice units using water pumped from an adjacent river.

a. The rainfed rice projects financed by the FAC, are uniformly 24-hectare parcels divided into six 4-hectare (200m x 200m) dyked fields. Each of these is sub-divided into parcels of 0.5 ha (50m x 100m). Bunds are approximately 50 cm high and are constructed by the farmers themselves.

   Given the regular landform of the sites selected, they are staked out without a prior topographical survey. The sites are selected by reference to a soil survey conducted before 1978 with World Bank aid. Since 1982, 22 units of this type have been established. Yields in 1983, a dry year (800mm rainfall which was 20% less than average), were slightly better than those on nearby non-project land. In 1984, with an even more severe rain shortage (600mm), the IRAT 173 demonstration farm at Benibo obtained a yield of 1.5 t/ha, but the yield increases on project fields were close to zero.

   These rainfed rice schemes are an outgrowth of a large rainfed rice intensification operation started in 1978, which was based on very large individual parcels of 100 to 180 hectares, with mechanical land-clearing and bund construction and employing tractors for plowing.

   After about a thousand hectares had been developed, the operation encountered failure both from the technical standpoint (very uneven distribution of water due to poorly aligned fields and from soil problems) and from the social standpoint (units too large to be handled by the existing local communities, failure to attract the interest of the population, and vandalisation of dykes by fishermen).

b. The establishment of small irrigated rice perimeters using river pumping is new to the region. The project was initiated following droughts in 1983 and 1984 with financial aid from a charitable organization (MISEREOR).

   The irrigation perimeters are planned for about 20 ha each. They are to be enclosed behind flood barriers, with field irrigation by unlined canals and stonework control points. The systems utilize a 25-CV pumpset mounted in the river on a floating platform. Above ground PVC pipe reaches to the highest point of the irrigated area and water then flows by gravity to individual fields.

   The purpose of the scheme is to secure at least one good crop in dry years (most of the sites having no reliable source of water during the dry season), and permit double cropping in years when the water resource is sufficient.

B2.2 The Zone of Operations

The "Rice Operation" covers the ONDR sectors of East Mayo-Keobi, Kelo (Tandjile), West Logone (Moundou), Pende (East Logone) and Mandoui (Middle Chari). It falls almost entirely within the Sudano-Guinean climatic zone, with a mean annual rainfall running from 950 mm in the North to 1,200 mm in the South.

The rainy season is 6-7 months long, from May to November. There is a cool dry season from November to February and a hot dry season from February to May.

Rainfall peaks sharply in August (250 to 300 mm), and temperatures reach their maximum in April (average high 40°C, absolute high 45°C). Potential evapotranspiration as measured by the Piche meter is between 1,500 and 2,030 mm annually.

The benefits of a high rainfall, on both an annual and a monthly basis, is somewhat offset by the large between season variation, (as for example the bad droughts of 1972-73 and 1983-84), and by the relatively frequent dry periods early in the cropping season, especially in the North.

The zone is strongly affected by the Logone River whose floodplains cover large areas. At Lai, roughly in the centre of the zone, floods start in June/July, rising to maximum height between September and November (with a slight fall in October), before dropping to the low-water level in December. The water-level range is about 5 to 7 meters. This staggering of the rainy and flood periods respectively means that large areas are under water from July/August to October/December.

The soils of the zone belong mainly to one of five types:
In the emergent areas:

(1) Slightly ferrallitic modal red soils on sand and sandy clay. These are the equivalent of the "terres de barre" found in the "Continental terminal" regions of West Africa. They are highly permeable on the surface, less so in depth, of very variable fertility (depending on pH value), and used for growing rainfed cotton/millet crops or sometimes with groundnut and/or miscellaneous crops. Their organic matter content diminishes rapidly, requiring fallow periods of from 5 to 6 years;

(2) Tropical ferrigineous soils, washed with iron patches and concretions, on silicifierous or clayey sand. These are mainly found as strips bordering on the ferrallitic soil areas or along drainage channels, or as emergent banks standing above flood zones. Despite a sandy top-layer, they are not very permeable and are generally of poor fertility. They are planted mainly with cotton, sorghum and manioc. Without fertilization, they must be left fallow for 8 to 10 years after 3 to 4 years of cultivation. Animal-drawn implements, by increasing the plowing depth, leads to significantly improved yields.

In the flood areas (rice soils):

(3) Deeper pseudo-gleisoils, with iron concretions, on recent clayey-silt or silty-clay, found mainly in the flood valleys of watercourses and in flood-basins;

(4) Deeper pseudo gleisoils on siliciferous or clayey sand, occupying two large zones juxtaposed with tropical fernigineous soils, East of Doba and around Gounou-Gaya and Kelo. These latter two soil types are

well suited to rice. Depending on their texture and degree of submersion, most other crops such as groundnut, millet, cotton, rainfed or berbere sorghum and garden crops can be grown also.

(5) Hydromorphous heavy clays, broadly structured on top with calcalareous nodules and subsidence, on clayey-sand to clay alluvions, occupy the major part of the floodplain lying East of the Logone River downstream of Lai and drained by the Ba-Ille towards the Chari. These soils, flooded for 4 to 6 months out of the year, are very clayey and mostly left uncultivated.

B2.3 Characteristics of the Small Perimeter Irrigation Schemes

The small perimeter irrigation schemes are developed in the following way. (1) A land survey is carried out by ONDR survey unit; (2) Land levelling is done using mechanical graders; (3) irrigation development works (canals, drainage system) are built by farmers using hand tools sols to them by ONDR; (4) a 22-CV Diesel pumpset with a lifting capacity of 200 m^3/h is mounted on a floating platform. The pumps are to be maintenanced by an ONDR crew of two expatriate volunteer mechanics with a pick-up truck and six assistant mechanics with motorcycles.

The rice farm operations are planned as follows. Plowing is to be done by the farmers using implements sold by ONDR. Seed and fertilizer will be purchased from ONDR with deferred payment. Weeding and harvesting will be with hand labor. ONDR will provide a high-capacity mechanical thresher and collect loans at threshing time. According to planned marketing procedures farmers will deliver a quota to a marketing board and receive a partial payment. The board in turn stores the grain, then sells off to commercial dealers (market information supplied by ONDR) and makes final payment to producers. Program equipment and personnel training are to be supplied by ONDR "Village Group Support Unit" with the assistance of INADES.

Overall the scheme is designed to cover 48 individual parcels per main irrigation unit, making 1,056 in all for the 22 units and employing about 2,640 farm workers. Including the farm families, this represents a total of some 7,500 people included in the scheme.

A number of benefits are expected to accrue from the project. First, production will be less vulnerable to rainfall variations and second, agricultural production will be more intensive. Growers will become more technically proficient because of the removal of major climatic risks. Third, organized marketing is expected to ensure higher prices to the farmers, making it possible to reduce their reliance on harvest loans. Fourth, the farmers will gradually become more independent of the extension services, as they become better organized and better trained in commercial techniques.

B2.4 Project Costs

The investment cost per main irrigation unit is estimated at 13,200,000 F(CFA) - or about 550,000 F(CFA) per hectare - without counting the costs of ONDR intervention or of farm labor, but including that of materials for building a storage facility measuring 35 m^2. The scheme is expected to generate sufficient revenue to allow for its own expansion, via the dues charged to farmers which will cover amortizing of development costs.

Farmers will be required to pay the following dues:

(1) provision for renewal of pumping equipment	44,000 F/ha
(2) current irrigation inputs	78,000 F/ha
(3) maintenance (running costs of maintenance crew plus amortization vehicles and related equipment)	29,000 F/ha
(4) land development (amortization over 25 years)	21,000 F/ha
TOTAL	172,000 F/ha

The land development charge, destined to finance the setting up of further irrigation units, is introduced as a means of making the farmers aware of the value of development works.

The other production costs (seed, fertilizer, threshing) are estimated at 108,000 F(CFA) per hectare, to make a grand total of 280,000 F(CFA)/ha, equal to the value of 3.5 tons of rice. The project is said to justify this outlay in the light of an expected rice production of 7 tons/ha (compared with the current figure of 0.6 tons in a good year without irrigation). The net income earned by a parcel of 0.5 ha, allowing for family consumption of 1,000 kg per year, would come to 60,000 F(CFA) annually.

APPENDIX C

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1980 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Sysems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-On Activities

WMS 25 Interdisciplinary Diagnostic Analysis of a Work Plan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

WMS 26 Prospects for Small-Scale Irrigation Development in the Sahel

WMS 27 Improving Policies and Programs for the Development of Small-Scale Irrigation Systems

WMS 28 Selected Alternatives for Irrigated Agricultural Development in Azua Valley, Dominican Republic

WMS 29 Evaluation of Project No. 519-0184 USAID/El Salvador, Office of Small-Scale Irrigation - Small Farm Irrigation Systems Project

WMS 30 Review of Irrigation Facilities, Operation and Maintenance for Jordan Valley Authority

WMS 31 Training Consultancy Report: Irrigation Management and Training Program

WMS 32 Small-Scale Development: Indonesia/USAID

WMS 33 Irrigation Systems Management Project Design Report: Sri Lanka

WMS 34 Community Participation and Local Organization for Small-Scale Irrigation

WMS 35 Irrigation Sector Strategy Review: USAID/India; with Appendices, Volumes I and II (3 volumes)

WMS 36 Irrigation Sector Assessment: USAID/Haiti

WMS 37 African Irrigation Overview: Summary; Main Report; An Annotated Bibliography (3 volumes)

WMS 38 Diagnostic Analysis of Sirsia Irrigation System, Nepal

WMS 39 Small-Scale Irrigation Design Issues and Government Assisted Systems

WMS 40 Small-Scale Irrigation Design-Kenya: Current Public and Private Sectors

WMS 41 Strategies for Irrigation Development: Chad/USAID