Joint UNDP/World Bank
Energy Sector Management Assistance Program

Activity Completion Report

No. 032/85

Country: THE GAMBIA

Activity: PRE-INVESTMENT REPORT ON SOLAR PHOTOVOLTAIC APPLICATIONS IN THE HEALTH AND TELECOMMUNICATIONS SECTORS

MARCH 1985

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP), started in April 1983, assists countries in implementing the main investment and policy recommendations of the Energy Sector Assessment Reports produced under another Joint UNDP/World Bank Program. ESMAP provides staff and consultant assistance in formulating and justifying priority pre-investment and investment projects and i providing management, institutional and policy support. The reports produced under this Program provide governments, donors and potential investors with the information needed to speed up project preparation and implementation. ESMAP activities can be classified broadly into three groups:

- Energy Assessment Status Reports: these evaluate achievements in the year following issuance of the original assessment report and point out where urgent action is still needed;

- Project Formulation and Justification: work designed to accelerate the preparation and implementation of investment projects; and

- Institutional and Policy Support: this work also frequently leads to the identification of technical assistance packages.

The Program aims to supplement, advance and strengthen the impact of bilateral and multilateral resources already available for technical assistance in the energy sector.

Funding of the Program

The Program is a major international effort and, while the core finance has been provided by the UNDP and the World Bank, important financial contributions to the Program have also been made by a number of bilateral agencies. Countries which have now made or pledged initial contributions to the programs through the UNDP Energy Account, or through other cost-sharing arrangements with UNDP, are the Netherlands, Sweden, Australia, Switzerland, Finland, United Kingdom, Denmark, Norway, and New Zealand.

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THE GAMBIA

PRE-INVESTMENT REPORT ON SOLAR PHOTOVOLTAIC APPLICATIONS IN THE HEALTH AND TELECOMMUNICATIONS SECTORS

MARCH 1985

ABBREVIATIONS AND ACRONYMS

Ah	Ampere-hours
DEL	Direct Exchange Line
DOH	Department of Health
EPI	Expanded Program for Immunization
GPMB	Gambia Produce Marketing Board
GAMTEL	Gambia Telecommunications
GOTG	Government of The Gambia
GTZ	German Technical Assistance Agency
GUC	Gambia Utilities Corporation
ITU	International Telecommunications Union
IBRD	World Bank
km	kilometers
kVA	kilovolt-amperes
kWh	Kilowatt hours
m	meters
MCH	Maternal and Child Health Care Program
MEPID	Ministry of Economic Planning and Industrial Development
MHZ	Megahertz
mm	Millimeters
PANAFTEL	Pan-African Telecommunications
PV	Photovoltaic
UHF	Ultra High Frequency
UN	United Nations
UK-ODA	United Kingdom Overseas Development Administration
VHF	Very High Frequency

CURRENCY EQUIVALENTS

Dalasis 4.20	=	US \$1.00 (December, 1984)
D 3.75	=	US \$1.00 (April, 1984)
D 1.68	=	US \$1.00 (1981)

CONVERSION FACTORS

British thermal unit (Btu)	= 1.054 kJ
	= 1.054×10^{10} erg
	= 1054 J
	= 778 ft-lb
	= 252 cal
	= 0.293 Wh
Btu/ft^2	= $11.35\ kJ/m^2$
	= $0.271\ cal/cm^2$
	= $1.135\ J/cm^2$
	= $3.15 \times 10^{-3}\ kWh/m^2$
$cal/cm^2\ h$ (langley/h)	= $11.63\ W/m^2$
	= $3.687\ Btu/hft^2$
	= $0.1667\ cal/cm^2/min$
	= $41.8\ kJ/h\ m^2$
kW/m^2	= $1000\ W/m^2$
	= $3600\ kJ/h\ m^2$
	= $317.2\ Btu/hft^2$
	= $1.432\ cal/cm^2/min$
kWh/m^2	= $3600\ kJ/m^2$
	= $317\ Btu/ft^2$
	= $86\ cal/cm^2$

TABLE OF CONTENTS

SUMMARY

Background and Objectives

The Country Background

1. The Republic of The Gambia, located on the west coast of Africa at about latitude 13° north, measures about 300 km from east to west and is narrow, averaging about 20-30 km in width from north to south. Banjul, the capital, lies on the western-most end of the country and faces the Atlantic Ocean. The population of about 600,000 is over three quarters rural, with the urban population concentrated in and around Banjul.

2. The Gambia is one of the poorer countries of Africa, with an estimated GNP per capita of US$300. Its economy is based on non-energy-intensive agriculture, the main cash-crop and export commodity being groundnuts. The country has suffered from serious economic problems in recent years, resulting from a combination of increased import prices, particularly oil prices, and declining export earnings. This decline was largely due to reduced groundnut production brought on by a decade of lower than average rainfall. Oil imports consumed only 9% of commodity export earnings in 1974-75, but in 1980-81, which was a particularly bad year for agricultural production and when rainfall was especially poor, they absorbed 70% of commodity export earnings. The government is currently proceeding with the Second Development Plan, which is premised on an average of 5% annual growth in GDP between 1980 and 1986. This rate of growth is based on the assumption that groundnut production will greatly increase.

3. Living conditions for the majority of the population are poor and malnutrition is combined with a high incidence of disease. Much of the disease is due to contaminated water supplies or epidemics that could be controlled through mass immunization. Infant mortality is particularly high in the rural areas where, in some districts, more than one third of the children die before the age of two. It is a government priority to combat these problems. Major programs have been initiated, with international support, to introduce a nation-wide immunization campaign as a key element in this effort. The improvement of village water wells is also a high priority item in the government's program. Another sector of the rural economy which has hitherto been neglected, and is somewhat in a state of disarray, is telecommunications. The rural telecommunications network has been affected by the fuel shortages, unreliable power supplies, and inadequate maintenance. Since 80% of the population is dependent on the rural network, the Government views its rehabilitation and improvement as important components in the national development program.

Background to the Report 1/

4. In 1982, a mission under the auspices of the Joint UNDP/ World Bank Energy Sector Assessment Program reviewed all aspects of the energy sector in The Gambia and prepared a report which inter alia evaluated some possibilities for substituting imported oil with indigenous energy resources, including solar energy. 2/ Subsequently, in April 1984, at the request of the Government, a Technical Assistance Identification mission 3/ under the Energy Sector Management Assistance Program (ESMAP) identified the fuel substitution potential of solar photovoltaic systems in two vital rural systems -- rural health care and telecommunications systems -- and prepared detailed terms of reference for a pre-investment study. A follow-up ESMAP mission visited The Gambia in July, 1984, to prepare this report.

Objectives of the Report

5. The primary objective of the July 1984 mission was to produce a pre-investment study which would assist the GOTG in obtaining external funding to replicate the use of solar photovoltaic power units in the rural health care and telecommunications systems. The specific objectives, as set out in the mission's terms of reference, were:

(a) to establish the costs and benefits from the introduction of solar photovoltaic power units to supply some or all of the critical electricity needs of the existing network of rural health centers and dispensaries in The Gambia (for refrigeration of vaccines, for lighting in-patient rooms, for hot water sterilization and, possibly, for pumping water from wells);

(b) to establish basic specifications of solar photovoltaic power units to supply a combination of the above needs for which potential savings can be made, and to establish the level of investment required to supply these systems to various health centers and dispensaries;

1/ This report is based on the findings of a mission comprising Messrs. Anwer Malik and Peter Fraenkel (Consultant) that visited the Gambia in July 1984. The report was written by Messrs. Fraenkel, Malik and Akanda.

2/ Joint UNDP/World Bank Energy Sector Assessment Program. The Gambia: Issues and Options in the Energy Sector, Report No. 4743-GM, November 1983.

3/ This Technical Assistance mission comprised Mr. Amarquaye Armar.

(c) to review the existing recurrent costs and the status of the use of solar photovoltaic power units at some of the rural single channel VHF stations in The Gambia's rural telecommunications system, as a basis for establishing the level of investment required to retrofit remaining rural single-channel VHF stations with solar photovoltaic power kits, the assessment of single channel VHF stations to be done with special reference to the needs of GOTG's Primary Health Care Program;

(d) to assess the feasibility and level of investment required to retrofit existing diesel power units at UHF repeater stations and provincial multi-channel VHF stations with solar photovoltaic systems;

(e) to prepare, on the basis of (a), (b), (c), and (d) above, a report specifying investment costs, benefits and an implementation plan: (i) of an optimal program to equip health centers and dispensaries with the appropriately sized solar photovoltaic power system for their essential electricity needs (inclusive or exclusive of water pumping); and (ii) to equip rural VHF stations with appropriately sized solar photovoltaic power systems; and

(f) to briefly look into the feasibility of utilizing solar photovoltaic powered pumps for small-holder irrigation in the McCarthy Island Division.

The Mission and its Approach

6. After initial meetings with officials from the relevant government agencies, the mission visited a cross-section of health and telecommunications facilities to identify potential solar energy applications in these two sectors. A total of 9 out of 29 government health centers and dispensaries, all 3 UHF repeater stations, 3 out of 7 rural telephone exchanges, and 7 out of the 13 remaining single channel VHF public telephone terminals were visited. The mission was accompanied in the field by personnel from the Department of Health (DOH) and from Gambia Telecommunications (Gamtel) who concurred that the sample of installations visited was truly representative and gave a realistic impression of the existing situation.

Findings and Recommendations of the Mission

Rural Health Sector

7. The primary health care program in The Gambia includes the Expanded Program for Immunization (EPI). The main targets for the EPI are the below-23 months age group and pregnant women. The program is

implemented through a network of 18 rural health centers, 13 dispensaries, and two private missions which cooperate with the government program. The health centers range in size from having five or six staff and a few beds to being, in effect, small hospitals, with a dozen staff and up to 20 beds. Dispensaries usually have four para-medical or nursing staff working from a single building with minimal equipment. There is also a network of rural sub-dispensaries that do not have permanent staffing but which are serviced from the dispensaries and health centers which offer clinics once or twice per week.

8. Four of the health centers have no power supply, and the rest receive it only intermittently. The dispensaries have no power at all. At present, all health centers and dispensaries are equipped with refrigerators for storing vaccines. Due to the general unreliability or non-availability of mains electrical power supplies in The Gambia, only two health centers have mains electric refrigerators, two have experimental solar photovoltaic refrigerators, and the rest rely on kerosene-fueled absorption refrigerators.

9. The EPI attempts to provide a regular supply of kerosene to all health centers and dispensaries officially dependent on kerosene refrigerators, and additional amounts of fuel are provided to allow for lighting requirements, spillage, or other losses. The supply of fuel, however, is highly inadequate. The situation has been aggravated by inadequate equipment maintenance and fuel shortage problems which have delayed or prevented kerosene deliveries. These problems significantly reduce the number of successful immunizations achieved and result in a great wastage of vaccines. They also increase costs because of the extra travel required of health center/dispensary staff to collect additional vaccines. In addition to the effect on the immunization program, the absence of an adequate fuel supply has other implications. For example, significant hazards to life can occur from lack of adequate lighting when dealing with emergencies at night and also from inadequate sterilization resulting from lack of fuel to boil water. Hot water needs (e.g., bathing newborn babies, dressing wounds, etc.) also cannot be met because of this fuel shortage.

10. The mission concluded that the principal applications for solar energy in the rural health centers and dispensaries were in: (a) powering vaccine refrigerators; (b) providing lighting; and (c) heating water for use at childbirth and other end uses and boiling water for sterilization. Other applications where solar energy could make an effective contribution were in: (d) pumping water from existing open wells at five health centers and 10 dispensaries currently using sub-standard water from open wells; and (e) water pumping for irrigation on small farms in the McCarthy Island Division.

11. <u>The mission recommends that an equipment package consisting of a solar-powered photovoltaic vaccine refrigerator, a pair of fluorescent lights (to run off the same power supply as the refrigerator) and a small, integrated solar water heater and storage tank unit should be</u>

supplied to 25 of the rural health centers and dispensaries involved in the EPI. The gross procurement, shipping and installation cost for these 25 sets of equipment, plus an adequate inventory of spare parts, is estimated at US$161,840.

12. The quantifiable benefits of using solar refrigerators are: (a) substitution for kerosene supply and delivery costs: US$778 per year per refrigerator, or a total of US$19,450; (b) in terms of reduced vaccine losses, an estimated US$4,605 worth of vaccines will be saved per year through reduced refrigerator down-time; and (c) improvement in vaccine availability due to an anticipated reduction in refrigerator down-time. It is expected that, with refrigerator availability, the productivity of the immunization program will improve by over 20%. The annualized life-cycle costs using solar refrigerators instead of kerosene are expected to be reduced from US$1,018 to an average of US$762. The cost per dose will drop from US$1.12 to approximately US$0.91 -- a saving of 19%.

13. Other benefits that cannot easily be quantified include: (a) reduced maintenance workload for technicians and medical personnel (i.e., no more kerosene burners to be cleaned and adjusted); (b) reduced need to transport vaccines to an alternative refrigerator many kilometers away when kerosene shortages force a shutdown; and (c) reduced incidence of disease if a more productive immunization program is achieved.

14. The provision of lighting does not replace any comparable existing technology, nor does it significantly affect DOH's recurrent costs. The main justification is that a certain minimum level of lighting is necessary to operate an effective rural health service, and that the cost of providing the lighting "on the back" of the solar vaccine refrigerator is small. Substituting photovoltaic lighting will result in a nominal annual saving of about US$650 (US$26 per center) of kerosene. If, at each center, the same degree of illumination were to be provided by kerosene lamps as would be obtained by the proposed fluorescent lights, six hurricane lamps would be required and the fuel cost would be about US$250 per year for each center. The unquantifiable benefits of providing lighting include: reduced risk for patients; improved staff and patient morale; and elimination of the frequent need for the staff to pay for candles and flashlights at their own expense.

15. Similarly, the provision of a small solar water heater at each center would meet an obvious need for hot water. This will considerably reduce the occasional use of kerosene or the frequent effort required at present to collect firewood for water heating. It would cost about US$60 a year with a kerosene heater to provide the equivalent energy of a solar water heater at each center. Other benefits of providing solar water heaters are: improved hygiene (hence, reduced health risk); reduced work for staff; improved staff morale.

16. The mission concluded that the need for solar water pumps at health centers and dispensaries with sub-standard water supplies was not

clear-cut. Despite the technical feasibility of solar pumps, a generally applicable "package" could not be recommended because the water requirements were different at each site. Moreover, the economic feasibility of solar pumps compared with wind, hand, and diesel pumps had not been established. Similarly, while the technical feasibility of using solar pumps for irrigation has been established, a detailed economic evaluation has not been done. Consequently, the mission recommends that a separate consultant study be undertaken to assess the role of solar water pumps for the health facilities and irrigation in the McCarthy Island Division. The study will cost between US$15,800 and US$23,800 to complete.

The Rural Telecommunications Network

17. Background. In The Gambia, the telephone network is operated by Gamtel, an autonomous corporation formed in 1984 out of the former government Department of Telecommunications (DOT). The Gambia has approximately 3,400 telephones, of which fewer than 300 are distributed throughout the countryside where 80% of the population lives. The present quality of the domestic service provided by Gamtel is generally poor, particularly in the rural network. While plans are being made to rebuild the peri-urban Banjul area network with French bilateral aid, there is no immediate provision for overhauling the rural network. Major technical problems cause a high proportion of the rural telephones to be out of service for extended periods, in some cases almost permanently. This results in high costs to maintain the rural telecommunications sector, a low quality of service and reduced revenues for Gamtel.

18. The rural telecommunications network is based on radio telecommunications using a single UHF multi-channel trunk route running the length of the country linking Banjul to Georgetown at the eastern end. A VHF extension runs eastwards from Georgetown to Basse via Bansang. Various single channel VHF links connect the main exchanges at provincial towns on the UHF trunk to surrounding villages and towns.

19. Power and maintenance problems, which are often interlinked, are the key factors affecting the performance of the rural telecommunications sector. The mission observed that any faults other than the most commonplace and trivial need to be investigated and rectified by centrally-based staff, which is a time-consuming operation. Ironically, the repair teams are often incommunicado for many hours due to the very faults they are trying to correct, and therefore cannot be notified from headquarters of further problems that may have arisen in their area because they do not have two-way radio/telephones in their vehicles. The vehicles are often ill-equipped, and major components frequently have to be taken back hundreds of kilometers to Banjul for minor repairs because adequate mobile facilities for testing are not available. Similarly, there are no spare batteries, so that flat batteries have to be taken away to be recharged and returned later at great expense in travel costs and resulting in unnecessary extra down-time.

20. The importance of adequate telecommunications for economic development is difficult to establish, but examples of tangible benefits exceeding costs by several hundred percent have been found in case studies relating to the development of rural economies in many developing countries, including some in West Africa. 4/ Therefore, there are good reasons for believing that improvements to the sparse and inadequate Gambian rural telecommunications network would have a net positive impact on the economic development of the country.

21. Three main areas with maintenance and power supply problems which can be effectively addressed by solar-related equipment were identified by the mission. These are: (a) the national trunk system, (b) the provincial exchanges, and (c) the single channel VHF lines between the village terminals and the provincial exchanges.

22. The National Trunk System. The UHF system is equipped with 48 channels. Beyond Georgetown, the trunk backbone continues as a UHF nominal 24-channel link to Bansang and then 16 channels continue to Basse. There are also UHF 8-channel branches from Banjul to Barre, from Mansa Konko to Farafenni and from Georgetown to Kuntaur. The system uses drop repeater stations at the provincial exchanges, but three repeater relay stations are necessary to bridge gaps between provincial towns. These repeater relay stations, at Jelekato, Jattaba and Makagui, are identically equipped with twin 3.4 kW diesel generating sets, owned and maintained by Gamtel to provide their power requirements via a bank of batteries which are charged on a 12-hour per day duty cycle. Power supply problems with these repeaters have been responsible for a number of system failures in recent months and require frequent travel by engineers and technicians from Banjul to implement repairs. Fuel shortages compound the problems. The repeater stations are vital to the national telephone network. In fact, two of them carry all traffic between Banjul and the central and eastern part of the country. Thus, repeater station failures can have major strategic consequences since they may cause a complete break in communications between Banjul and the provinces. Also, breakdowns result in revenue losses which are probably substantial but cannot readily be quantified from available records. Therefore, it is imperative that reliable power supplies be provided at the repeater stations.

23. The mission recommends that the power supplies at all three repeater relay stations on the UHF trunk route be converted to solar power. This will involve the provision of solar photovoltaic arrays and new batteries. A system sized to deliver power with 99% availability in the least sunny month will cost about US$20,500, giving a gross procurement and installation cost for the three stations of US$61,500.

4/ For example, ITU-DECD Project Document, Telecommunication for Development, International Telecommunications Union (ITU), Geneva, 1983.

24. A conservative analysis of cost data indicates that the recommended solar powered systems will produce electricity at about 53% of the cost of the diesel generated electricity. The savings in direct recurrent diesel engine O&M costs for Gamtel resulting from the use of solar power for the repeater stations will be approximately US$11,400 per year. Other important benefits include: reduced demand on the limited maintenance resources of Gamtel; reduced system down-time (and hence increased traffic revenue and a more secure network); the release of six generating sets with about three to four years useful life each as extra standby plant for use at telephone exchanges; and the release of the rooms which currently house diesel engines for use as maintenance workshops.

25. Provincial Telephone Exchanges. There are seven exchanges 5/ associated with the trunk network, plus a small manual exchange at Kerewan to serve the town's 8 Direct Exchange Lines (DELs) and one remaining (intermittently available) rural spur to Salikene. All the provincial exchanges and repeater stations are dependent either on GUC local mains electric supplies or on Gamtel diesel generating sets, or sometimes on both. Since neither the mains supply nor the generating sets generally can provide a 24-hour service, the telecommunications equipment runs from a bank of lead-acid batteries which are charged by the mains or the generator. Maintaining an adequate state of charge in the batteries is proving to be a general problem for many of these exchanges. Irregular charging has led to excessively deep cycling of the batteries which in many cases has caused them to deteriorate and further reduce their capacity.

26. The mission recommends that batteries with four times the capacity of the existing equipment be provided for the inter-town radio network. The investment necessary to undertake these improvements at seven key rural exchanges will be approximately US$39,200 ($5,600 per exchange). It also should be noted that in any case most of the existing batteries are in urgent need of replacement and will cost Gamtel a minimum of US$1,450 per exchange (or US$10,150 altogether), so this investment represents a marginal extra cost of around US$29,000, or US$4,285 per exchange.

27. The recommended changes will allow much longer periods of operation without the need for using standby generators (extended from 11 hours to 44 hours for 50% discharge) and will also allow recharge at a higher rate without damage; so a full recharge can be obtained in 7.7 hours instead of 12 hours. Moreover the depth of cycling of the batteries will be reduced so as to extend their useful lives from the current 5.5 years (at best) to more than 13 years. Regarding benefits, the cash savings in recurrent costs depend entirely on how much use of standby generators is avoided. No saving is obtained with 100% use of

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5/ Farafenni, Mansa Konko, Kaur, Kuntaur, Georgetown, Bansang, and Basse.

GUC mains power, but US$3,800 per exchange can be saved when 100% use of standby generators is necessary. On the basis of past records, it seems likely that significant savings will accrue, probably around US$1,000 to US$2,000 per exchange, or US$7,000 to US$14,000 p.a. in total.

28. Although solar power can be cost-effective in situations where the only alternative is a small diesel generating set (as indicated for the case of the repeater stations), it cannot be cost-competitive with GUC mains power costing only about US$0.13/kWh, provided, of course, that such power is available. Therefore, the mission concluded that the problem at rural exchanges relates to the intermittancy of the mains power supply rather than the high cost of providing a small diesel supply and that solar power would not be justified in this case. Hence, it was recommended to address this problem by re-equipping the rural exchanges with significantly larger battery banks to provide power for the crucial radio telephone network.

29. Single-Channel VHF Lines to the Villages. These lines are beset with serious reliability problems. The mission visited a number of VHF single channel links and found that at least 14 out of 17 were not working and only two (solar-powered systems) were generally serviceable, functioning only when the sun shines strongly enough on the existing solar photovoltaic arrays. The equipment was originally intended to be powered from EMU type primary batteries; these, however, proved expensive and unreliable and were replaced by lead-acid secondary storage batteries (standard car batteries were used) which have been recharged either by a local generating set or by removing them for recharging elsewhere and substituting a freshly charged unit at appropriate intervals. Charging of batteries in this way has proved to be problematic, since they do not readily survive periods of over-discharge and it has been impossible to arrange reliable recharging. Therefore, a UN/ITU expert seconded to the DOT (Gamtel's predecessor) under a UNDP project improvised solar photovoltaic power systems which were fitted to nine village terminals. The solar powered systems were relatively successful when first introduced but, due to errors in sizing of their batteries, alignment of their arrays and other design problems, most of their batteries appear to have failed after a year or two of use. Consequently, most of the VHF links no longer function.

30. The mission found other individually less serious problems with the VHF single channel link terminals, but which collectively can render the system unserviceable. These include: poorly oriented antennae masts; faults with transceivers housed in poorly ventilated and over-heated conditions; human problems such as lack of knowledge as to how to use the telephone, interference by children, and people leaving the hand-set "off the hook"; and indications of poor siting in locations remote from potential users. The mission concluded that, for the VHF systems to operate satisfactorily, it was essential that they be properly designed and installed, and also supervised by trained attendants. After reviewing revenue receipts from various VHF installations, the mission concluded

that efficiently operating systems would restore public confidence and markedly increase revenues.

31. The mission also found that all health center and dispensary staff interviewed rated the provision of a telephone as about their highest priority. If working telephones were generally available at health centers and dispensaries, significant savings in travel and distribution costs could be expected for DOH as well as possible reduction in risk to life through being able to refer emergency patients to hospitals or larger centers with qualified doctors.

32. The mission recommends that twenty solar-powered new VHF single channel village telephone systems be provided to replace thirteen of the existing systems and also seven new links be provided for health centers and dispensaries without a telephone nearby. It is recommended that new batteries be provided to allow eight of the existing solar powered VHF systems to be rehabilitated and made to function effectively in addition to the twenty new systems. This will require a total investment of US$191,000. The mission also recommends that in order to meet Gamtel's need for supervision of rural telephones and DOH's need for telephones, insofar as possible, the rural telephones be located at or near DOH facilities and the DOH staff be given supervisory responsibility for the public telephone in such situations. A mutually agreeable arrangement between the two organizations could be worked out for this purpose. Investigations made by the mission indicated that such an agreement between the two organizations is possible.

33. The direct benefits to Gamtel accruing from the proposed new, well-designed, properly installed and reliable solar-powered single-channel VHF links are difficult to determine with certainty, since they depend on the amount of revenue generated. However, it can be shown that on the basis of current tariff rates and average lengths and costs of rural calls, it will require 21 to 27 minutes per day of traffic per link to break even on a pure revenue/cost basis. Since this is only 3.3% of the average available daylight hours when the system is most likely to be used, it seems reasonable to expect this level of usage not only to be attained, but, based on analysis of revenue receipts, to be significantly exceeded, especially when public confidence in the telephone system is restored. The revenues that can be expected at each station from, say, 80-160 minutes of telephone calls, range from US$96,000 to US$192,000 a year. Also, significant benefits can be expected for the rural economy.

The Project

34. To implement its recommendations for introducing solar photovoltaic systems in the rural health and telecommunications sector, the mission proposes a project comprising the following elements:

(a) the procurement of equipment for the rural health and telecommunications sectors, as discussed above;

(b) a technical assistance program to assist with the installation, commissioning and initial period of operation of the equipment, and to help train Gambian personnel in using it; and

(c) a consultant study to assess the potential of solar water pumping for water supply in the rural health sector, and for irrigation in the McCarthy Island Division.

35. The invitation of tenders for supplying equipment and the resulting selection of equipment would be implemented by personnel from the relevant Gambian departments, assisted where necessary by advisers from associated donor agencies. As part of the technical assistance a short-term "Specialist Adviser" would be recruited for the initial phase which would include equipment approval, installation, and commissioning and subsequently would be available for two more brief visits to respond to any specific requests for advice which may arise during the course of the project. The Specialist Adviser would help select and train an expatriate "Assistant Engineer" who would remain in the country for about 15 months, that is, until the equipment has been functioning satisfactorily for some months and is ready to be handed over to The Gambian counterparts. The Specialist will be responsible for producing a final report on the project. This should be of interest not only to The Gambia but to other developing countries.

36. The Consultant study on water supplies for health facilities and for small-holder irrigation in McCarthy Island Division is also proposed as a separate activity. However, the pre-investment study is included as an element of the technical assistance recommended for this project. The study would involve a mission to The Gambia to conduct the necessary investigations. The recommendations that result would require separate funding, but it is possible that they could be implemented in conjunction with this project.

Schedule and Budget

37. The total duration of the proposed project is about 27 months. If work commenced in June, 1985, as planned, equipment should begin to arrive in February, 1986 and installation should be completed by June, 1986. The final project report would be prepared at that stage for completion by about June, 1987. The total budgetary requirement is estimated at US$612,000-678,000, consisting of US$500,000 for equipment procurement and US$112,000-178,000 for technical assistance. The actual cost is likely to be closer to the lower figure.

Conclusions

38. The mission recommends undertaking the proposed project as the majority of the energy problems relating to the rural health and telecommunications sectors can be significantly reduced by introducing solar energy systems. For an estimated expenditure of US$612,000-US$678,000, including about US$15,000 for the follow-up consultant study on solar water pumps, the project will yield gross quantifiable benefits of US$145,000-US$250,000 annually. This would give rates of return on investment of 24-41% based on a 15-year system life. The proposed investment will also yield a number of unquantifiable but nevertheless important benefits which have been discussed earlier.

39. Finally it is worth noting that this project will be unique in that it uses, for the first time, solar-powered systems to substitute for conventional systems throughout two sectors of a country. It is expected that, apart from its value to The Gambia, much can be learned from the proposed project that will be of considerable relevance to a number of other developing countries.

I. INTRODUCTION

Background to the Report

1.1 The Gambia relies entirely on imported petroleum to meet all its commercial energy needs, including electricity. In recent years, the country has encountered energy problems which, in large part, can be attributed to difficulties in servicing the import bill for petroleum and subsequent interruptions in petroleum supply. The government has requested assistance from various donor agencies to develop a strategy to resolve these problems.

1.2 A mission under the Joint UNDP/World Bank Energy Sector Assessment Program visited The Gambia in August, 1983, and prepared a report 6/ to assist the GOTG transform its energy policy into action. This policy, outlined in broad terms, aims to: (a) secure adequate energy supplies to meet future requirements of the economy; and (b) minimize the cost of energy to the economy by improving the efficiency of energy use. The Energy Assessment Report reviewed all aspects of the energy sector in detail and identified solar energy as an indigenous energy resource which could substitute for imported oil in certain applications. Subsequently, in April, 1984, at the request of the GOTG, a Technical Assistance Identification mission 7/ under the Energy Sector Management Assistance Program (ESMAP) identified that solar photovoltaic applications had the potential to improve the reliability of energy supply for critical needs in the rural health and telecommunications sectors and prepared detailed terms of reference for a pre-investment study. A follow-up ESMAP mission visited The Gambia in July, 1984, to prepare this report.

Objectives of the Report

1.3 The primary objective of the July, 1984, mission was to produce a pre-investment study which would assist the GOTG obtain external funding to replicate the use of solar photovoltaic power units in the rural health care and telecommunications systems. The objectives as set out in the mission's terms of reference were:

(a) to establish the costs and benefits from the introduction of solar photovoltaic power units to supply some or all of the

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6/ Joint UNDP/World Bank Energy Sector Assessment Program. The Gambia: Issues and Options in the Energy Sector, Report No. 4743-GM, November 1983.

7/ This mission comprised Mr. Amarquaye Armar.

critical electricity needs of the existing network of rural health centers and dispensaries in The Gambia (for refrigeration of vaccines, for lighting in-patient rooms; for hot water sterilization; and, possibly, for pumping water from wells);

(b) to establish basic specifications for solar photovoltaic power units to supply a combination of the above needs for which potential savings can be made, and to establish the level of investment required to supply these systems to various health centers and dispensaries;

(c) to review the existing recurrent costs and the status of the use of solar photovoltaic power units at some of the rural single channel VHF stations in The Gambia's rural telecommunications system, as a basis for establishing the level of investment required to retrofit remaining rural single-channel VHF stations with solar photovoltaic power bits; the assessment of single-channel VHF stations to be done with special reference to the needs of the Government of The Gambia's Primary Health Care Program;

(d) to assess the feasibility and level of investment required to retrofit existing diesel power units at UHF repeater stations and provincial multi-channel VHF stations with solar photovoltaic systems;

(e) on the basis of (a), (b), (c), and (d) above, to prepare a report specifying investment costs, benefits, and an implementation plan: (i) of an optimal program to equip health centers and dispensaries with appropriately sized solar photovoltaic power systems for their essential electricity needs (including or excluding water pumping); and (ii) to equip rural VHF stations with appropriately sized solar photovoltaic power systems; and

(f) to briefly look into the feasibility of utilizing solar photovoltaic powered pumps for smallholder irrigation in the McCarthy Island Divison.

Viable Solar Energy Applications

1.4 In both the health and telecommunication sectors, technically reliable and cost-effective solar energy systems can help meet important energy needs. In the health sector, living conditions for the majority of the population are poor and there is malnutrition combined with a high incidence of disease. Much of the disease is due to contaminated water supplies or epidemics that could be controlled through mass immunization. Infant mortality is particularly high in the rural areas where in some districts more than one-third of the children die before the age of two. A successful immunization program and improved village water wells are critical to the country's development and, as such, are items of high priority for the government. The ESMAP mission investigated ways of contributing to improvement efforts and found that, since fuel and power supplies are erratic and unreliable at rural health centers and dispensaries, the provision of solar photovoltaic vaccine refrigerators and solar water heaters would go a long way towards alleviating the current energy supply problems. The systems would also help provide minimal but essential lighting at these centers/dispensaries.

1.5 In the telecommunications sector, the problem has been that of fuel shortages, unreliable power supply, and inadequate maintenance. It is clear that telecommunications is very important for economic development, and this is particularly true for The Gambia, where 80% of the population is dependent on a rural network which provides generally poor service. The Government of The Gambia (GOTG) views the rehabilitation and improvement of the telecommunications sector as important components in the national development program. The ESMAP mission identified three main areas with significant maintenance and power supply problems which can be effectively addressed by introducing solar photovoltaic powered systems. These areas are: (a) the national trunk system; (b) the provincial exchanges; and (c) the single channel VHF telephone lines between the village terminals and the provincial exchanges.

1.6 The technical feasibility of solar water pumps is well-established for: (a) water supplies at health centers and dispensaries currently using sub-standard water from open wells; and (b) irrigation for small landholdings in the McCarthy Island Division. However, it will require extensive analysis to determine the economic viability of such applications. The scope of the investigation was too large to be carried out in this report and, as such, warrants a separate consultant study.

The Project

1.7 The recommendations of the mission have led to the formulation of a project which is presented in this report. The project has three main elements: (a) procurement and installation of solar energy equipment; (b) technical assistance to help The Gambia's personnel procure and install the equipment, and also train them in its use; and (c) a consultant study to assess the potential of solar photovoltaic water pumps for use in the health sector and in irrigating small landholdings in the McCarthy Inland Division. The project will cost an estimated $612,000 - 670,000, require 27 months to implement, and has a rate of return of about 24-41% based on a 15 year system life. In addition to making an impact on two sectors of The Gambia's economy, the project will also serve as an important example for many other developing countries.

II. HEALTH SECTOR

Rural Health Sector and the Immunization Program

Structure of the Service and its Organization

2.1 The primary health care program in The Gambia has two main components: the Expanded Program for Immunization (EPI), and the Maternal and Child Health Program (MCH). The components are managed through a network of 18 rural health centers, 13 dispensaries and 2 private sector missions which cooperate with the government program. The dispensaries are generally smaller, less well-equipped and have fewer staff than the health centers. Details of the primary health care network are shown in Map 18624 and Table 2.1.

2.2 It can be seen from Table 2.1 that the health centers range in size from 5 or 6 staff members and a few beds, to 12 staff members and up to 20 beds (becoming, in effect, small hospitals). Four of the health centers have no power supply, and the rest have only intermittent service. In one or two cases, recently constructed centers have operating theaters which have not yet become functional because of unreliable electricity supply. The dispensaries are very basic, usually employing four para-medical or nursing staff, working with minimal equipment from a single building. Most have one or two beds, usually intended for delivery of babies; serious cases are generally referred to either the nearest health center or to a hospital. None of the dispensaries have any power supply. It is government policy to upgrade all dispensaries into health centers by the year 2000. There is also a network of rural sub-dispensaries which do not have permanent staffing but which are serviced from the dispensaries and health centers usually once or twice per week. This work is carried out by a small team that visits the sub-dispensaries by Land-Rover to hold regular clinics. Vaccines are transported to these clinics in insulated cold-boxes. The sub-dispensaries, too, are without power supplies.

2.3 The Gambia also has a number of privately operated health centers or dispensaries run by religious missions. Most of these are outside the state health service and levy fees for their services, but two private missions offer free medical service similar to that of the government centers; these cooperate with the government program. The mission at Sibanor deserves special mention in that it is fully integrated into the government program. Consequently, on the recommendation of the Medical Director for the Rural Health Service, it has been included in the proposed program discussed in this report.

Table 2.1: GOVERNMENT HEALTH CENTERS AND DISPENSARIES

Location	Staff	Beds	Patients a/	Immunizations a/
Health Centers				
Bakau				
Basse b/	30	45	3,000	1,000 +
Brikama				
Bwiam b/	6	6	1,200	300
Essau				
Farafenni				
Fatoto	6	8	-	800
Georgetown				
Gunjur b/	6	2		
Kaur b/	9	14	3,000	500
Kerewan	-	4		
Kiang Karentaba	12	20		
Kudang b/	12	20	5,000	400
Kuntaur b/	5	5	2,000	1,750
Mansa Konko				
Serrekunda				
Sibanor c/				
Yorobawal	-	8		
Dispensaries				
Baja Kunda	-	1		
Brikamaba b/	4	1	1,000	1,800
Brufut b/				
Chamen				
Dankunku	4	2	3,000	400
Diabugu Basilla				
Gambisarra b/	4	1	1,500	1,000
Kuntair				
Marakissa c/				
Medina Bafaloto				
Sami Karantaba				
Salikene	-	4		
Sukuta	-	2		

a/ Estimates of monthly averages.
b/ Health centers and dispensaries visited by the mission.
c/ Private sector missions which are integrated with the government's EPI program.

Source: DOH, The Gambia.

2.4 Official statistics for the catchment size served by individual health centers and dispensaries do not exist, but the villages in which most are located typically comprise 4,000-10,000 people, with another 10,000 or more people in the surrounding hinterland. Several dispensers estimate their total catchment at about 20,000 people. The six health centers and four dispensaries visited by the mission dealt with about 1,000 to 5,000 persons per month.

2.5 There are two full-scale hospitals in the country, one in Banjul, the capital, and the other in Bansang, which serves the eastern half of the country. These two fall outside the scope of this report as they are not administered within the rural health program.

The Expanded Program for Immunization (EPI)

2.6 The target population for the EPI is the below-23 months age group. They are being vaccinated against yellow fever, diptheria, tuberculosis, polio and measles. Pregnant women are also vaccinated with tetanus toxoid as a precaution against infection at childbirth.

2.7 The EPI depends on the availability of reliable refrigeration capacity at health centers and dispensaries for storing vaccines. Most vaccines need to be stored at temperatures in the -10° to 0°C range. Some, however, may be damaged by freezing and need to be stored in the +4° to +8°C range. Any deviation from these temperature ranges tend to render the vaccine ineffective; the longer the deviation and the further from the recommended storage temperature, the shorter the shelf-life of the the vaccine and greater the risk of spoilage.

2.8 At present, all health centers and dispensaries use refrigerators to store vaccines. Due to the unreliable mains electrical power supplies in The Gambia, only two health centers have mains electric refrigerators, both located in places with better than average power supplies. Two other health centers have experimental solar photovoltaic-powered electrical refrigerators supplied by an American company, Solar Power Corporation; these were provided under a project funded by USAID (para. 2.15). The rest of the health centers and all the dispensaries rely on 154 liter-volume kerosene-fuelled absorption refrigerators, (model RAK660) manufactured by Electrolux, a Swedish company. The kerosene refrigerators which normally operate with reasonable reliability are beset with major problems in The Gambia. Fuel supply and maintenance facilities for them are quite unreliable. With the consequent refrigerator down-time and loss of vaccines this results in a serious drop in the rate of immunization.

2.9 Details of the costs of the MCH/EPI program in The Gambia for the fiscal years 1982-83 and 1983-84 are shown in Table 2.2, which reflects a major increase in the cost of the program. This increase in costs, from Dalasis 1.4 to 2.4 million, is probably related to the devaluation of the Dalasi that has occurred over the past few years (from Dalasis 1.68 to US$1.00 in 1981, to Dalasis 3.75 for US$1.00 in 1984).

It is difficult to separate EPI and MCH costs, since they share many staff and facilities, but the latest year for which a breakdown of the actual EPI program costs was available was 1980-81 and at that time the EPI budget accounted for about 70% of the total. Table 2.3 presents average monthly vaccine disbursements recorded for the EPI for 1983, and approximate unit costs and total costs for different vaccine types. As shown, about 492,000 doses of vaccine are being distributed each year in The Gambia at a cost of some US$31,000. It should be noted that the vaccine budget is financed mostly through international grants as a part of the International CCCD Program, which is providing funds to health programs in Africa. The exact breakdown between local and aid funds in the procurement of vaccines is not known.

Table 2.2: MCH AND EPI RECURRENT EXPENDITURE, 1982-84
(Dalasis)

	1982/83	1983/4
MCH/EPI Unit	139,710	143,840
MCH/EPI Salaries/Wages	67,710	69,340
Health Centers	878,890	1,737,770
Dispensaries/Sub-Disps.	314,860	463,080
Total	1,401,170	2,414,030

Source: Government of The Gambia "Estimates of Recurrent Revenue and Expenditure, 1983-84".

Table 2.3: ANNUAL VACCINE DISBURSEMENTS, 1983

Vaccine Type	Delivered (doses/yea)	Unit Cost (US$)	Annual Cost a/ (US$)
DPT	106,068	0.50/20	3,050
Polio	126,444	0.40/20	2,858
BCG	81,480	0.95/20	4,450
Measles	52,716	1.25/10	7,577
Tetanus Toxoid	89,880	0.45/20	2,325
Yellow Fever	37,236	5.00/20	10,705
Total	491,664		30,965

a/ Total allows for 15% excess required to cover unavoidable waste in discarding used vaccines in vial at conclusion of clinic.

Source: DOH estimates.

Energy-Related Problems

GUC-Powered Health Centers and Dispensaries

2.10 Twelve health centers in some of the larger provincial centers and villages are provided with electricity by The Gambia Utilities Corporation (GUC) electricity supply. Table 1.4 lists the health centers having power supplies and indicates the nature of those supplies. The GUC is also generally responsible for water supply to those centers, since the water is usually pumped from a borehole.

2.11 All mains electricity in the provinces is supplied from isolated networks energized by small diesel generating plant that are rated at tens or, in a few cases, hundreds of kilowatts. Although these isolated electricity systems originally were intended to provide 24-hour service per day, GUC policy since May 1984 has been to run the generating plants for no more than 12 hours in 24, usually in two 6-hour periods from 6:00 a.m. to 12:00 noon, and from 6:00 p.m. to midnight. GVC adopted this policy in response to the worsening fuel supply situation in The Gambia which reflects the shortage of foreign exchange with which to pay for petroleum products. In reality, however, electricity supply has virtually never been continuously available in most provincial centers, and even the current daily 12-hour service can hardly be maintained. While fuel shortage is the primary cause, there are also significant maintenance problems. Given the high cost of maintaining the isolated systems and the recurring fuel shortages, it seems highly unlikely that the degree of reliability offered by solar photovoltaic systems will ever be achieved by GUC in its provincial electricity supply services.

2.12 At some of the smaller centers, the local diesel generating plant provides power almost exclusively to the health centers, and is some cases managed by DOH. However, DOH has recently handed over the responsibility for operating all such diesel generating plants to the GUC, whose own staff operate and maintain the equipment. In cases where the equipment is small and used principally for supplying the needs of the health center, the GUC charges DOH on a full cost recovery basis, but regular GUC electricity tariffs apply when the supply comes from the local GUC station. In the situations where the GUC charge is on a full cost recovery basis and the local power plant is out of service for extended periods, DOH has to pay significant overheads for power (Tables 2.5 and 2.6). Where a GUC provincial grid is involved, the tariff varies from D 0.335/unit (for first 30 units) to D 0.51 (for over 1,000 units). However, as of January 1984, GUC has increased its tariff by an average of 30%, which has in effect raised the price of electricity to some US¢10-16/kWh.

Table 2.4: SERVICES AVAILABLE AT HEALTH CENTERS AND DISPENSARIES

Location	Power Supply	Water Supply	Telephone	Refrigerator
Health Centers				
Bakau	mains	piped	yes	kerosene
Basse	mains	piped	yes e/	kero & elec
Brikama	mains	piped	yes	electric
Bwiam	diesel	borehole	yes e/	kerosene
Essau	none	well	nearby	kerosene
Farafenni	mains	piped	nearby e/	kerosene
Fatoto	diesel	piped	nearby	kerosene
Georgetown	none a/	piped	nearby	kerosene
Gunjur	none	well d/	nearby	solar PV
Kaur	none b/	well	nearby e/	solar PV
Kerewan	none	well	nearby	kerosene
Kiang Karantaba	diesel	borehole	yes e/	kerosene
Kudang	diesel	borehole	nearby	kerosene
Kuntaur	none	river	nearby	kerosene
Mansa Konko	mains	piped	yes	electric
Serrekunda	mains	piped	nearby	none
Sibanor	diesel	borehole	no	kerosene
Yorobawal	diesel	piped	yes c/	kerosene
Dispensaries				
Baja Kunda	none	well	no	kerosene
Brikamaba	none	well d/	no	kerosene
Brufut	none	borehole	nearby	kerosene
Chamen	none	well	no	kerosene
Dankunku	none	well	nearby e/	kerosene
Diabugu Basilla	none	well	nearby e/	kerosene
Gambisarra	none	well	nearby	kerosene
Kuntair	none	well	no	kerosene
Medina Bafaloto	none	well	no	kerosene
Sami Karamtaba	none	well	no	kerosene
Salikene	none	well	nearby e/	kerosene
Sukuta	none	well	nearby	kerosene

a/ Mains power in town, but health center not connected.
b/ Health center about to move to new premises with diesel.
c/ Telephone equipment removed after failure and not replaced.
d/ Well frequently dries up leaving no water supply.
e/ Telephone believed to be generally not working.

Source: DOH, The Gambia.

2.13 Some typical examples illustrating the power supply situation for those health centers having GUC connections are:

(a) The large health center at Basse (30 staff and 45 beds) received no electrical power at all for five and a half months (January to June 1984) due to major maintenance and repair problems with the local GUC power plant. This failure caused great inconvenience to this health center since its water supply, and hence sanitation, lighting, and refrigeration were all dependent on regular electricity supply. Medical staff were reduced to driving in private cars to a public water point some distance away and bringing water back in buckets.

(b) The large Kudang health center, only just completed with bilateral assistance from the Peoples' Republic of China, is more like a small hospital than a health center as it even has a well-equipped theatre. However, it had no electrical power for over twelve weeks prior to the mission's visit due to a technical problem in integrating the center's new diesel generating plant with the local GUC network.

(c) The small (59 kVA) generating station at Bwiam is limiting its output to only 6 hours per day (6 p.m. to midnight) because of inadequate fuel supplies.

(d) The Peoples' Republic of China has built two other health centers, also equipped with diesel generating plants, at Kaur and Kiang Karantaba; these centers have electric water pumps, numerous electric lights, refrigerators, and other electrical equipment. Although the generating plant is new and mechanically reliable, it is expected that restricted fuel supplies will limit the electricity supply even after regular operation of the generating plants has been established by GUC.

(e) Although Georgetown, the provincial administrative center for McCarthy Island Division, has GUC power supply, the health center there is no longer connected to it. However, the GUC still provides the water supply.

Other Health Centers and Dispensaries

2.14 As mentioned before, most of the smaller health centers and all the dispensaries are without either electric power or piped water supply. They rely mostly on kerosene to power their vaccine refrigerators, and either kerosene or candles, and sometimes even privately owned flashlights, for lighting. Hot and boiling water is produced by using kerosene or, more often, wood. Drinking water from the wells is obtained through the use of buckets. Inadequate and unreliable kerosene fuel supplies is the major problem facing these health centers and dispensaries.

Table 2.5: ELECTRICAL POWER PROCURED ON A FLAT-RATE COST BASIS FROM GUC BY THE DOH FOR HEALTH CENTERS WITH GUC-RUN GENERATING PLANT

	Cost in Dalasis per Quarter				
Health Center	1st/83	2nd/83	3rd/83	4th/83	1st/84
Kudang	20,475	19,866	25,467	25,644	29,463
Karantaba	6,553	2,581	(1,266)	(1,266)	(1,266)
Fatoto	13,169	9,349	8,485	9,121	10,399
Bwiam	9,687	9,211	11,114	12,312	17,534
Yorobawal	23,759	10,298	(4,367)	(4,556)	10,069

Note: Figures in parentheses indicate periods when breakdowns prevented any power from being delivered. Variability of other figures indicates shorter breakdowns probably occurred and reduced operating costs as less fuel would have been consumed as a result.

Source: GUC Accounts Department.

Table 2.6: ELECTRICAL POWER PROCURED ON A METERED COST BASIS FROM GUC BY THE DOH FOR HEALTH CENTERS TAKING MAINS ELECTRICAL POWER

	Cost in Dalasis per Quarter				
Health Center	2nd/83	3rd/83	4th/83	1st/84	2nd/84
Mansa Konko	n/a	760	1,067	981	306
Mansa Konko	n/a	n/a	4,080	852	50
Georgetown	0	0	0	0	272
Farafenni	n/a	n/a	177	228	245
Bansang hospital	462	575	535	237	1,245
Basse	n/a	673	986	0	0

Note: Zero figures indicate periods when no power was delivered. Variability of other figures indicates that shorter breakdowns probably occurred and reduced the power that could be consumed.

Source: GUC Accounts Department.

Solar Photovoltaic Refrigerators for Vaccines

2.15 The dissatisfaction with kerosene refrigerators has spurred interest in solar refrigerators in The Gambia. Two solar photovoltaic powered (electric) vaccine refrigerators have therefore been introduced on an experimental basis in The Gambia at the health centers in Gunjur and Kaur. These are identical units manufactured by Solar Power Corporation Inc., a former subsidiary of the Exxon Oil Company which has recently been liquidated. Each unit consists of an electric compression refrigerator/freezer in a well insulated, top-opening casing. The unit is powered from a bank of six 105Ah 12V Delco model 2000 lead-acid batteries, which are charged by a photovoltaic array rated at approximately 315 W(p).

2.16 These units were supplied by the Center for Disease Control, (CDC) of Atlanta, Georgia (USA) working with the National Aeronautical and Space Administration (NASA), Lewis Research Center, and financed by USAID. The two solar refrigerators in The Gambia have been fitted with instrumentation to measure internal and ambient temperatures, plus other key operating parameters such as solar irradiance, operating hours, battery voltage, etc. The data are analyzed periodically by NASA-Lewis in the U.S.

2.17 The mission was told that the two solar refrigerators had performed quite satisfactorily since their installation, except for one occasion when the unit at Kaur had to be defrosted and disconnected for about three days. This was done on instructions from NASA-Lewis in order to fully recharge the batteries after the data had indicated that the batteries were not staying at an adequate voltage. There are two probable reasons for inadequate voltage: first, there may only have been a minor fault either in the charging circuit or in one of the batteries since all the primary components appeared to be functioning properly; second, there may have been some abuse of the system, e.g., through overloading of the refrigerator by the operators with food or drinks in addition to the normal vaccines and ice-packs. The former could have been corrected easily if the attendant were properly trained, as is planned through the present project. The latter fault could have been prevented by equipping the refrigerators with a padlock, as indeed the kerosene refrigerators are currently equipped. The experience with solar refrigerators in The Gambia can, therefore, be considered successful.

Well-defined Needs: Refrigeration, Lighting and Water Heating

2.18 There are certain energy-related applications which are common to all The Gambian rural health centers and dispensaries where solar energy systems might be used quite effectively. For these applications the solar energy systems can form a standard "package" which would be common for all intended locations. These are: refrigeration of vaccines, lighting; and water heating for bathing newly delivered babies as well as for sterilization.

2.19 Refrigerators for Vaccines. It has already been demonstrated in The Gambia and several other developing countries that the use of solar powered vaccine refrigerators is technically feasible. Furthermore, there are now a number of solar vaccine refrigerators on the market. Therefore, it is feasible to invite bids for the supply of reliable solar powered vaccine refrigerators which could be used to substitute for all the existing kerosene refrigerators in rural health centers and clinics in The Gambia. Technically speaking, the solar refrigerators can be introduced into The Gambia to successfully overcome the problems currently being experienced due to kerosene shortages and distribution difficulties, provided only well-proven equipment is procured, local staff are trained, procedures to prevent misuse are implemented, and suitable technical assistance is provided in the initial stages of the project implementation.

2.20 It is important to ensure that the investment in solar photovoltaic vaccine refrigerators represents a reasonably sound use of development funds when compared with the costs of the existing kerosene fuelled system. As such, this report has analyzed the economics of solar versus kerosene vaccine refrigerators. As the EPI is not an "economic activity" the only meaningful quantified results relate to the relative costs of the options and their likely influence on the achievement of EPI goals. This latter point is important since the overheads for the EPI are significant at about US$350,000 per year and if better results can be obtained through the introduction of improved technology, it can be argued that this represents a better return in relation to EPI general overheads. The analysis is summarised in Table 2.7 and presented in detail in Annex 1.

Table 2.7: COMPARATIVE ANALYSIS OF SOLAR AND KEROSENE REFRIGERATION (US$)

	Kerosene	Solar Low	Solar High
Capital cost (installed)	400	4,680	6,569
Recurrent costs	853	60	120
Annualized life cycle costs	901	716	1,108
Reliability (assumed) (%)	80	100	90
Yearly Doses per refrigerator	13,373	16,716	15,044
Refrigerator direct cost/dose	.07	.04	.07
EPI overhead per dose	1.05	.84	.93
Total cost per dose	1.12	.88	1.00

2.21 This analysis assumes two scenarios for solar refrigerators, designated as 'solar low' and 'solar high'. The 'solar low' scenario is based on the lower range of refrigerator prices available in the market plus a higher degree of system reliability (100% - performs faultlessly throughout the year). The 'solar high' scenario, on the other hand, is marked by a higher range of refrigerator market prices and permissible system reliability (90%). The two scenarios, therefore, provide the lower and upper bounds for evaluating the economics of solar refrigerators in The Gambia. As Table 2.7 shows, the effect of displacing kerosene refrigerators by solar refrigerators would effectively reduce the cost per dose by about 12-22%.

2.22 The main benefits to be expected from the use of solar vaccine refrigerators include: (a) substitution for kerosene (worth US$19,450 p.a.); reduction in spoiled vaccines (worth US$4,605 p.a.); (b) reduced refrigerator down-time due to elimination of problems caused by kerosene supply problems; (c) increased immunization success rate due to both improved vaccine availability and better chance of being able to provide follow up "booster" shots; and (d) reduced maintenance work-load for skilled technicians and medical personnel, thus releasing them for other tasks.

2.23 Lighting. One of the most serious difficulties pointed out to the mission by medical personnel was the lack of proper lighting at the health centers and dispensaries. This problem applies even in centers nationally connected to a mains supply, since the supply is both intermittent and unreliable. Lack of adequate lighting can actually be a hazard to life in emergency situations, such as difficult deliveries of babies, and stitching of serious wounds. These are often conducted either by candlelight or the failing batteries of a small flashlight. Solar PV lights can effectively address this problem.

2.24 The economic benefits of providing lighting cannot readily be quantified, since there are no costs incurred by the DOH that will be displaced, other than a marginal excess of kerosene added to that supplied for the refrigerators at present (notionally 0.06 liter/day delivered, or about US$26.00 per annum). No doubt that small sum of money will also be saved by medical personnel who currently purchase candles and torch batteries from their own funds. Besides that, insufficient information on the mix and usage patterns of different types of lighting sources prevents any meaningful analysis. In addition, none of the existing options can, in reality, be considered as real alternatives since the basic reason for considering solar powered lighting is that existing options are inadequate. However, if the same degree of illumination were to be provided by kerosene lamps as that provided by two 20W solar fluorescent lamps, 6 kerosene hurricane lamps would probably have to be used, with a total recurrent cost of over US$250 per year.

2.25 An important factor to be considered is that, at present, while kerosene is notionally intended to be used for lighting, and a hurricane lamp is provided by DOH, the kerosene supplies in practice are quite inadequate. If the kerosene refrigerators are replaced by solar refrigerators, then even the limited supply of kerosene that is at present available will probably cease to be supplied. So it can be argued that some steps should be taken to provide an alternative to kerosene for lighting, or an already difficult situation could be made worse.

2.26 If solar powered vaccine refrigerators, equipped as they are (in the interest of extra reliability) with sizeable battery-electric storage, are provided, then a low powered lighting package could easily be provided at a marginal extra cost in relation to the total budget for the proposed program. This will help provide the minimal lighting for night-time emergencies which should be an integral component of an effective rural health service.

2.27 Energy demand for lighting, and hence costs, will depend on the average daily usage. Unless adequate solar array and battery storage capacity are made available, excessive usage could result in over-discharge of the batteries which in turn could introduce a hazard for the stored vaccines. Some measures proposed to guard against this include: (a) conservative sizing of the array; (b) stricter regulation by DOH; and (c) provision of "time clocks" on the lighting systems.

2.28 Water Heating. Hot water is needed for activities such as bathing newborn babies, dressing wounds, and staff hand washing. Boiling water is needed to sterilize instruments and syringes, especially as the high cost of disposable syringes causes them to be re-used, on average, seven times in the rural health sector. A supply of boiled water is also necessary for making up medications and for other applications requiring sterile water. Kerosene left over from the fuel supply for the vaccine refrigerators is expected to be used for heating and boiling water, but as already explained, it is not available in sufficient quantity, and wood is often used instead. It should be noted that often hot water, even when it is needed, is not used for want of fuel.

2.29 It would be a simple matter, technically, to provide a continuous small supply of hot water by providing a combined solar water heater and insulated storage tank and thereby help meet some of the basic hot water needs in the rural health sector. Obviously, the hot water would require subsequent boost in temperature (through the use of kerosene or wood) to bring it to boil and meet sterilization needs, but the fuel needs will be more than halved through the use of solar water heating.

2.30 There are a number of commercially available solar water heaters capable of fulfilling the needs of The Gambian health sector. Their costs are variable, but to produce about 30 gallons/day of water typically at 60°C would require a system costing approximately US$300. Each solar water heater would harvest about 8 million Btus per year. If this energy were to be provided by kerosene, it would cost about US$60. Therefore, for 25 centers the fuel savings would be about US$1,500. Additionally, the availability of hot water would have a favorable impact both on the hygienic conditions in the health centers and on staff morale.

Less Clear Needs - Telecommunications and Water Supplies

2.31 It is clear that additional serious difficulties are experienced in the rural health sector due to either lack of communications or unreliable communications, and also inadequate and often polluted water supplies. However, unlike the needs discussed in the previous section, these requirements are less easily solved through a simple technical "package".

2.32 Telecommunications. As indicated in Table 2.4, only 7 out of 30 centers have a telephone, which in many cases is quite unreliable, while one privately-run health center and six dispensaries lack any access to a nearby telephone. In reality, then, with the general unreliability of the rural telecommunications system, the majority of the telephones that are installed or lie within an accessible distance are so unreliable that there is little expectation of ever being able to make a successful call, except at centers close to Banjul. Consequently, the health centers and dispensaries are generally not able to use telephone communication. Chapter III describes in more detail proposed steps for rehabilitating and extending the rural telephone system to provide a reasonably reliable telephone link at or near each health center and dispensary. Some of the benefits for the rural health sector expected from this effort include: (a) saving of unnecessary travel and distribution costs; (b) reduced risk in emergencies; and (c) improved morale for medical staff.

2.33 Without detailed microeconomic studies, the benefits listed above are difficult to quantify, although cash savings should result. For example, benefit (a) above should reduce the amount of travel that is needed by DOH personnel, whose only method of seeking information or advice, or obtaining urgently needed supplies is to travel to an appropriate source of supply. Additionally, lack of communications prevents the efficient distribution and restocking of consumables, which inevitably involves unnecessary journeys, wastage through over-delivery, and inconvenience through under-delivery.

2.34 It is proposed to extend and upgrade the existing rural telecommunications system to improve the reliability of the existing system and to expand it so that all health centers and dispensaries either have a telephone at the center or one in close proximity. The justifications, details and costs of doing this are presented in Chapter III.

2.35 Water Supplies. The mission identified at least five health centers and ten dispensaries with sub-standard water supplies where measures need to be taken to upgrade and improve the existing facilities. These facilities are described in Table 2.4. The precise requirements for each center will generally be different in terms of both water needs (quantities required) and physical pumping requirement (pumping head and distance to be delivered). It was beyond the scope of this mission to conduct a detailed survey for all centers, which would have been necessary to specify the equipment requirements and costs of providing an adequate and reliable water supply system. It is proposed that the next step should be a consultant study of the water needs of all health centers and dispensaries with the objective of defining in detail the optimum pumping systems to satisfy the requirements. This is discussed in detail in Chapter IV.

Recommendations for the Rural Health Sector

Solar Photovoltaic Vaccine Refrigerator and Lighting Package

2.36 It is recommended that: (a) all 25 kerosene-fuelled vaccine refrigerators listed in Table 2.4 be replaced by photovoltaic (PV) vaccine refrigerators; and (b) each vaccine refrigerator should have, included as part of each package, two small fluorescent lights running off the same batteries. A total of 26 complete PV systems should be procured in order to provide one complete spare system, and that an additional system should also be procured -- minus the photovoltaic array -- to provide a second complete spare "balance of system" package for use as spares. This latter provision is necessary because arrays are less likely to develop faults than the remaining components, but they are the most expensive single element of each system. However, in practice, it is recommended that when the government invites bids, each prospective supplier should be requested to incorporate an appropriate spare-parts inventory to accompany the consignment offered in their respective bids. 8/

2.37 All the systems to be procured should be identical and provided by one supplier. The provision of an adequate warranty is an important criterion for selecting the supplier. Annex 2 provides a general description of vaccine refrigerators, while Annex 3 gives details of methods recommended for sizing and evaluating the economics of PV systems. The Technical Supplement includes a draft tender document (Annex A) for inviting bids from suppliers which effectively details the procurement requirements. Also included as part of the draft tender document are technical specifications of the solar refrigerators to be procured for The Gambia.

2.38 The displaced kerosene refrigerators and kerosene lamps should be retained by the centers concerned and remain the property of DOH rather than being sold. It is recommended that these be offered for the use of staff (who would be responsible for providing kerosene). The displaced equipment, thus, will be available if the solar unit were to fail, which would be unlikely. Also, the availability of kerosene refrigerators for staff use (for drinks, etc.) would further reduce the possibility of abuse of solar refrigerators by the staff.

8/ The additional cost of two PV systems has been factored into the economics of solar refrigerators in Annex 1.

2.39 It is recommended that specialized technical assistance be provided as a component of the project to assist the Government of The Gambia in appraising the tenders received, selecting the equipment and then with installing and commissioning the delivered vaccine refrigerators. The details of how this should be implemented are given in Chapter V.

2.40 The cost of solar refrigerators and fluorescent lamps is shown below:

Table 2.8: COST OF SOLAR REFRIGERATORS AND FLUORESCENT LIGHTS

(a) Solar Refrigerators	(US$)
26 systems	133,825
1 spare subsystem (minus the array)	2,425
Total cost of component:	136,250
(b) Fluorescent Lights	
2 x 12V 20W fluorescent lighting units	100
680 Wh extra battery capacity to allow 4 h/night operation (allowing for battery efficiency at 70% and up to 33% maximum discharge)	150
70 Wp extra photovoltaic modules to provide the power supply (2 modules)	420
Total cost of each set:	670
Total procurement of 27 sets (including 2 spares)	18,090

The cost of fluorescent lights can be reduced to one half (i.e., US$9,045) if only one fluorescent light is provided at each center. This, however, will not provide adequate lighting, and should be avoided.

Solar Water Heating

2.41 It is recommended that 25 solar water heating systems be procured, one for each center. At a price of US$300 per system, the estimated cost for all 25 systems would be US$7,500.

Solar Telecommunication Systems and Water Supplies

2.42 Since the telecommunication application in the health care program is shared with that of the telecommunication sector overall, the recommendations and the budgetary requirements are discussed in the next chapter. Similarly, the consultant study on water supplies, which is linked with irrigation water pumping in the McCarthy Island Division, is covered in Chapter V.

III. TELECOMMUNICATIONS SECTOR

The Rural Telecommunications Network

3.1 Geographically, The Gambia is a long and narrow country with the capital (Banjul) located at one end. As a result, the telecommunications network is based on a single UHF trunk running the length of the country, linking Banjul to Georgetown via the provincial towns of Mansa Konko and Kaur. A VHF trunk extension runs eastwards from Georgetown to Basse via Bansang. Also, various single channel VHF links connect the main exchanges on the UHF trunk to surrounding villages and towns (IBRD Map 15991R1).

3.2 In July 1983 The Gambia had approximately 3,400 telephones, of which 92% were located in and around Banjul, the only truly urban area in the country. In other words, less than 300 telephones are distributed throughout the rest of the country, where 80% of the population live. This gives The Gambia 0.55 telephones per 100 people, compared with the average for Africa of 0.66 per 100. The current UN Transport and Communication Decade in Africa has a target of achieving one telephone per 100 people by 1987. Currently The Gambia is clearly below even the relatively low standards of Africa and seems unlikely to achieve the Decade target on schedule. The actual number of Direct Exchange Lines (DELs) is 1,920 (June 1981, Table 3.1), of which 1,670 are located in Banjul and the adjoining Serrakunda and Yundum area, leaving just 250 "rural" DELs for the rest of the country. The situation is further aggravated by the fact that most rural telephones are very unreliable and many of them are not functioning.

3.3 The telephone network is operated by Gamtel, an autonomous corporation formed in 1984 from the former government Department of Telecommunications (DOT). Gamtel has also recently taken over responsibility for international telephone, telex and cables, which up to 1984 had been handled by Cable and Wireless PLC, a UK-based company, via a Standard B satellite earth station located near Banjul and inaugurated in 1978. There is also an international microwave link with Dakar in Senegal which comes under the Pan-African Telecommunications (PANAFTEL) scheme. The general quality of international connections is reportedly good and the capacity appears adequate for present international traffic.

3.4 By contrast, the present quality of the domestic service provided by Gamtel is generally poor. The peri-urban network suffers from almost life expired equipment and lack of adequate maintenance. 9/

9/ Gambia Telecommunications Sector Memorandum, The World Bank, Transportation, Water and Telecommunications Dept., Western Africa Regional Office, Report No. 3603-GM, December 23, 1981.

There is such severe congestion in the trunk network that many local and trunk calls cannot be completed, especially at peak periods. The national long distance network is mostly manually operated, and " ...the quality of service provided by the operators is unsatisfactory and there are frequent complaints". 10/ This situation refers to 1981, and the impression gained by this mission is that, if anything, the situation is worse in 1984, particularly in the rural network. In fact, the UHF trunk backbone connects to the peri-urban network in Banjul through a manual switchboard of obsolete design which is usually manned by only one or two people.

Table 3.1: GAMBIAN TELEPHONE EXCHANGES

Exchange	Capacity	Type	DELs a/
Banjul	1,400	s/s auto	1,027
Serrekunda	800	"	587
Yundum	100	"	56
Brikama	50	"	36
Barra	50	RAX	15
Farafenni	50	"	38
Kaur	50	"	34
Kuntaur	50	"	20
Bansang	50	"	20
Basse	50	"	47
Total auto s/s	2,650		1,880
Kerewan	50	Manual	8
Mansa Konko	50	"	17
Georgetown	50	"	15
Total manual	150		40
Total all types:	2,800		1,920

a/ Number of lines as of June 1981.

Source: Gamtel.

3.5 Further problems occur in the UHF trunk backbone and in the rural network. Many of these problems stem from lack of reliable power supplies for exchanges, repeater stations and single-channel VHF terminals, and from maintaining and operating life-expired and inadequate equipment with limited numbers of staff, insufficient spare parts, and a

10/ Ibid.

shortage of transport. These problems are detailed in the following sections, and means to overcome them are partially addressed by the recommendations made in this report.

3.6 The peri-urban network is expected to be rebuilt and overhauled with modern automatic equipment provided as French bilateral aid, so it is expected that the constraints on the rural network caused by the inadequacies of the peri-urban network will soon be largely removed. However, there are no plans at present to overhaul the rural network, this despite the fact that 80% of the population lives in the rural areas and the economy of The Gambia is largely based on produce from the rural sector. The improvement of the peri-urban system will release some maintenance resources which could be used by the rural networks.

3.7 The economic importance of telecommunications is difficult to establish, but there is considerable evidence of a close correlation between investment in telecommunications and economic growth. A project document of the ITU 11/ argues, inter alia, that investment in telecommunications has often been a consequence of economic development rather than a prerequisite and therefore economic development has been inhibited. It shows also that, although the costs of rural telecommunications are relatively high and no doubt inhibit such investment, particularly where benefits tend to be intangible, the benefits revealed by recent analytical studies are exceptionally high, especially in remote rural areas having poor transport facilities. Examples of tangible benefits exceeding costs by many hundreds of percent have been found in case studies relating to development of rural economies in many developing countries (cited in the above document). Unfortunately, considerable on-the-spot investigation and analysis would be needed to quantify benefits from improving and enlarging The Gambia's rural telephone network. Therefore, although this report looks at the direct benefits to Gamtel of implementing the recommendations which follow, and justifies them mainly on that basis, much greater intangible benefits to The Gambia can be expected as well.

The Multi-Channel Trunk System

3.8 The first trunk system in The Gambia was installed in 1961/62 by General Electric Company, Ltd. This was a VHF five channel backbone connecting Banjul to Basse via Kerewan, Mansa Konko, Kaur, Kuntaur, Georgetown and Bansang. By 1978 only two channels in the system were still working. Project UNDP/ITU GAM/78/003 was the main element of technical assistance for the rural telephone network and was provided with the services of an ITU appointed expert, who implemented a number of developments specifically relating to single-channel VHF spurs and links,

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11/ Project Document of ITU-OECD Project, Telecommunications for Development, International Telecommunication Union (ITU), Geneva, 1983.

which are detailed later. He also assisted the DOT in acceptance trials of the UHF trunk backbone.

3.9 The UK government financed the construction of the replacement trunk system, this being the 470MHz UHF trunk backbone currently used; this project was executed by the Crown Agents, starting in 1977, and was implemented by the UK firm, Pye. After a number of delays caused by technical problems, it was finally commissioned and accepted in June 1980. A UK engineer has been seconded to Gamtel by the UK Overseas Development Administration (UK-ODA) to provide technical assistance in maintaining the UHF system.

3.10 The UHF system is generally described as a 60-channel system, which is the maximum capacity of the equipment, but the system in The Gambia, in reality, is only equipped with 48 channels. These 48 channels are dedicated in blocks of 12 to different destinations. Beyond Georgetown, the trunk backbone continues as a nominal 24-channel UHF link to Bansang, and thereafter 16 channels carry through to Basse. This is illustrated in Map 15991R and in Table 3.2. It can be seen that there are also 8-channel UHF branches from Banjul to Barre, from Mansa Konko to Farafenni and from Georgetown to Kuntaur.

3.11 The UHF/VHF system generally has a range of 50 km to 60 km between stations. The new system follows the new tarred road on the south Bank of The Gambia River, rather than going along the shorter but more difficult north Bank route via Kerewan as before. Two repeater stations were consequently located between Banjul and Mansa Konko (at Jelekato and Jattaba) and suffer from being at almost the maximum range. The Banjul to Jelekato link also has potential reception problems due to interference from the signal passing low over a substantial stretch of water. Mansa Konko is the first exchange out of Banjul and takes 12 channels to serve itself and surrounding towns. The UHF trunk route then switches to the north bank and passes via another exchange at Kaur and a repeater at Makagui to Georgetown, provincial headquarters of McCarthy Island Division, the province from which most of The Gambia's commercial agricultural produce is derived. The eastern end of the country is served from Basse exchange, which is reached via the repeater and exchange at Bansang. The Bansang-Basse 24-channel UHF link is again at the limit of its range and suffers at times from interference caused by two hilltops, Nella Kunda and Bagadagi, very close to the line-of-sight for signal transmission.

Provincial Telephone Exchanges on Trunk Network

3.12 There are seven exchanges associated with the trunk network, plus a small manual exchange at Kerewan to serve the town's 8 DELs and one remaining (intermittently available) rural spur to Salikene. The seven exchanges are: Farafenni, Mansa Konko, Kaur, Kuntaur, Georgetown, Bansang, and Basse. The first five exchanges in Table 3.1 are in effect part of the peri-urban system.

3.13 There is no national electricity grid in The Gambia, so all the provincial exchanges and repeater stations are dependent either on small GUC local mains electric supplies, on Gamtel diesel generating sets, or sometimes both. Since neither the mains supply nor the generating sets generally can give a 24-hour service, the telecommunications equipment runs from a bank of lead-acid batteries which are charged by the mains or the generator. Table 3.3 summarises the power supplies and battery capacity installed at the exchanges.

3.14 Maintaining an adequate state of charge in the batteries is proving to be a problem for many of these exchanges due to both deteriorating batteries and difficulties in providing regular and adequate recharging. This is discussed further in (para. 3.29).

Single-Channel VHF Links to the Villages

3.15 There are 17 single channel VHF links and spurs from the provincial town exchanges to villages and small towns. These are all 148-174 MHz VHF duplex two-frequency systems which terminate in the villages at a public pay phone, usually in a brick-built kiosk fitted with a 10 to 15m guyed mast and antenna. The standard equipment is Plessey (UK) model PRD707 1W or 8W transceivers of about 1978 vintage, but a few Philips (Australia) 1W or 15W FM880s of about 1980 vintage are also in use. Standard Associated Automation 2-button pay phones (UK) are connected to the transceivers.

3.16 The equipment was originally intended to be powered from EMU type primary batteries. These proved expensive and unreliable under tropical conditions and were replaced by lead-acid secondary storage batteries recharged, in a few cases, by a local generating set, or removed for recharging elsewhere and replaced by a freshly charged unit at appropriate intervals. Standard car batteries of 12V 30Ah rating are used for this purpose as they are readily available in The Gambia. Charging of car batteries in this way has proved to be problematic, since they do not readily survive periods of over-discharge and it has been impossible to arrange reliable enough recharging facilities. Therefore a solar photovoltaic power system using 20W Solarex (UK) solar panels and German sealed lead-acid "Dryfit" batteries was devised for this purpose.

Table 3.2: UHF AND VHF RURAL RADIO TELEPHONE LINKS (1984)
(excluding Banjul semi-urban network)

From	To	Channels (used nominal)	Distance b/ (km)	In use? a/ (Y/N)
	A. 470 MHz UHF Trunk System			
Banjul	Jelekato	48/60	41	Y
Jelekato	Jattaba	48/60	50	Y
Jattaba	Mansa Konko	48/60	38	Y
Mansa Konko	Kaur	32/60	35	Y
Kaur	Makagui	32/60	46	Y
Makagui	Georgetown	32/60	28	Y
	B. Multi-channel 470 MHz UHF Trunk and Spurs			
Banjul	Barra	8	5	Y
Mansa Konko	Farafenni	8	14	Y
Georgetown	Kuntaur	8	19	Y
Georgetown	Bansang	24	16	Y
Bansang	Basse	16	53	Y
	C. Single-channel VHF Links and Spurs			
Banjul	Gunjur	1	33	Y
Banjul	Bwiam	1	58	N
Banjul	Ndungu Kebbe	1	30	Y
Banjul	Kerewan	1	55	Y
Kerewan	Jowara	1	8	N
Kerewan	Manduar	1	16	N
Kerewan	Salikene	1	14	N
Mansa Konko	Illiasa	1	25	N
Mansa Konko	Kwinella	1	30	N
Kaur	Dankunku	1	16	N
Kaur	Kudang (GPMB)	1	25	N
Kuntaur	Kudang (village)	1	18	N
Bansang	Sami Karantaba	1	16	N
Basse	Gambisarra	1	12	N
Basse	Diabugu	1	30	N
Basse	Fatoto	1	30	?
Basse	Sutukoba	1	30	N
Basse	Yarobawal	1	12	N

a/ Denotes whether link was functioning as of July, 1984.
b/ Line-of-sight distance.

3.17 Table 3.4 indicates the power sources and status of all the VHF single-channel links, including nine converted during 1980-81 to solar power. The solar powered systems were relatively successful, especially when first introduced, but due to errors in sizing their batteries and aligning their arrays, most of their batteries appear to have failed after a year or two of use brought on by excessively deep discharge cycles and inadequate recharge. As a result, most of the solar powered systems now can only function when the solar irradiation is strong enough to produce sufficient power to run the transmitter directly from the solar array.

3.18 The problems are further compounded by improper alignment of antennas, incorrect tilt of PV arrays, weak supporting guy wires and, in general, poor maintenance. There are also human problems such as lack of knowledge on the use of the telephone, interference by children, and the habit of leaving the hand-sets "off the hook", which leaves the transmitter switched on and rapidly drains the battery. Fortunately, vandalism has not been a problem. Another important problem relates to siting, namely, a sufficiently unobstructed "line of sight" from the exchange antenna to the terminal antenna. The terminal antennae are generally quite low (10-15m) and are therefore prone to obstruction and interference by trees or low hilltops. The mission recommends that the adequacy of the line-of-sight should be re-checked before renovating of existing single channel lines and, if necessary, there should be re-siting of systems to gain a more favorable transmission path. Yet another major problem has been occasional indiscriminate siting of the systems in underpopulated regions.

3.19 The problems are exacerbated for people wishing to make trunk calls from single channel VHF links the further up-country from Banjul they are due to the many other weak links in the chain. In any case, more than 90% of rural calls from pay-phones are operator-assisted, and even when the system is technically functional, problems have arisen due to poor performance of operators. Similarly, the poor performance of the system dissuades people from even attempting to use the telephones. If public confidence in the reliability of these systems could be re-established, it would have a marked effect on the number of people attempting to use the telephone.

3.20 Tables 3.2 and 3.4 indicate that, as a result of these problems, only about three, or possibly four, out of the seventeen original single-channel VHF units are functioning at this time. In fact the reliability of these systems has been so poor, due mainly to power supply problems, that a number have been removed from their locations (Table 3.4) and returned to storage in Banjul; for example, there is no longer any equipment at Jowara, Kwinella, Manduar or Yarobawal. The two main exceptions, at Gunjur and Fatoto, appear to have functioned relatively reliably and have yielded revenue consistently. This is, perhaps, due to the fact that they have properly aligned antennae and better than average solar arrays. The system at Fatoto is also unique in having a paid attendant who cleans the solar array, reports faults and explains its use to potential customers, and this certainly has a positive influence on its reliability. The system at Gunjur is sufficiently close to Banjul to give a good signal strength even under marginal operational conditions and to be accessible for maintenance by headquarters technical staff.

Table 3.3: POWER SOURCES AND BATTERIES AT PROVINCIAL EXCHANGES AND THE REPEATER STATIONS
(In approx. order eastwards from Banjul)

Location and (Type) a/	Average Telecomm Load (amp) b/	Battery Capacity (no)x(Ah) c/	Battery Charger Rating (amp) d/	Power Source Type e/ (amp)	Charge Rate (h/day)	Duty Cycle	Remarks
Jelekato (U,R)	5A	12x200Ah	30A	2,4kVA D	11A	12	24V
Jattaba (U,R)	5A	12x200Ah	30A	2x4kVA D	11A	12	24V
Farafenni (V,T,X)	7A	2x30Ah	30A	GUC & 5kVA D	17A	12	48V Exchange 24V Radio
Mansa Konko (U,V,D-R,X)	10-11A	12x200Ah	40A	GUC & 5kVA D	22A	12-	24V Exchange 24V Radio
Kaur (U,V,D-R,X)	10-11A	12x200Ah	50A	GUC & 1x8kVA D 1x5kVA D	22A	12-	48V Exchange 24V Radio
Makagui (U,R)	5A	12x200Ah	30A	2x4kVA D	11A	12	
Kuntaur (V,D-R,X)	8A	12x200Ah	30A	3x5kVA D	17A	12+	48V Exchange 24V Radio
Georgetown (U,V,D-R,X)	8A	12x200Ah	40A	GUC & 5kVA D	20A	12-	24V Exchange 24V Radio
Bansang (V,D-R,X)	8A	12x200Ah	30A	GUC only	17A	24	48V Exchange 24V Radio
Basse (V,D-R,X)	12A	12x200Ah	30A	GUC & 5kVA D	17A	12	48V Exchange 24V Radio

a/ Legend: U=UHF V=VHF D-R=drop repeater R=Repeater T=Terminal X=Exchange
b/ Load given as mean current (at 24V in all cases).
c/ Capacity at 10h discharge rate given (where known).
d/ Harmer & Simmons SCI/24 transductor units in all cases.
e/ GUC = mains power (usually supplied 12h per day); D = Gamtel standby diesel; the duty cycle given is "intended" rather than "actual".

Source: Gamtel.

Table 3.4: POWER SOURCES AND BATTERIES AT RURAL SINGLE CHANNEL VHF TERMINALS

Location	Power Source	Battery		Working? a/	Reason for Failure
Gunjur	20Wp solar	6Ah	12V	Yes	
Ndungu Kebbe	20Wp solar	6Ah	12V	Yes	
Bwiam	diesel mains	30Ah	12V	No	flat battery
Jowara	none b/			No	removed
Salikene	diesel mains	30Ah	12V	No	flat battery
Manduar	none b/			No	removed
Illiasa	none c/	30Ah	12V	No	flat battery
Kwinella	none b/			No	removed
Dankunku	20Wp solar	6Ah	12V	No	faulty installation
Kudang (GPMB)	diesel gen.	missing		No	no battery
Kudang village	20Wp solar	6Ah	12V	No	faulty installation
Sami Karantaba	20Wp solar	6Ah	12V	No	faulty installation
Gambissara	20Wp solar	6Ah	12V	No	faulty installation
Diabugu	20Wp solar	6Ah	12V	No	faulty installation
Fatoto	20Wp solar	6Ah	12V	?	faulty installation
Sutukoba	20Wp solar	6Ah	12V	No	faulty installation
Yarobawal	20Wp solar	6Ah	12V	No	removed

a/ Note that some of the faulty solar powered systems shown as not working do occasionally function, while those marked as working do function most days, but usually without a high level of reliability.

b/ Systems with no power source originally used EMU cells; when these proved too troublesome, no alternative was available so the system was removed.

c/ This system had a car battery to replace an EMU cell; this is supposed to be regularly taken away to be charged, but lack of transport prevents this.

Source: Gamtel.

Structure of Telecommunications Operation

3.21 Until recently, Gamtel was a government department integrated with the postal service. It is now a commercial corporation with a board of directors and a mandate to seek profits.

Gamtel Finances

3.22 On the financial side, a major problem for the old DOT was that around 50% of telephone traffic had been through government departmental telephones and it had not been reimbursed for this traffic. Consequently, the DOT operated at a loss. For example, telecommunications operating revenue for 1978-9 was approximately D 587,000 and expenditure was D 710,012, resulting in a loss of about D 123,000. According to the Government estimates, the expected expenditure for FY83-84 has risen to D 1,316,400, and an associated loss of over D 350,000. Since Gamtel as an autonomous corporation will now be able to bill government departments, it is expected that a large proportion of the potential revenue from government traffic will be collected and that Gamtel will achieve a far better financial return than the DOT did. In addition, it is expected that the imminent rehabilitation of the peri-urban system, which contains most of the current telephone DELs, will generate extra traffic and additional revenues.

3.23 Revenue from the rural network is naturally small at present due to the limited number of lines in use and the poor condition of the system. Nevertheless, Table 3.5 indicates that ten public call boxes yielded D 12,285 per quarter on average for the five quarters from January 1983 through March 1984. The data shows that the call box at Basse appears to function reliably and has yielded nearly three times the average revenue per call box; this may give some indication as to the possible revenue to be obtained from call boxes if they develop a reliable reputation. The mean cost per call is also estimated in Table 3.5 and can be compared with the tariff rates given in Table 3.6. The table shows that local calls are not timed and are at a flat rate, but trunk calls are timed and have a minimum charge for three minutes. The high average cost of calls originating from the Banjul call box may be due to a number of international calls to Senegal or because a large proportion of calls are from people with families in the provinces. For similar reasons the average cost of calls originating in Basse is high, as any calls from there to Banjul will be at the highest rate. The average cost per call for the ten call boxes is D 1.73 and for the nine call boxes (excluding Banjul) is still D 1.43.

Table 3.5: USE OF PUBLIC CALL BOXES
(capital & main centers) a/

Location	No. of Calls (per qtr)	Gross Revenue (Dalasis)	Mean Cost/Call (Dalasis)
Banjul	828	1952	2.36
Brikama	924	730	.79
Kerewan	197	120	.61
Farafenni	567	984	1.73
Mansa Konko	364	610	1.68
Kaur	853	1038	1.22
Kuntaur	525	823	1.57
Georgetown	853	1478	1.73
Bansang	566	935	1.65
Basse	1860	3615	1.94

a/ Average figures for 1983 plus 1st quarter 1984.
Source: Gamtel.

Table 3.6: SUMMARY OF TELEPHONE CHARGES (1984)

Type of Call	Cost (Dalasis)
Local call (same exchange or auto-dial area)	
private subscriber:	0.20
public call box :	0.25
Trunk calls per minute (minimum charge 3 minutes) same for both private subscriber and public call boxes:	
From Banjul up to Kerewan or Bwiam	0.25
From Banjul to Farafenni, Mansa Konko & Dankunku	0.50
From Banjul to Kuntaur, Georgetown and beyond	0.75

Source: Gamtel.

Maintenance Problems

3.24 The UHF trunk back-bone and the single-channel VHF links come under Gamtel's Department for Transmission of Radio and Telex, which has a limited number of centrally-based technical maintenance staff (three or four plus two vehicles). Any faults other than the most commonplace and trivial need to be investigated and rectified by centrally-based staff. Therefore, if a number of simultaneous faults develop in different parts of the rural network, it is a time-consuming operation to send out a team headed by a technically proficient person to correct the faults. Ironically, the team is often incommunicado for many hours due to the very faults it is trying to correct. It often cannot be notified from headquarters of further problems that may have arisen in its area, simply because there are no two way radio-telephones in team vehicles. In fact, the vehicles are ill-equipped and often major systems have to be taken back to Banjul for repair because not enough mobile facilities for testing are available. Similarly, there are no spare batteries, so that flat batteries have to be taken away to be recharged and returned later at great expense in travel costs and unnecessary extra down-time. Therefore a modest investment in spare batteries, mobile radio-telephones and mobile test-equipment could radically improve the effectiveness of the maintenance team. This need appears to be well known within Gamtel, but the resources to procure the necessary items do not exist at present.

3.25 Some proposals to remedy this problem are discussed later in this chapter. The general philosophy for the future specification of equipment should be to pay a premium, where necessary, on new equipment to minimize failure modes. For example, the provision of better battery charge regulators might reduce the incidence of battery problems and limit the transmission of excessive voltage spikes from the generating sets, while the provision of better shaded and ventilated enclosures for the VHF equipment would no doubt reduce the incidence of electronic component failures. A poor country like The Gambia can ill-afford the use of cheap equipment. Systems procured for The Gambia need to be as failure-free as possible in order to allow technical staff to successfully complete routine maintenance; otherwise considerable time will be spent rushing from one breakdown to the next, as appears to be the case at present.

Power Supply Problems in the Telecommunications Sector

3.26 It is clear that power supply problems, including fuel shortages, undersized and damaged batteries and inadequate means to charge them, represent perhaps the biggest problem area for the rural telephone system. Power problems directly or indirectly cause significant but unquantifiable system down time, as illustrated in the following paragraphs.

UHF Repeater Stations

3.27 One particular problem arises at the three UHF repeater stations at Jelekato, Jattaba, and Makagui, which, being in remote areas, do not have a GUC supply but are provided with a pair of Gamtel diesel generating sets. These stations have only one semi-skilled attendant and security guard who operates and maintains the generating plant and reports faults. In recent months, power supply problems with these repeaters have caused a number of system failures and a great deal of travel for engineers and technicians from Banjul to make repairs; fuel shortages have seriously aggravated the problem. The weakest points in the UHF links are recognized to be the UHF repeaters and their unreliable power supplies.

3.28 An indirect problem associated with the power supplies relates to voltage regulation. Even very brief "voltage excursions" can cause damage to batteries and to charging equipment, and can possibly be transmitted through the battery charging system and affect telecommunications equipment. Transient excess voltages can occur because the electrical load at the repeater stations is very small in relation to the generating plant capacity, and the diesel system is grossly derated. 12/ The gross derating also no doubt adversely affects both diesel engine efficiency and its maintenance, since continuous running of diesels at part load can

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12/ The repeater stations use small Lister single cylinder air-cooled diesel single-phase generating sets rated at 3.8 kVA (3.4 kW). The normal (or intended) charging rate, however, is only 11A at 24V, or 264W. This requires about 350W from the generator, which is only about 10% of its rated output.

cause carbonization and hence require more frequent maintenance. Unfortunately, there is no solution to this problem while using diesel power, as the engines being used are about the smallest size available that have adequate durability and reliability. This is why the application in question is particularly well suited to conversion to solar photovoltaic power.

Provincial Terminal Exchanges

3.29 The battery storage is generally adequate for a situation where a regular and reliable 12h/day charging current is available (except at Farafenni where two car batteries with inadequate capacities are in use). However, as explained in Chapter II, the GUC supplies at present tend to be 12h/day at best. In some cases there have been many weeks of GUC supply down time. This is indicated in Table 3.7 where, for example Gamtel paid only the standing charge of D 10.00 for Basse during the 1st quarter of 1984 because zero kilowatt hours were metered. Only the standing charge was paid because of the many months of down-time at the Basse GUC plant. Unlike DOH, Gamtel has had to use its own standby plant with diesel engines similar to those at UHF repeater stations as the prime power source. Thus, the Gamtel plants suffer from exactly the same problems as the repeater stations.

3.30 Unfortunately, a combination of excessively deep discharge cycles and excessive voltage excursions has led to evidence of serious deterioration of many batteries. Once a few cells in a series string begin to fail, the remaining cells receive an excessive charging voltage, which in turn shortens their lives. Lack of spare batteries has led to such desperate measures as the insertion of odd smaller 2V cells in a series of larger cells (witnessed by the mission at Basse) to keep the voltage per cell at an acceptable level; despite this "bodge", many of the cells are gassing badly and their electrodes are visibly breaking up. There is therefore a vicious circle of decreasing battery capacity due to deteriorating batteries and lengthy gaps between recharging due to a deteriorating electricity supply service. Even Gamtel's own standby plant, which appears to be relatively well maintained and functional and which, therefore, is being increasingly depended on, is threatened by nationwide fuel shortages.

Single-Channel Rural VHF Links

3.31 Transport difficulties, due mainly to fuel shortages, have made the regular replacement of discharged lead-acid batteries with recharged ones impracticable, and these installations have generally been removed. Besides, even if transport were not a deterrent, the high cost of transporting batteries would render this option very questionable.

3.32 The solar power systems, for the VHF links use sealed lead acid "Dryfit" batteries of only 5.7 Ah depending on assumptions on the duty cycle (transmit time), are significantly below the necessary capacity for reliable operation. Actually, about 50 Ah would have been more suitable.

This undersizing of batteries has made the operation of solar powered VHF systems nearly impossible.

Table 3.7: ELECTRICAL POWER PROCURED ON A METERED COST BASIS FROM GUC BY GAMTEL FOR EXCHANGES TAKING MAINS ELECTRICAL POWER

Exchange	Cost in Dalasis per Quarter 2nd 83	3rd 83	4th 83	1st 84	2nd 84
Mansa Konko	835	502	751	711	691
Georgetown T	n/a	n/a	1,523	1,439	1,981
Bansang VHF stn	1,314	1,573	1,797	1,943	1,874
Basse P & T	2,583	1,428	857	10	514

Note: Low and variable figures indicate breakdowns probably occurred and reduced power that could be consumed. D 10 is the quarterly standing charge, therefore no power was procured in Basse in 1st quarter 84.

Source: GUC Accounts Department.

3.33 The single channel VHF units proved that they can work under favorable circumstances, but a combination of errors in their implementation marred the systems sufficiently to render the majority unserviceable by mid-1984. As mentioned earlier, two or three continue to function; nevertheless, it is probable that they, too, are prone to develop faults and that they could be improved by introducing appropriate corrective measures.

Recommendations for the Telecommunications Sector

3.34 The objective of these recommendations is to eliminate or reduce some of the aforementioned constraints to providing an adequate rural public telephone service in The Gambia. A number of further recommendations follow, aimed at further reducing some of the factors known to inhibit the operation of the rural telephone service.

UHF Repeater Stations

3.35 It is recommended that the existing diesel generating sets, battery chargers and battery banks be completely replaced at all three UHF repeater stations (Jelakato, Jattaba and Makagui) with solar photovoltaic powered systems. All three repeater stations are identically equipped and can, therefore, be identically re-equipped. It is assumed that this electricity demand is to be met by providing an appropriate new bank of lead acid batteries, plus, of course, a photovoltaic array and battery charge regulator.

3.36 Results of Analysis and Justification. The costs and benefits to be expected from the implementation of this recommendation are detailed in Annex 6 and summarized in Table 3.8. The financial benefits to be gained are primarily savings in both diesel fuel and maintenance of diesel generating plant, combined with a reduction in down-time gained from the use of an inherently more reliable power system. Additional benefits are: first, that three, and eventually all six of the diesel generators, plus the three Harmer and Simmons 30A battery chargers can be redeployed to telephone exchanges to provide extra stand-by capacity; and second, the space created in the engine house can be converted into extra workshop space for overhauling telecommunications equipment. No financial allowance for these latter benefits has made in the analysis, and consequently the benefits shown are conservative.

Table 3.8: COST COMPARISON OF SOLAR AND DIESEL AT REPEATER STATIONS (US$)

	Solar Low	Solar High	Diesel
Installed Cost	18,238	27,220	6,463
Annual Recurrent Cost (O & M)	100	200	3,938
Annualized Life-Cycle Cost	2,617	3,869	4,914
Unit Cost/kWh	1.68	2.49	3.17
Cost as % of Diesel	53%	78%	100%

3.37 The substitution of solar photovoltaic power systems will result in real cost savings, and the cost of power ($/kWh) will decrease by about 22-47%. The high cost of diesel-generated electricity is attributable to the fact that the diesel engines are considerably derated and operate at about 10% of their rated capacity.

3.38 As far as Gamtel is concerned, the financial benefits will be much greater if the solar powered systems are provided in the form of bilateral aid, as the recurrent costs of the solar system are negligible in relation to those of the existing diesel plant. Conversion of the repeater stations to solar power will reduce the annual running costs of each one by a minimum of US$3,838 ($11,514 for all three). Other benefits to be derived from the conversion to solar power include: (a) minimal maintenance requirements, which would release skilled technicians for maintenance of other weak links in the rural system; and (b) increased telephone revenue from reduced UHF system down-time. The increased revenues to be derived from improving system reliability could be significantly higher than might be assumed simply by proportioning it to down-time. This is because many potential users are no doubt deterred from using the telephone by poor expectations of obtaining a connection reasonably quickly.

Provincial Exchanges

3.39 Since the provincial exchanges are an essential link between the proposed rural VHF single channel terminals, it is important to ensure that these are able to function properly. Therefore, it is recommended that all the batteries associated with the trunk network and the VHF single channel feeders at provincial exchanges be replaced and provided with new battery chargers with a higher rating. It is, in any case, essential to replace the existing batteries because most of them are near or beyond the end of their useful lives and there would be significant system down-time resulting from over-discharge of the batteries if no early replacements are provided. However, it is recommended that the existing worn out batteries not simply be replaced with batteries of a similar sized bank, but that the replacement batteries also offer a larger storage capacity. This would reduce the risks of over discharge in the future and allow more rapid charging during the generally shorter periods for which power is available from the GUC or, where stand-by generators are used, to allow charging at a power rate more compatible with the size of the generating set.

3.40 Results of Analysis and Justification. The technical and cost assumptions used for the analysis, and the results obtained are detailed in Annex 5. A summary is provided in Table 3.9. The technical specifications related to the choice of batteries are also discussed in Annex 5. The replacements will be necessary at seven telephone exchanges, namely, Farafenni, Mansa Konko, Kaur, Kuntaur, Georgetown, Bansang and Basse. The total cost to upgrade the battery storage as recommended will be about US$40,000. The main cost savings will be in reduced use of standby generators, as follows: cost of mains power (Table 3.6) average D 0.50 = US$0.13/kWh; and cost of 3.4 kW diesel per hour (Annex 5) = US$1.10/h. It is clear that the present inadequately sized system is marginally less expensive in straight life-cycle cost terms than the proposed replacement, despite having an assumed life of 5.5 years instead of 13.7 years (based on 1 cycle/day).

Table 3.9: COST SAVINGS FROM USING NEW BATTERIES

	Existing Battery (US$)	New Battery (US$)	Difference (US$)
Annual cost with 100% mains	351	351	
Hours needed for 25% engine use	1,095h	703h	
Annual cost with 25% engine use	1,468	1,037	431
Hours needed for 50% engine use	2,190h	1,406h	
Annual cost with 50% engine use	2,584	1,722	862
Hours needed for 100% engine use	4,380h	2,810h	
Annual cost with 100% engine use	4,818	3,091	1,727

3.41 The benefits to be gained by replacing the existing batteries with a larger bank of batteries are: first, greater certainty and predictability of the actual life of the new system; second, reduced battery maintenance and risk of down-time caused by battery problems. This latter benefit is the primary justification for the recommendation, although there is a distinct possibility that implementation will also result in direct financial savings. The reason for this is the significant, but not easily predictable, benefit to be gained through reducing the period of each battery recharge and through extending the allowable gap between recharging. This should significantly reduce the need to use standby generators. However, given the largely unpredictable mains supplies, the need to use the standby generators will continue.

3.42 The cost implications of this are indicated at the bottom of Table 3.9, where the electricity costs with the existing system are about US$351/yr. with 100% mains use and increase to around US$4,818/yr. with 100% diesel generating set use. Increasing the size of the battery bank as proposed will have two effects: first, it will reduce the probability of having to use diesel generating sets, since only an average of 7.7h/day of mains will be needed, and the gap between recharges will be extended to perhaps 48h (compared with 12h/day and 22h at present); second, if lengthy periods of mains down-time occur, then the generating set only needs to be used for perhaps 7.7h in 24 instead of for 12h in 24. The financial benefit of this can range from zero in the unlikely case of 100% mains availability (for both options) to as much as US$1,727/yr. in the event that the system is run continuously on standby generators. Also, the actual efficiency of the standby generators is likely to increase, and their lives will be extended, through running them at a greater percentage of their rated power for fewer hours per year; this will actually reduce generator running costs, although no allowance for this has been made in the analysis. Hence, the probability is that the larger battery storage will allow engine running cost savings to compensate for its extra annualised life-cycle cost once the need for using the standby generators exceeds approximately 15% of charging time.

3.43 The proposed larger batteries will have significant advantages for Gamtel in financial terms if the investment is provided as grant-aid, in that the recurrent costs and future battery replacement costs will be reduced. Assuming that the engines are used 50% of the time, the annual savings for seven provincial stations would equal about US$6,000. Other benefits which are difficult to quantify but which nevertheless could be significant are reduced system down-time, reduced demand on manpower and resources for maintenance, and perhaps increased telephone traffic.

3.44 The budgetary requirement for replacing the existing batteries with a larger bank, as recommended, of 800Ah capacity, will be US$5,600 per exchange including new battery chargers, or US$39,200 for all seven rural exchanges. The existing batteries are, in any case, urgently in need of replacement, and this could be done at a minimum cost of US$1,450 per exchange (if the old chargers are not replaced) or US$10,150 for all seven exchanges. However, the minimum recommended replacement should actually be twice the present capacity and would thus cost about US$29,050 (without new chargers), and the marginal cost of the recommendation would then be US$29,050.

Single-Channel Rural VHF Links

3.45 It is recommended that a total of 20 single channel VHF links terminating with public pay-phones (and one commercial private line to GPMB), be established or, in some cases, rehabilitated; Map 15991R and Table 3.10 illustrate their distribution. These are all to be solar powered, using a fully integrated and purpose-designed solar power system and purpose-designed ventilated enclosures to house the electronic systems.

3.46 Location of Telephones at Health Centers. It is recommended that the new VHF single channel terminals be located at or as near as possible to health centers and dispensaries. In fact, the choice of locations is intended to ensure that every location having a government health center or dispensary will also acquire a public telephone connecting to the rest of the country. There are three main reasons for locating public telephones at or near health centers and dispensaries: (a) these centers are generally accessible to a sizeable catchment of people, and where hundreds of people already gather at clinics several times per week, the locations should be accessible to enough people to generate useful telephone traffic; (b) as explained in Chapter I, the provision of telecommunications for health centers and dispensaries will have major health-related benefits, and DOH staff accords a high priority to it; and (c) the DOH officer in charge could be given responsibility to assign one of his staff to act as caretaker of the public telephone. This appears to be a feasible proposition acceptable both to DOH and Gamtel, and would solve a number of the problems outlined below.

3.47 The mission believes that many of the operational problems experienced with the first generation of rural public telephones can be overcome when an attendant is provided to clean the solar array, and to assist people unfamiliar with the telephone in using it for the first time, and, of course, to report faults. The evidence for this is the successful installation at Fatoto which is unique in being about the only working rural single-channel link up-country, and also unique in having a paid caretaker. Gamtel cannot afford to employ caretakers for remote public telephones, but discussions held by the mission with senior Gamtel and DOH staff indicate that there are advantages in arranging for the health centers and dispensaries to be officially authorised by Gamtel to be responsible for the telephone. DOH would have to be compensated for this service. One possible option would be to allow the respective health centers to make a pre-specified number of calls each month for free, or alternatively receive every month a percentage of the proceeds from the coin boxes.

3.48 Rationale for Selecting the Locations. The first thirteen proposed VHF single-channel links listed in Table 3.10 consist of existing or formerly existing VHF links, eleven of which already terminate at or near a health center or dispensary. They are marked on the table with "T&H", having been originally sited by former DOT and, therefore, obviously selected to suit telephone department needs and, coincidentally, suiting DOH needs, too. The others, at Illiasa and Kwinella (marked "T"), do not have a nearby health center and, while the location selected was to serve DOT rather than DOH interests, they cater to sufficiently large catchments to warrant the telephone which they already have -- except that it rarely works. Additionally, seven new single channel VHF links are proposed for all the locations having health centers or dispensaries that do not currently have a telephone nearby.

3.49 The telephone at the GPMB warehouse at Kudang also needs immediate rehabilitation because of important economic implications. Kundang collects agricultural produce for the whole region, but it is not part of the public telephone network; therefore, it is recommended that Gamtel be provided with an extra solar power unit for this telephone installation, using the existing transceiver and telephone equipment since the operation of the GPMB diesel generator is not reliable enough to warrant its use.

3.50 Table 3.10 also indicates that three former links are not recommended for renewal because they do not serve any DOH interests and their siting is somewhat questionable. These are at Jowara (because it is quite near Kerewan and the reason for having a telephone there was not clear), at Manduar (because a better site is a few kilometers away at the large, newly built health center at Kiang Karantaba), and at Sutukoba where the original installation was badly sited and where a new unit at the nearby dispensary at Baja Kunda can replace it.

3.51 Eight further centers that could benefit from a later phase or from an optional extension to the present project are also listed as "second priority" locations for single channel links. These eight centers could be incorporated in the program as a result of rehabilitating and redeploying some of the existing failed solar powered systems. In this way sufficient equipment would become available to equip these eight additional locations immediately at marginal extra cost. The reason for selecting these extra eight was that seven of them, marked "T" were in the old DOT plan for extending the rural telephone network and should therefore be pursued, provided that Gamtel can demonstrate that the original reasoning for selecting them is still valid. The eighth is the one health center (at Essau) not given a telephone as a "first priority" on the grounds that Essau is very near to Barra, which has a telephone exchange and is just a ferry ride from Banjul; however, for completeness it seems proper that Essau should also eventually have a more convenient telephone at or near the health center too.

Table 3.10: SUMMARY OF RECOMMENDATIONS FOR LOCATIONS OF SOLAR POWERED SINGLE CHANNEL VHF TERMINALS

location	exchange link	est. dist.	proposer	recommendation (action)
		(km)	T=Gamtel H=DOH	(HC=Health Cr.)
A. Existing or Former Single Channel Links				
(i) replace/rehabilitate 13 pre-existing systems				
Gunjur	Banjul	33 +	T&H	renew & resite at HC
Ndungu Kebbe	Banjul	30 +	T&H	renew & resite at HC
Bwiam	Banjul	58 +	T&H	renew
Saikene	Kerewan	14	T&H	renew & resite at HC
Iiliasa	Mansa K.	25	T	renew & review site
Kwinella	Mansa K.	30	T	renew & review site
Dankunku	Kaur	16	T&H	renew & resite at HC
Kudang village	Kuntaur	18	T&H	renew & resite at HC
Sami Karantaba	Bansang	16	T&H	renew & resite at HC
Gambissara	Basse	12	T&H	renew & resite at HC
Diabugu	Basse	30 +	T&H	renew & resite at HC
Fatoto	Basse	35 +	T&H	renew
Yarobawal	Basse	12	T&H	renew at HC
(ii) rehabilitate single GPMB link power system				
Kudang (GPMB)	Kaur	25	GPMB	Gamtel to renew battery & provide solar power
source				
(iii) scrap following pre-existing systems				
Jowara	Kerewan	8	T	do not renew (close enough to Kerewan)
Manduar	Kerewan	16	T	do not renew (replace by new system at K'taba)
Sutukoba	Basse	30	T	do not renew (replace by new syst. at Bajakunda)
B. Seven New Single Channel Links (rationale: to serve HCs and dispensaries currently not near to a telephone)				
Medina B'eto	Banjul	21	H	site at dispensary
Karantaba	Banjul	50 +	H&T	site at HC (replaces Manduar)
Sibanor	Banjul	50 +	H&T	site at mission
Kuntair	Banjul	40 +	H	site at dispensary
Chamen	Banjul	20	H	site at dispensary
Brikamaba	G'town	16	H	site at dispensary
Baja Kunda	Basse	25 +	H	site at dispensary
C. Eight Second Priority Single Channel Links (rationale: part of old DoT plan and/or to serve HCs/dispenseries not covered by A or B because they have access to a nearby phone)				
Faraba Banta	Banjul	21	T	DOT plan proposal
Kafuta	Banjul	30 +	T	DOT plan proposal
Juffure or Albreda	Banjul	25	T	Juffure and Albreda are too close together to justify separate links
Essau	Banjul	8	H	site at HC (not far Barra, hence Cat.C)
Manduar	Kerewan	16	T	defunct link (nr Karantaba which is Cat. B)
Pakali Ba	M'Konko	32 +	T	DOT plan proposal
Fulabantang	G'town	8	T	DOT plan proposal
Bakadagy	Bansang	30 +	T	DOT plan proposal

a/ Note that links marked "+" need more powerful 5-10W transceiver and a matching solar power system.

Table 3.11: COST ANALYSIS OF SINGLE CHANNEL VHF RURAL LINKS

Item	Cost (US$)	
A. Total Procurement		
11 High power (5-10W) systems	102,000	
9 low power (1W) systems	75,000	
Solar power at GPMB (kaur), 1 W system	1,000	
Spare batteries (for rehabiliation)	1,000	
Cross-country vehicle	10,000	
Two-way mobile radio-plus test equipment for vehicle	2,000	
Total	191,000	
B. Analysis per installation		
	21 Installations	29 Installations
Investment per installation	9,095	6,724
Annualized investment cost (10%, 15 yrs)	1,087	803
Annual recurrent costs	200	200
Annualized total cost	1,287	1,003
C. Analysis per call		
Mean cost per call	0.45	0.45
Average daily traffic per link to breakeven with mean duration of 3.5 minutes per call	7.83 calls 27 minutes	6.11 calls 21 minutes

3.52 Finally, it must be emphasized that these suggested locations must be treated as tentative since a proper survey (by Gamtel) of the terrain profile is vital before finalising a decision on locating any line-of-sight VHF equipment. In addition, it is important that the original justification for the sites should be reviewed and if on reconsideration these sites do not seem viable enough to attract sufficient traffic, alternative sites be selected. However, the number and sizing of the solar PV system is expected to remain unchanged.

3.53 Results of Analysis and Justification. Analyses of the load, necessary solar power system size and cost data, together with an economic analysis, are presented in Annex 6 and summarized in Table 3.11. The complete installed cost of each link, including the exchange equipment, the complete terminal and its solar power system, if "single-sourced", will be in the region of US$8,300 to 9,300. This estimate is based upon information obtained from potential suppliers and is felt to be conservative. If several specialized suppliers were involved rather than a single supplier, there might be lower costs, but this could result in higher risk and, as mentioned earlier, should be avoided. The total budget installed cost for all the equipment necessary to implement the recommendations is US$191,000. If only 21 working links are installed then the average annualised cost per installation using a 10% discount rate over 15 years will be US$1,287, while if 29 installations are achieved (by rehabilitation of old equipment as well), then the average annualised cost will be US$1,003.

3.54 It is not feasible to predict the benefits in terms of actual revenue, but on the basis of experience with other call boxes, the traffic requirements to break even may be predicted. Table 3.5 indicates that a typical revenue yield per call from public call boxes is D 1.73; (if the average call in the rural areas is at the intermediate D 0.50/minute rate - see Table 3.6 - this would imply a mean call duration of approximately 3.5 minutes). Consequently, an average rate of about 8 calls/day would be needed to yield an annual break-even revenue for the 21 installation objective or about 6 calls if 28 installations are realized. In other words, if the assumption of 3.5 minutes per call is correct, it is necessary to achieve a traffic duration totalling about 27 minutes per day in the first case and 21 minutes in the second. Any traffic exceeding these requirements would bring in a profit. While it is difficult to predict with any certainty the traffic that may be generated if the rural telephone system is perceived by most people as being likely to work most of the time, it seems reasonable to expect this modest usage necessary for break-even to be substantially exceeded. As shown in Table 3.12, even a modest 54-108 minutes/day of traffic can generate revenues of US$64,260-$128,520 a year. Moreover, as explained earlier, there are also significant intangible benefits for the rural areas and health centers and dispensaries.

Table 3.12: ESTIMATED REVENUE FROM VHF LINKS

Average Daily Utilization	No. Calls per Day	No. Calls per Terminal per Year a/	Total Average Revenue from 29 Links
(minutes)		(US$)	(US$)
27	7.1	1,108	32,130
54	14.2	2,216	64,260
81	21.3	3,324	96,390
108	28.4	4,432	128,520
135	35.5	5,540	160,650
162	42.6	6,648	192,780

a/ Assumes 5% incentive payments to DOH for supervision of telephones.

Source: Mission estimates.

IV. SOLAR WATER PUMPING

Water Pumping Needs in the Health Sector

4.1 The government health centers and dispensaries have four possible types of water supply: piped, borehole, open well, and, in one case, directly from the river. The safest of these is the piped supply, provided in most cases by the GUC, which meters the volume delivered and levies an appropriate water rate. Piped supplies usually originate from a borehole producing water which is generally unpolluted and clear. However, it is sometimes beset with a problem in that the water is generally lifted by an electric pump to a storage tank, after which it is distributed by gravity flow through pipes; consequently, long-term power failures can make it difficult to refill the main storage tank and render the water source inaccessible. On the other hand, intermittent power supply marked with short to medium term power failures are of little consequence so long as the tank gets filled. Since the water supply situation with piped systems is not absolutely critical, the mission does not propose any changes to these nine health centers.

4.2 Four health centers and one dispensary are equipped with a borehole supply. This is similar to a piped supply, except that it generally has a single output rather than a piped distribution system. The borehole supplies at health centers usually also have electric pumps energised from small diesel generating sets; in these cases, so long as reasonable diesel fuel supplies can be guaranteed, water supply problems are not likely to be critical. The only dispensary with a borehole (Brufut) has no power, and a hand-pump is used to lift the water instead. As this is a new dispensary, it is too early to judge how effective a handpump is in this context. Again, since the water supply problems are not absolutely critical there, the mission does not propose any water supply changes to health centers and the dispensary equipped with a borehole supply.

4.3 The remaining five health centers and the dispensaries all have sub-standard water supply from open wells which are subject to contamination and are a major source of disease both for DOH staff and patients. Excessive demand is also made of their water resources. In addition to supplying the usual needs of the staff, hundreds of patients and other local people frequently use the wells because others have been drying up in recent years due to the falling water table in The Gambia. Whereas the staff water needs would typically range from 100-1,000 litres/day, the additional demand often requires water supplies in the range of 2,000-10,000 litres/day. Moreover, the usage of wells by additional people multiplies the risk of contamination.

4.4 The mission recommends that initially, attention be focused on improving the water supply at the fifteen health centers and dispensaries with open wells. Except for the coastal locations, (where windpumps could be more viable), solar water pumps could be expected to adequately meet their pumping needs at a cost ($/unit hydraulic energy) lower than would be incurred with diesel systems and often with even handpumps. However, owing to the variety of different water resources, varying water needs and pumping heads at these wells, it is not possible to recommend a standard "packaged" system which could be installed in each location. A consultant study is needed which would investigate each site in detail, and develop specific recommendations. The study is proposed as a part of a larger project which would also explore the use of solar water pumps for irrigation in the McCarthy Island Division. It is to be noted, however, that although windpumps on the coastal sites and solar pumps for the remainder of the country are expected to be the most viable options for mechanical water pumping, the only benefits to be derived from their use is better quality water, less contamination and improved public health. No direct energy savings would result. (Annex 7 describes solar water pumps in more detail.)

Relationship with the Activities of the Department of Water Resources

4.5 About 10,000 hand dug wells serve 80% of the population in The Gambia. A major UNDP-sponsored program which is being implemented by the Department of Water Resources is seeking to improve water quality by constructing concrete lined wells with adequate above ground protection. Many of these wells would probably not be covered because rope and bucket would probably remain the only water lifting device available. The chances of contamination, though reduced, would therefore still be high and the productivity of the wells would remain low. In the interests of cleaner water and higher productivity a number of handpumps are therefore being installed through support from some bilateral donors; also two experimental solar and two windpumps have been installed in recent months (para. 4.12). The consultant study of a water supply improvement program for the health centers and dispensaries should take into consideration these parallel activities of the Department of Water Resources as well as the data obtained from the experimental solar, wind and handpumps.

Irrigation Pumping and the Use of Solar Pumps in McCarthy Island Division

4.6 Irrigation is not widely practised in The Gambia, even though it could conceivably have a significant impact on agricultural production owing to the lengthy dry season and often unreliable rains. The limited irrigation in use is at both ends of the scale of irrigation techniques in terms of cost and volume of water delivered, area of fields covered, etc. A few large commercial agricultural enterprises use standard commercial irrigation equipment with diesel pumps, and villagers also are known to use a small amount of well water for their vegetable gardens.

4.7 In general, the cost of delivering irrigation water is closely related to the vertical pumping head, because the energy requirements for a given output are directly related to head. Therefore, it is generally uneconomic to irrigate using well water lifted 10 m or more (as is necessary in The Gambia) unless there are no other water sources and energy is cheap. Since The Gambia is a riverine country, the most useful source of irrigation water is The Gambia River, but only up-country, as the lower reaches (for a great distance inland) are partially tidal and fresh is intermixed with sea water.

4.8 The main area for agricultural production is Georgetown in McCarthy Island Division, the central province of the country. Hence Gambia Produce Marketing Board (GPMB) has its main warehouse and collection point at Kaur on The Gambia River. The terms of reference for the mission included a to brief review of the feasibility of using solar pumps for small-holder irrigation in the McCarthy Island Division. However, in terms of its suitability for solar water pumping, this is a very different pumping requirement, both technically and in financial/economic terms, from pumping small amounts of well water for health center or village use. The volumes of water required are often tenfold (typically 50 to 100 m^3/ha per day), and the pumping heads need to be much lower (maximum of 4m) if a solar pump is to be economically feasible. In addition, the volume for irrigation purposes is not constant, but seasonal, and highly variable even in the dry season. Since the water source is almost certain to be surface water, it requires a different pump from the ones used for village water supply. The economic value of the delivered water, which determines the maximum acceptable pumping cost, will be a fraction of what is acceptable for drinking water supplies. Irrigation water typically needs to be in the region of US$0.05/$m^3$, while drinking water can often cost much more and still be economically justified in extreme cases where no other water source is available nearby.

4.9 While there is a sound economic rationale for using solar pumps in village water supply, the case for their use in irrigation is much more marginal. Much depends on the crops to be grown, the efficiency of the farmers and the market value of the crops. It is, however, worth mentioning that solar pumps are at their most competitive with the chief alternative (namely i.c. engine pumps) in small scale applications such as irrigating small-holdings through a low head, where only a small power requirement (typically 100-200 W) is necessary.

4.10 The mission recommends that the most effective way to assess the role of solar water pumping in irrigation in the McCarthy Island Division is to commission a detailed consultant study. The study could be undertaken in tandem with that which investigates solar water pumping in the health sector.

Experience with Solar Pumps in The Gambia

4.11 Some experience with solar pumps in The Gambia has been obtained through the Tanji and Sarakunda projects. A village solar pump has also been installed at the village of Kaiaf (in May 1984). 13/ The system at Kaiaf was supplied by the Solarex Corporation (USA) using Solarex solar panels and a Grundfos (Denmark) motor-pump unit. Field testing has shown that it typically delivers 20 m^3/day in an irradiation of 15MJ/m^2 per day, up to 45 m^3/day in 23MJ/m^2 per day - these being typical "low" and "high" daily irradiation levels for The Gambia on a hazy/cloudy day and on a clear day, respectively. This particular system has a nominal power rating of 1.2 kW(p) and a delivered and installed (turnkey) cost of US$25,000. It is probable, therefore, that this system is significantly larger than would generally be appropriate for rural health center and dispensary wells; for example, it may be expected that systems about one third of this rating (400Wp) would deliver at least 5 to 10 m^3/day and would cost (installed) in the region of US$8,500 each.

4.12 One other solar pumping system has been installed in The Gambia at Jambanjali. This was financed by Saudi Arabian bilateral aid and installed under contract by the German bilateral agency GTZ. It is a German system with a Pleuger motor-pump unit and AEG-Telefunken solar panels, having a peak rating also of approximately 1.2 kW(p). This solar pump has been installed as one of the Saudi-assisted water supply projects in West Africa. Being a demonstration unit in The Gambia, the solar pump has been deliberately oversized and is consequently somewhat more expensive than the one at Kaiaf. Future units are expected to be cheaper. No performance data on the GTZ pump was available.

Comparison of Solar Pumps with Wind and Hand Pumps

4.13 In areas without indigenous power supplies such as The Gambia, there are three potentially viable options that might be used for lifting water from closed wells or boreholes. They are, in order of increasing capital cost: handpumps, windpumps, and solar pumps. These are discussed below.

(a) Handpumps may in many cases be the most cost-effective solution. However, many of them are unreliable and suffer from having a low output at heads in the 10-15m range which is common in The Gambia. Hence they may not be able to approach the output that would be obtained from several people using ropes and buckets simultaneously, as they do at present. This could cause queueing at the well and encourage people to seek other unhygienic water supplies instead. Also, unlike mechanized methods of water lifting, handpumps cannot generally be used to pump water into a storage tank to feed a small distribution network, so they tend to involve longer mean distances for people to walk to collect water. Handpumps should,

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13/ Peter L. Fraenkel, Supplementary Report on Solar Photovoltaic Water Pumps (I T Power Ltd, UK), for Republic of the Gambia Department of Water Resources and UNDTCD, May 1983.

however, always be the first possibility for consideration in public water supplies of this kind.

(b) Given an adequate wind regime, windpumps are generally the least-cost mechanised method of water lifting for the quantities of water required in this case; however, The Gambia has only a limited wind resource. 14/ This factor limits the effective use of windpumps to the west of the country, especially near the coast, and in sites clear of large trees where a windpump gains good exposure to the wind. However, as a result of the recommendations in the Fraenkel (1983) study cited above, two Tozzi & Bardi (Italy) windpumps with 6 m diameter rotors have been installed in The Gambian villages of Tanji, near the coast, and Sarakunda, 150 km inland. The total installed cost of each system, including a water storage tank, was US$9,400, which is low compared with most other mechanical water lifting possibilities. Water supplied by the windpump is generally well in excess of the local water requirement, with daily outputs in the 10 - 30 m^3 range. Even the unit located inland is performing better than anticipated and it appears that inland locations may prove adequately windy for a lightly-loaded windpump. Clearly, useful lessons relevant to the rural health sector may be learnt from these two installations, although it is unlikely that more than one or two health centers or dispensaries will have the appropriate needs and conditions to allow the use of a windpump. The consultants should at least consider the windpump option for the health centers and dispensaries located near the coast.

(c) Solar pumps are relatively capital intensive, but the solar regime in The Gambia is adequate to allow their use in almost any location in the country. Therefore, in situations where say 10 cubic meters per day or more of water are required, a solar pump may prove to be the most effective solution since a hand-pump will not be adequate to provide the required output and in most cases wind conditions will be inadequate for windpumps.

Recommendations

4.14 Although the need for improved water supply is urgent in The Gambia, it is not possible to recommend immediate procurement and installation of equipment without a more detailed review of needs specific to

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14/ Peter L. Fraenkel, Report on a Consultancy Visit on Water Pumping Windmills, (IT Power Ltd, UK), for Republic of the Gambia Department of Water Resources and UNDTCD, May 1983.

selected locations. Therefore, it is recommended that a consultant with specialised knowledge of water supplies, irrigation and water lifting techniques be appointed to fulfill the following objectives:

(a) Discuss the water supply problem with officials in DOH, the Department of Water Resources, the UNDP and the Department of Agriculture, to establish in some detail their views on the problem, the priorities, and how any new project will fit with existing activities.

(b) Visit all health centers and dispensaries with sub-standard water supplies in order to make a basic site survey and determine the specification of suitable systems for each site. These systems could be solar pumps, but a case for their use needs to be made in techno-economic terms against other options such as hand-pumps or wind-pumps.

(c) Determine with further investigation whether there may be a case for initiating the use of solar pumps for small scale irrigation in McCarthy Island Division, i.e., if the market value of the crops, size of land-holding, typical pumping head and length of the irrigation season appear to offer some prospect for economic viability. This could be done using data collected in Banjul during the initial discussion referred to above. The consultant should then visit typical smallholdings in the relevant area in order to determine the specific technical requirements, with a view to carrying out a techno-economic feasibility study. The study should seek to compare the use of solar irrigation pumps with alternative options, such as diesel, as well as demonstrating that solar power can deliver water at an economic cost.

(d) Prepare a detailed report, justifying (wherever feasible) and specifying:

   (i) pumping equipment most suited for specific health centers and dispensaries (which could be a mixture of hand-pumps, solar pumps, etc.); and

   (ii) the case, if any, for introducing solar irrigation pumps in the McCarthy Island Division, or elsewhere in The Gambia, and preparation of a costed proposal for a possible project.

Budgetary Requirement

4.15 It is estimated that a three to four week mission to The Gambia, followed by two man-weeks of investigation, analysis and report writing, will be necessary to implement the recommendations set out above. The tentative budget is as follows:

	US$	
International travel	1,800	
Travel within The Gambia	200	
Subsistence (26 days)	2,800	
Consultancy (approx 44 man-days)	9,000	- 17,000
Miscellaneous (telephone, telexes, secretarial, etc.)	2,000	
Total:	15,800	- 23,800

The lower consultant charges are for a free-lance consultant, while the higher figure is for a person hired through a company with associated overheads. The lower figure of US$15,800 is the more realistic, since qualified individuals should be available at that rate.

V. THE PROPOSED SOLAR APPLICATIONS PROJECT

Project Description

5.1 The project consists mainly of the procurement and installation of solar powered equipment for use in the Health and Telecommunications sectors of the rural areas of The Gambia. It also provides for associated technical assistance and for the possible development of a consultant study on solar water pumping for use in the health sector and the McCarthy Island Division.

5.2 The initial call for tenders and procurement would be issued from Banjul by DOH and Gamtel working in association with the Ministry of Economic Planning and Industrial Development (MEPID). If need be, they could seek technical advice from ESMAP. DOH and Gamtel would supervise the acceptance and installation of the equipment. They would be assisted in their task by a Specialist Adviser whose services would be paid for through the project. He would be responsible for technical aspects of the installation and work closely with Gambian counterparts and train them in the operation and maintenance of the new systems. The Specialist Adviser would also assist in the appointment of an Assistant Engineer whom he would partly train. The Assistant Engineer would remain in the country for about a year after equipment installation is completed and correct any equipment problems that may ensue. The Specialist Adviser would return briefly, probably once in the middle of the first year of system operation and again about a year after commissioning the equipment, in order to prepare the Project Review Report.

5.3 The proposed consultant study on solar water pumping would be undertaken by MEPID in collaboration with Water Resources Board, the Department of Agriculture and other relevant agencies in accordance with the outline presented in Chapter IV. Annex B of the Technical Supplement provides the climatic data which will be needed by bidders to design their equipment.

Health Sector

5.4 It is recommended that a total of 25 health centers and dispensaries be each supplied with a standard package consisting of a photovoltaic powered vaccine refrigerator and two fluorescent lights powered from the same array and battery pack. In addition, a solar water heating unit should be provided for each center. It is also recommended to provide public telephone terminals at or near all the government rural health centers and dispensaries as part of the telecommunications package discussed below (para. 5.5). Finally, the preparation of a separate consultant study is recommended to define specific technical improvements for the water supplies at the five health centers and ten dispensaries not at present equipped with piped water. Although solar pumps have been discussed as a possible solution, the study would review all appropriate options (solar, wind, handpumps, diesel etc.) with a view to recommending the most effective solution for each location. The study would also review a non-health-sector related activity, namely, the prospects for using solar water pumps for irrigation in the McCarthy Island Division. The objective of the study would be to prepare a separate pre-investment report which could be used to seek financing for the procurement and installation of suitable water pumping equipment.

Telecommunications Sector

5.5 It is proposed that three primary elements of the rural telephone network be re-equipped in order to overcome power supply and fuel supply problems which currently plague the effective operation of the system specifically, recommendations are: . (a) conversion of the existing diesel-electric power supplies for the three key UHF trunk repeater stations to photovoltaic power; (b) replacement of life-expired and under-sized battery banks for powering the VHF links and spurs from seven provincial telephone exchanges; and (c) replacement of 19 existing (or formerly existing) single channel VHF public telephone links in the villages, and one private single channel VHF link at Kuntaur, with solar power units and new telecommunications systems. This is to be supplemented, if feasible, by rehabilitation of existing solar powered VHF systems and creation of eight further VHF single channel terminals. Insofar as possible, the VHF terminals are to be located at or near the health centers or dispensaries. It is recommended that, wherever possible, DOH personnel be responsible for operating and supervising the public telephone booths.

Implementation Plan

5.6 The proposed schedule of activities is given in Table 5.1. These are summarised below:

(a) Approval by the Government of The Gambia. The project was approved by the Government in December 1984.

(b) Choice of donors. The Government would identify prospective donor(s) to finance the project. In this task they could seek assistance from ESMAP -- June 1985.

(c) Invitation of tenders. Tender documents would be finalized and circulated to potential equipment suppliers. 15/ The call for tenders would be issued from appropriate government departments and technical assistance may be provided by ESMAP in preparing the equipment specifications -- August 1985.

15/ Draft documents are presented in Annex A of the Technical Supplement.

Table 5.1: PROJECT FOR THE DEPLOYMENT OF SOLAR POWERED SYSTEMS IN THE HEALTH AND TELECOMMUNICATIONS SECTORS OF THE GAMBIA

		--1984--		---- 1985 ----							---- 1986 ----												---- 1987 ----								
Activity	Implementing Agency	Nov	Dec	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep
1. Approval by the government	GOTG (ESMAP)		*****																												
2. Choice of donors	GOTG (ESMAP)			****																											
3. Invitation of tenders	GOTG (ESMAP)					****																									
4. Evaluation of Tenders	GOTG (ESMAP)							****																							
5. Place orders	GOTG								****																						
6. Delivery and Acceptance of																															
Equipment	SA a/ & GOTG											****	****																		
7. Installation of equipment	SA & GOTG											****	****	****	****	****															
8. Equipment evaluation & training	AE b/ & GOTG															****	****	****	****	****	****	****	****	****	****	****	****	****	****	****	
9. Completion																												*			
10. Project Review & Report	SA																													****	
11. Seperate study on Water Supplies	Consultant							****	****																						
Specialist Advisor present	SA											****	****	****	****	****	****	****	****			****									
Assistant Engineer/Volunteer																															
present	AE													****	****	****	****	****	****	****	****	****	****	****	****	****	****	****			

a/ SA = Specialist Advisor
b/ AE = Assistant Engineer

(d) Evaluation of tenders. Tenders should be received in Banjul in about 2 months and be reviewed by the appropriate government officials with possible assistance from ESMAP -- October 1985.

(e) Placement of orders. Orders would be placed through the Government's normal procurement channels of the Government -- November 1985.

(f) Delivery and acceptance of equipment. It is expected that equipment would begin arriving at Banjul in February 1986. At this stage the Specialist Adviser would arrive to assist with the acceptance and installation of the equipment and to start training his Gambian counterparts. The Specialist Adviser would ensure that the equipment supplied is acceptable and corresponds to specifications -- February-March 1986.

(g) Installation of equipment. The Specialist Adviser will locate the exact sites and supervise site preparation and installation of equipment. The Government, with assistance from the Specialist Adviser, would then appoint the Assistant Engineer, who should be scheduled to arrive in March 1986. The Assistant Engineer would support the Specialist Adviser with equipment installation. An important element of the work of the Specialist Adviser during this period would be on-the-job training of Gambian counterparts in the correct installation and maintenance of the equipment -- February-June 1986.

(h) Equipment evaluation and training. It is possible during the early months of system operation, that some typical shakedown problems might surface. The Assistant Engineer would be responsible -- with minimal guidance from Specialist Adviser -- for their resolution. The Gambian counterparts and the Assistant Engineer would establish a planned maintenance and monitoring program in which all the installed equipment would be regularly visited. They would check that the equipment is properly used and develop long-term maintenance plans and fault reporting procedures. The Specialist Adviser would be present during the first part of this phase and be available to respond to any questions that cannot be resolved by the Assistant Engineer and his colleagues. He might undertake a brief return mission, perhaps for two to three weeks around 1986 to visit the sites and resolve any problems that may have arisen and which may require his specialist expertise -- July 1986-August 1987.

(i) Completion. The projected completion date for the project is June 1987, after which the relevant Gambian institutions would take sole responsibility for the operation and maintenance of the equipment. At this point the Assistant Engineer's contract would terminate.

(j) <u>Project Review and Report</u>. Much will no doubt be learnt during the course of the various activities outlined above which will be of value for both future planning in The Gambia and elsewhere in the developing countries. Therefore, the Specialist Adviser would return to The Gambia to evaluate the project and prepare a review report for the use of the Government, donor agency(ies) and ESMAP. It would probably also be of serious interest to other developing countries -- August/September, 1987.

(k) <u>Consultant study on solar water pumping</u>. It is recommended that a consultant be appointed to investigate and make recommendations for specific measures to be taken to improve the water supplies at a number of health centers and dispensaries. He would also explore the potential use of solar pumping systems for irrigation in the McCarthy Island Division. Since this activity is not linked to the mainstream project, its scheduling is flexible and could tentatively be carried out during 1985.

Budget

5.7 The breakdown of the budget is given below:

I. Equipment Procurement

	US$
(a) Equipment for Health Department (25 rural health centers and dispensaries)	
26 solar vaccine refrigerators plus spare parts	136,250 16/
27 pairs of fluorescent lights with extra PV modules and batteries	18,090
25 integral solar water heaters with storage tanks	7,500
Subtotal	161,840
Unit cost	6,473
(b) Equipment for Gamtel	
(i) power supplies for 3 UHF repeater stations	
Subtotal	61,450
Unit cost	20,483
(ii) new batteries for 7 provincial exchanges	
Subtotal	39,200
Unit cost	5,600
(iii) 20 new VHF single channel links plus 1 extra solar power system and 8 spare sets of batteries; including cross-country vehicle with two-way radio and test-equipment	
Subtotal	191,000
Unit cost	6,586
Total equipment procurement budget:	453,490
contingency fund at about 10%	46,510
Total	500,000

II. Technical Assistance

(a) Light vehicle (eg. pick-up truck)	7,000
Running costs for 20,000 miles (15 months)	6,000
Subtotal	13,000

16/ Existing international prices for equipment were reviewed and the budgeting figures used here represent the lowest cost plus 25% of the differential between highest and lowest price.

(b)	Specialist Adviser:	
	Fees: (8 man-months) 17/	28,000 - 80,000
	International travel (3x)	5,400
	Subsistence (30 weeks at US$350)	10,500
	Subtotal	43,900 - 95,900
(c)	Assistant Engineer:	
	Pay: (15 man months) 18/	15,000
	International Travel (2x)	3,600
	Subsistence (65 weeks at US$175)	11,375
	Subtotal	29,375
(d)	Water supply consultancy:	
	Fees: (approx 44 m-d)	9,000 - 17,000
	International travel (1x)	1,800
	Local travel	200
	Subsistence (26 days)	2,800
	Miscellaneous (telephone, telexes, secretarial, etc).	2,000
	Subtotal	15,800 - 23,800
Total technical assistance budget:		102,075 - 162,075
	contingency (approx. 10%)	9,793 - 15,925
	Total	112,000 - 178,000

Total budget requirement

1.	Equipment procurement	500,000
2.	Technical assistance	112,000 - 178,000
		612,000 - 678,000

5.8 It is expected that an individual freelance consultant should be available to undertake the consultant study on solar water pumps (para. 4.14) as well as take on the Specialist Adviser's position. Therefore, the technical assistance budget should tend toward the lower figure.

17/ Reflects fee for consultant hired through company.

18/ Assumes junior/volunteer status with payment at US$10,000 p.a. plus 50% overhead to cover social costs and recruitment overheads.

COMPARATIVE ANALYSIS OF KEROSENE AND SOLAR VACCINE REFRIGERATORS

A. Kerosene Refrigerators

Electrolux model RAK660 costs US$348 f.o.b. Sweden.
Estimated 15% shipping gives installed price of US$400.

Fuel consumption 1.6 liter/day; 200 liter of kerosene delivered every four months (residue of 0.04 liter/day for lighting purposes).

Price kerosene D 2.32/litre = US$0.77 per liter ex-Banjul.
Delivery costs average US$175 per 400 liters or US$0.44 per liter (on basis of average of two drums per delivery average distance return from Banjul of 390 miles at 45¢ mile). Delivered price of kerosene is therefore US$1.21/litre.

Spare parts recurrent costs for kerosene fridges as follows:

wicks (size 10)	125 units at	D 40.00	D 5000
glasses	150 units at	D 50.00	D 7500
burners	2 units at	D 200.00	D 400

hence average spares per unit is D 516 = US$136

hence average per unit:	fuel	US$453
	fuel delivery	US$264
	spares	US$136

average annual recurrent costs (total):	US$853
annualised capital cost: (15 yr at 10%)	US$ 48
annualised life-cycle cost:	US$901

number of doses per refrigerator-year: a/	13,373
refrigerator cost (annualised) per dose: b/	6.74¢
EPI annual overheads (est)	US$350,000 ($14,000 per center)
therefore EPI overhead per dose =	104.69¢

Total cost per dose:	111.43¢

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a/ Allowing for 15% loss to cover unavoidable wastage on basis of 1983 vaccine disbursement (Table 2.3) plus further 20% loss due to refrigerator down-time.

b/ Using 1981 dollar total minus allowance for vaccines and for kerosene at reduced 1983 rate; see Table 2.3.

B. Solar Vaccine Refrigerator

Assumptions
Average electrical load 1 kWh per 24 hrs a/
battery 90% charged at end of sunniest month (October) 99% availability required in least sunny month (December) using one year's daily insolation data for the Gambia.
Array size 280W(p), and Battery 8 kWh(e) b/

Cost functions:	unit low	unit high	per	as sized low	as sized high
	US$			US$	
Lead-acid batteries	190	210	/kWh	1,520	1,680
PV modules	5	7	/Wp	1,400	1,960
Controls & ancilliaries	1	1.5	/Wp	280	420
Refrigerator cabinet	500	700	each	500	700
sub-total:				3,700	4,760
System integration	15	20	%	555	952
sub-total f.o.b. price:			$	4,255	5,712
Shipping and installation	10	15	%	425	857
Total installed cost:				4,680	6,569

a/ Note that the SPC PV refrigerator at Gunjur has maintained operating temperatures within WHO spec. at typical daily electrical loads of 840 to 1080 Wh/day. The system at Kaur had a higher load of 960 to 1440 Wh/day and frequently failed to keep within the spec. Actual measured results are most meaningful in this case since the primary variable affecting refrigeration load is operator activity in terms of opening cabinet and inserting warm items rather than simple heat transfer through the cabinet.

b/ For comparison, the SPC units in use in the Gambia have a nominal 315 Wp array with 7.56 kWh(e) battery storage.

	10% Discount Rate low	10% Discount Rate high
	(US$)	
Reliability	100%	90%
Doses per refrigerator-year a/	16,716.00	15,044.00
Annualised capital cost	656.00	898.00
Annual O&M costs (est)	60.00	120.00
Annualised life cycle cost	716.00	1,018.00
EPI overhead per dose	0.84 -	0.93
Refrigerator cost per dose	0.04 -	0.07
Total cost per dose	0.88 -	1.00

a/ . Allowing for 15% loss to cover unavoidable wastage before deducting any losses due to refrigerator and on basis of 1983 vaccine disbursemenr (Table 2.3).

C. Summary Comparison: Kerosene and Solar Refrigerators

		10% Discount Rate		
		Kerosene	Solar low	Solar high
			(US$)	
Reliability		80%	100%	90%
Number of doses per annum		13,373.00	16,716.00	15,044.00
Capital cost (installed)		400.00	4,680.00	6,569.00
Recurrent costs		853.00	60.00	120.00
Annualised life cycle cost		901.00	716.00	1,018.00
Refrigerator cost per dose		0.07	0.04	0.07
EPI overhead per dose		1.05	0.84	0.93
Total cost per dose		1.12	0.88	1.00
PW of capital invested in solar option	[A]		5,497.00	7513.00
Net benefit of solar option in saved recurrent costs			793.00	733.00
PW of net benefit	[B]		6,637.00	6,135.00
PW of recurrent costs			502.00	1,004.00
Net benefit/cost ratio	[B/A+C]		1.11	0.72
Gross benefit per dose			23.40	11.60
PW of gross benefit			32,743.00	14,606.00
PW of recurrent costs			502.00	1,004.00
Gross benefit/cost ratio	[D/A+E]		5.46	1.71

PW = Present Worth (or Present Value)

1. The methodology used for the analysis consists of calculating life cycle costs for each option by taking the summed present values of their respective cash flows and annualizing these using a 10% discount rate. It is also assumed that the solar vaccine refrigerator will be 90-100% reliable, compared with 80% reliability of kerosene refrigerators, i.e. 90-100% of the vaccines stored (after allowing for 15% unavoidable losses from the total disbursement due to packing) in solar refrigerators will be usable, but only 80% from kerosene units. In other words, it is expected that there will be an improvement in the number of successful immunizations by reducing the occurrence of vaccine unavailability due to down-time with kerosene refrigerators. Since there are no reliable statistics for actual down-time, the somewhat conservative figure of 20% losses from kerosene refrigerators has been used as it appears to accord with several independent estimates by field personnel.

2. It is important to note that many immunizations require a course of several vaccinations to be successful. Refrigerator down-time is, thus, more damaging in terms of wasted vaccinations than simply the loss on the days in question, since people who return for boosters, often after walking several kilometers, find they cannot have them and then rarely return on another occasion. Such incomplete and ineffective courses also reduce the general credibility of the DOH campaigns to encourage the population to seek immunization.

3. The current true overheads are not known with certainty, but it is probable that the EPI program total costs in terms of US dollars have remained approximately the same as they were in 1980-81 -- US$400,000. Allowing for kerosene costs, plus kerosene distribution costs which are already incorporated in the refrigerator cost analysis, and for a rather higher vaccine budget in 1981 than in 1983 (the year for which immunization statistics are being used), the possible EPI overhead stands at about US$350,000, or US$14,000 per health center or dispensary. It has been assumed in the analysis that on the basis of 1983 figures, 13,373 doses per refrigerator year would be administered using kerosene refrigerators, while 15,044 to 16,716 could be administered from the same supply of vaccines using solar refrigerators. These figures reflect 20%, 10% and zero vaccine losses respectively due to refrigerator down-time. It can be seen from Section A that the EPI overhead per dose ranges from US$1.12 with a kerosene refrigerator down to US$1.00 to US$0.88 using more reliable solar units. This is not of course a cost-saving as such, but it does draw attention to the substantial overheads involved in giving a vaccination over and above the costs of the refrigerator and its operation and maintenance.

4. The conclusions and assumptions of the economic analysis set out in Section A indicate that the annualized life cycle cost of a kerosene refrigerator is US$901 and the cost per dose for this option is US$1.12. The solar low option has an annualized life-cycle cost of US$716, with a cost per dose of US$0.88, while the annualized cost of solar high is US$1,018 at US$1.00 per dose.

5. Finally, it is worth pointing out that the recurrent costs of solar refrigerators are much smaller than those of kerosene refrigerators. Therefore, if the solar powered vaccine refrigerators are financed by grant aid, there will be a major impact in reducing the recurrent costs, and will release these limited funds for other purposes. The analysis estimates an annual recurrent cost of US$853 per kerosene refrigerator, ($21,325 for all 25 units) compared with a probable recurrent cost from US$60 to US$120 for solar units. Therefore the net saving in recurrent costs for the EPI program will be in the range of US$18,325 to US$19,825 simply on refrigerator operation and maintenance.

6. The solar refrigerators are not significantly more expensive in life-cycle cost terms, and their advantages consists largely of significant savings in recurrent costs combined with an expected improvement in the efficiency with which vaccines are stored and used, which is after all the primary objective of the entire US$400,000 EPI program. Since the current problems in the Gambia with fuel shortages are likely to persist, it is possible that the advantages to be gained from solar vaccine refrigerators will increase in future.

TECHNICAL DESCRIPTION OF REFRIGERATORS AND LIGHTING SYSTEMS

1. The general requirement is for a proven model of solar photovoltaic vaccine refrigerator, preferably having World Health Organization (WHO) approval and supplied complete with an appropriate photovoltaic array and battery pack. The refrigerator must be capable of achieving the WHO specification of holding a freezer temperature between 0 and -15°C and a refrigerator temperature within the range 4 to 8°C with a day time ambient temperature averaging 43°C and a night time holdover at 35°C average. A supplementary lighting package is also to be supplied, as detailed below, powered from the same array and battery pack. The supplier is required to provide evidence that their product has previously been used, successfully, in tropical locations. Under no circumstances should a new and untried make or model of solar vaccine refrigerator be procured. A list of suppliers of tried and tested equipment is given in Annex A5.

2. The freezing compartment is required to hold a minimum of 4 ice-packs as well as vaccines. It is preferable to procure a unit capable of freezing up to 8 ice-packs. The ice-packs are plastic containers filled with water which hold approximately 300gm of water and have dimensions of approximately 165 x 115 x 19 mm or (6.5 x 4.5 x 0.75 in). Therefore the ideal freezer size is in the region of 50 litres, (1.8 cu. ft.). The existing Solar Power solar vaccine refrigerators in use in the Gambia have a freezer of 34 litre capacity which is about the minimum acceptable volume. Refrigerator volume is less critical as only a small proportion of the vaccines are stored in that compartment.

3. The refrigeration load consists of refreezing ice-packs, as detailed above, twice per week. It can be assumed that the ice-packs will contain water at about 25°C when inserted into the refrigerator and that at least 48 hours will elapse before they are removed and replaced. The vaccines are inserted into the refrigerator only once per month and in cold condition and therefore do not represent a significant load on the system as such. The remaining load is due to opening and closing the door to remove vaccines and ice-packs, and due to heat gain through the cabinet.

4. The cabinet requires to be fitted with a lock to ensure that only authorised staff have access and that the door is less likely to be opened unnecessarily. It must be supplied with three keys, two for each centre and a spare to be retained at headquarters from which further spares can be cut.

5. The solar refrigerator must be supplied with a small lighting package consisting of two appropriate low voltage DC fluorescent lights in robust portable enclosures. These lights should be about 20 W each using transisterized high frequency inverters built to a tropical specification and integral with the units. Each light needs to have sufficient heavy insulated cable to allow it to be positioned up to 10 m from

the solar refrigerator. The lights should draw power from the same battery pack and PV array as the vaccine refrigerator, and it is essential that the battery and photovoltaic array sizing must take account of the power needed to operate the lights on a 4-hour in 24-hour duty cycle.

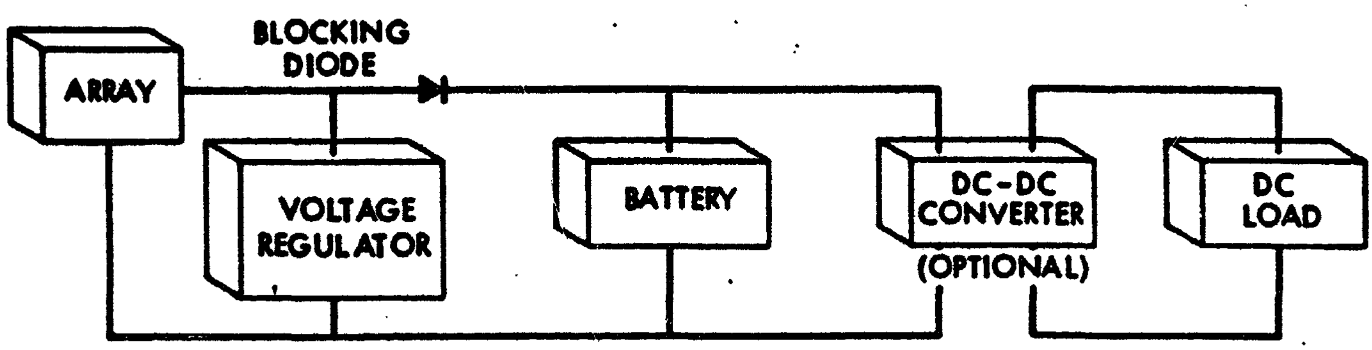
6. The following minimum instrumentation is also to be provided to facilitate monitoring of the refrigerator performance (and to allow fault finding) to be carried out: (i) max-min thermometer in freezer; (iii) max-min thermometer in refrigerator; (iii) max-min ambient (external) thermometer battery voltage indicator; and (iv) array current (charge current) ammeter. It would in addition be desirable to have some or all of the following additional instrumentation, if they can be supplied within the budget: (i) freezer temperature continuous; (ii) refrigerator temperature continuous; (iii) compressor running hours meter; and (iv) battery ampere-hour (or watt-hour) meter. A compromise measure worth considering would be to procure two or three sets of the second group of instruments for trouble-shooting purposes with units suspected of being faulty.

PHOTOVOLTAIC POWER SYSTEM SIZING AND COST ANALYSIS

System Description

1. Photovoltaic systems are electrical generating systems based on photovoltaic, or solar cells (built into arrays) which convert incident sunlight directly into DC electricity. The amount of electric current generated by a solar cell array is primarily dependent on the intensity of solar radiation striking its exposed area. The open circuit voltage produced, however, is primarily dependent on temperature of the cells. Voltage and cell temperature are inversely related (i.e., an increase in temperature lowers both the output voltage and the output power, thereby reducing the cell's efficiency).

2. A practical stand-alone photovoltaic power system typically requires several elements in addition to the array in order to satisfy the intended load. A typical configuration for a DC load is shown in Figure (1).



3. Battery storage, most commonly involving a lead acid battery in present applications, stores electrical energy produced by the solar array in daytime for use during the night or under cloudy conditions. To be considered practical for remote applications, a storage battery should have a long life, require low maintenance, and be able to survive a number of deep discharge cycles with subsequent recharge by the array.

4. Another important component of a photovoltaic power system using storage is a voltage regulator that controls the output voltage from the array when used to charge the battery. The regulator also limits the loss of water that could occur from gassing of the battery if it were permitted to become overcharged. At night or on cloudy days, a blocking diode (see Figure 1) prevents the electrical energy stored within the battery from discharging through the voltage regulator or the

array. A system serving a DC load may require a DC-DC converter to match the system output voltage to the rated voltage of the load.

5. Some photovoltaic applications do not necessarily require battery storage. An example of this is water pumping, which needs only a photovoltaic array, a water pump, a water storage tank, and minimum power regulation. In this case, water is pumped into the storage tank during sunlight hours. The storage tank then acts as a reservoir, providing water during non-sunny periods.

System Sizing

Insolation Characteristics and Their Effect on System Sizing

6. Array and battery storage size requirements to adequately serve the load energy requirement ultimately depend on the amount of insolation at the location of the site. Since the amount of energy received from the sun will depend on location, season, weather, and array orientation, it is essential to account for these factors in sizing the systems. Furthermore, since the intended load may also vary seasonally, sizing will normally require a systematic accounting approach to ensure that sufficient solar energy will be captured by the array to achieve acceptable system reliability throughout the year. Insolation characteristics important for sizing photovoltaic system components include the following: diurnal variation, regional and seasonal variability, weather (cloud cover and its frequency) and array orientation relative to the direction of the sun.

Introduction

7. The term "sizing" means estimating the required size or capacity of all major photovoltaic system elements so that the system will be able to satisfactorily serve the intended load. The sizing methodology described in this section is based on a target level of photovoltaic system reliability that is equivalent to conventional diesel or battery alternatives. The size estimates obtained by this methodology are used to cost the system, and the cost estimates, in turn, are compared with estimates for other possible power generating options in order to determine whether selection of a photovoltaic power system is justified on a comparative life-cycle cost basis.

Sizing Methodology

8. The steps in the sizing methodology are summarized below:

(a) Calculate the Load. The average daily energy load in kilowatt-hours is calculated for each month of the year. In the simplest case, a single load element draws constant power at all times. If several load elements are present, the individual elements must be summed. If the load totals vary from day to day, an average daily load over each month of the year will be required.

(b) Determine the Local Insolation. The appropriate amount of input energy (i.e., insolation, I) to the photovoltaic system at the application site may be obtained from local monthly insolation data for various array tilt angles.

(c) Calculate "Worst-Month" Insolation and Load Values. The sizing approach requires identification of the load and insolation values expected during the "worst month" of the year. This is done by constructing a table of average insolation and load values for each month of the year and then determining the month with the lowest ration of insolation to load. The insolation and load values for the selected month are used in subsequent steps to calculate required array size and battery storage capacity.

(d) Determine Array and Battery Storage Sizing Factors. The approach used in the methodology to size the array and storage is to apply previously determined "sizing factors" 1/ in array and storage calculations in order to scale the system to achieve a desired level of autonomy (i.e., availability). In some sizing application, the user may specify the level of system autonomy by placing a requirement on the number of sunless days during which the system must be able to satisfy the intended load.

(e) Calculate Array Power and Area. Calculating array size means calculating both its required peak power output in watts and its corresponding area in square meters. The array sizing calculations incorporate the worst-month load, array sizing factor based on the worst-month insolation, efficiencies of all major system elements, and a term to account for long-term array degradation.

(f) Calculate Battery Storage Size. Calculating battery storage size requires scaling the storage to supply the daily energy load for a sufficient period of time to assure that the photovoltaic system meets the load requirements at least 96 to 98% of the time (or equivalently, a 0.1 "loss of energy probability" (LOEP) during the worst month of the year). Alternatively, the storage can be sized to supply the load for a specified number of sunless days. In either case, the actual

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1/ Macomber, H. L., Ruzek, J.B., Photovoltaic Stand-Alone Systems, DOES/NASA/0195-1, NASA CR-165352 M206, August, 1981.

rated capacity is adjusted to ensure battery operation within acceptable depth of discharge limits.

(g) Calculate the Voltage Regulator Size. The battery charging voltage regulator is sized to handle the maximum amount of array output power (DC) that is not being used to supply the load. For conservatism, this will be considered to be the full rated peak array output power to account for situations in which the load has been disconnected.

System Cost Analysis

9. Photovoltaic power system life-cycle cost is estimated from the initial cost of the system installed at the site and the present = value of all recurrent costs associated with system operation. Photovoltaic systems are typically capital intensive (i.e., they require a large initial capital expenditure), but have low operating costs (i.e, zero fuel cost and small expenditures for replacement, operation, and maintenance). The sum of capital and recurrent expenditures represents the equivalent amount of money required at the time of system installation to completely cover all costs associated with the photovoltaic system, including a return on the investment, over its operating lifetime (typically assumed to be 30 years). Life-cycle cost of the alternative to a photovoltaic system similarly combines the associated first cost and operating cost for comparison with the photovoltaic option.

10. The recurrent cost in photovoltaic systems are attributed primarily to battery replacement plus battery operation and maintenance.

11. Battery lifetimes are typically between 5 to 10 years depending on manufacturer-specific battery characteristics, number of discharge cycles, design depth of discharge, and operating temperature. In contrast, the anticipated life of a photovoltaic array is estimated to be about 30 years. Battery replacement at regular intervals are, therefore, required throughout the operating lifetime of the photovoltaic array.

12. The present value of the sum of all battery replacements (RPV) over the photovoltaic system lifetime, escalated and discounted to account for the timing of the expenditure, is estimated as follows:

$$RPV_{j+1} = [(BATC)(1-SV) + LREP] \times \frac{1 - esc}{1 + dv}^{b} \; j \times k$$

where

BATC = delivered cost of batteries

SV = fractional salvage value of batteries at time of replacement

LREP = labor cost of battery replacement (in base-year dollars)

j = counter for number of battery replacements (1, nrep)

k = battery lifetime (years)

j x k = constrained to be strictly less than photovoltaic system lifetime or lifetime used in life-cycle cost analysis (years)

13. Regular operation and maintenance costs are estimated on an annual cost basis. These costs include expenditures for activities such as array, battery, and inverter maintenance; component replacements (other than batteries); and grounds, structural and electrical upkeep. Annual operation and maintenance costs (OM) can be estimated on the basis of the number of required visits to the site per year times the cost per trip in base-year dollars. A heuristic frequently used to estimate annual operation and maintenance expenditures is to assume that annual expenses are a fixed percentage of the initial cost of equipment. The present value of the cost of operation and maintenance procedure is the derived annual amount summed over the system lifetime, including any real escalation and discounting of expenditures over time. Annual expenditures are, therefore, growing in dollar amount at the constant rate of real escalation, if any. Present value of operation and maintenance cost (OMPV) is presented as follows:

$$OMPV = OM \times \left(\frac{1 + esc_{om}}{dr - esc_{om}}\right) \times \left(\frac{1 - 1 + esc_{om}^{\;N}}{1 + dr}\right), \text{ if } dr \neq esc_{om}$$

or

$$OMPV = OM \times N, \text{ if } dr = esc_{om}$$

where

OM = annual operation and maintenance cost in base year dollars

esc_{om} = real (above inflation) annual escalation rate for operation and maintenance activities (fraction), typicaly 0%

Photovoltaic system life-cycle cost (LCC) is then the sum of the initial installed system cost, and the present value of recurrent costs, Equation (1) plus Equation (2) above.

ANALYSIS OF REPEATER STATION POWER SYSTEMS

A. Electrical Load

(a) Telecommunications load:	
5A at 24V 24h/day	2.88kWh/day
(b) Lighting load:	
(i) Security lights for 12h/day	
3 x 18W sodium (SOX) 12h/day	0.65kWh/day
(ii) Transmitter room & caretaker's	
lights - 4x30W fluorescent 6h/day	0.72kWh/day
Total electrical load:	4.25kWh/day

B. Solar Powered System

(a) Assumptions:

Array tilt angle	15° facing due south
Least sunny month (December)	4.5 kWh/m^2 day (in the plane of the array)
Sunniest month (October)	5.8 kWh/m^2 day (in the plane of the array)
Photovoltaic system life	15 years
Battery life	7.5 years

(b) Calculated results:

Availability	Array Rating		Battery Capacity	
(%)	W(p)/kWh	W(p)	(kWh)	(days)
95	266	1,130	25.5	6
99	280	1,190	34	8

(c) Cost assumptions (for 99% available system):

		solar low		solar high
Solar PV modules	at \$5-7/W(p)	5,950	to	8,330
Battery	at \$170-210/kWh	5,780	to	7,140
Control equipment	at \$.75-1.25/kWh)	892	to	1,487
Ancilliaries	at \$0.5-1/W(p)	595	to	1,190
Component cost sub-total:		13,217	to	18,147
System integration at 20% of above		1,982	to	3,629
Bid price (fob)	range	15,199	to	21,776
Shipping & installation	range	3,039	to	5,444
Installed budget cost	range	\$ 18,238	to	27,220

Alternatively, if procured on a "turnkey" basis, the cost could be expected to be in the $20-25 per peak watt range, as follows:

Turnkey total cost range	$ 23,800 to 29,750

C. Diesel Generating Set System

(a) Assumptions:
Existing generating sets & battery chargers have 50% of their useful lives available (total life 7.5 yrs)

Existing batteries need immediate replacement; (when charged from an engine useful life 5 yrs)

Capital cost of 2 x 3.4kW generating sets	$ 3,000
Capital cost of 12 x 200Ah 2V batteries	$ 1,010
Capital cost of H&S 30A battery charger	$ 1,170
Capital cost of control/switch gear (10%)	$ 440
Total procurement cost:	$ 5,620
Installation & shipping cost (at 15%)	$ 843
Total installed cost:	$ 6,463
Fuel costs at Ds 2.32/liter	$ 0.60/l
Fuel delivery 45c/mile x 180ml x 2000 l	$ 0.04/l
Total fuel cost (delivered) $/liter	$ 0.64/l
Annual fuel consumption (at 16 liters/day)	5,840
Annual gross fuel cost	$ 3,738
Engine O&M costs	$ 200/yr
Annualised capital cost @ 10% discount rate	$ 976
Annualised life-cycle-cost @ 10% discount rate	$ 4,914

D. Economic Cost-Benefit Comparison

(a) Assumptions: costs are annualised over 15 years

(b) Calculated results:

	for 10% discount		
	solar low	solar high	diesel
		(in US$)	
A. Installed cost	18,238	27,220	6,463
Recurrent costs (O&M) p.a.	100	200	3,938
Annualised life-cycle cost	2,617	3,869	4,914
Unit cost per applied kWh	1.68	2.49	3.17
Cost as percentage of diesel	53%	78%	100%
Benefits of solar (saved recurrent costs)	3,838	3,738	-
Simple pay-back time (years)	4.75	7.28	-
B. P.W. of benefits of solar	32,124	31,287	-
Recurrent costs of solar p.a.	100	200	-
C. P.W. of recurrent costs	837	1,674	-
Benefit/Cost ratio $\left(\frac{B}{A+C}\right)$	1.68	1.08	-

REPLACEMENT BATTERY REQUIREMENTS FOR PROVINCIAL EXCHANGES

Assumptions and Results

Telecommunications load:	7 to 9A at 24V 9 (cont.)	
Other loads:	nil	
Average power output (taking 9A load)	216 W	
Assumed charging efficiency	70 %	
Energy input required per 24h	7.405 kWh	
System:	existing	new
Time needed to fully charge batteries	12 h	7.7 h
Mean power input during charge	617 W	1,234 W
Charging current at 24V	26 A	40 A
Battery capacity	200 Ah	800 Ah
Recommended charge rate (Tungstone)	10 A	40 A
Battery storage capacity	4.8 kWh	19.2 kWh
Period for 100% discharge	22 h	88 h
Depth of discharge for proposed cycle	45 %	91 %
Depth of discharge after 12h	45 %	86 %
Number of useful charging cycles/life	2,000	5,000+
Life in years assuming 1 cycle/day	5.5yr	13.7yr+
Capital cost of replacement battery	$1,300	$3,900
Capital cost of replacement charger	$1,300	$1,500
Shipping and installation (est)	$ 150	$ 200
Installed cost (est)	$2,750	$5,600
Annual O&M costs	$ 200	$ 100
Present worth over 15yr at 10% disc.	$5,179	$7,292
Annualized capital costs	$ 619	$ 871
Annualized life-cycle costs	$ 819	$ 971

POWER SUPPLY FOR PROVINCIAL - TECHNICAL CONSIDERATIONS

1. Recognizing the unreliability of the power supplies and charging systems, it seems reasonable to design the battery storage to have several days' capacity without recharging, instead of about 22 hours and to be able to accept an adequate recharge in as short a time as possible.

2. The table above indicates that the existing system can only safely support a maximum of about 11h between charges (for 50% depth of discharge) and even if recharged in 12 hours, as is intended but not always achieved at present, the necessary charging current (at 26A) considerably exceeds that recommended by the manufacturers for float charging (it should be 10A). The number of cycles a battery can survive is closely related to the maximum depth of discharge as well as to

whether the charging current is within the limits recommended to avoid gassing. Typical life-time estimates for tubular plate cells (as are used at present) are: (i) 20% maximum discharge -- 5,000 cycles; (ii) 50% maximum discharge -- 5,000 cycles; and (iii) 80% maximum discharge -- 2,500 cycles.

3. The occasional 100% (or nearly 100%) discharge, believed to occur with existing equipment, when combined with an excessive rate of charging, will in reality make the achievement of 2,500 cycles problematic. Therefore, for the purposes of analysis, a useful life of 2,000 cycles has been assumed for the existing batteries. This is probably generous, as the life becomes generally unpredictable, and can be radically reduced due to occasional periods of gross over-discharge combined with regular gassing due to the excessive rate of charge.

4. The type of cell normally used is the Tungstone 4TPG50 200Ah 2V cell, which has tubular plates, making it resistant to damage, but which is limited to a recommended 10A float charge rate and is clearly significantly too small for the existing 12h charge rate of about 26A, let alone the proposed rate of 50A. The consequence is that the batteries have virtually been worn out in three to five years instead of achieving a possible 10-15 year life. The recommended Tungstone replacement would therefore be the 8TPG100 with 10hr discharge capacity ratings of 800 Ah. This implies increasing the battery capacity by a factor of 4 compared with at present.

5. The sizing proposed for the replacement batteries of four times the present capacity was dictated primarily for reasons of allowing a high enough charging current so that only 7.7 hours per day are needed instead of 12 hours. In any case, if 12 hour recharging is planned, any replacement battery would need to be bigger by about 100% so as to reduce the rate of charge as the voltage rises. Obviously, a compromise is possible in that a lesser capacity then recommended could be procured, although this should really exceed about 400 Ah if only to ensure the charging rate is acceptable.

TECHNICAL AND COST ANALYSIS OF VHF LINKS

A. Electrical Load

Nominal transmitter rating	1W	8W
Standby power need (idle)	35mA	35mA
Transmit power need (at 12V)	0.8A	3.5A
Energy requirement (6h/day output)	68Wh/day	252Wh/day

B. Solar Power System

Assumptions exactly as set out in Table 3.11 (B) for 99% availability in least sunny month plus, duty cycle of 6h/day total transmit time:

Nominal transmitter rating	1W	8W
Precise array sizing	19W(p)	71W(p)
Actual array sizing (std. modules)	20W(p)	70W(p)
Battery sizing	0.54kWh	2.02kWh
Battery rating 12V	45Ah	168Ah

C. Cost Data

Actual costs will vary, depending on supplier, specification and technical features. These are guideline figures for a single VHF link gained as a result of making enquiries to several potential suppliers:

Item	Unit Cost (US$)	Quantity (per link)	Total Cost (US$)
Transceiver unit	2,000	2	4,000
Yagi antenna	250	2	500
Mast and fittings	500	1	500
Solar power system a/	1000-2,000	1	1000-2,000
Weatherproof housing	500	1	500
Telephone/coin collector	1,500	1	1,500
Telephone booth	500	1	500
Shipping and installation	800	1	800
Total per system:			8,300 to 9,300

a/ The lower price relates to a 20Wp array with a 45Ah (12V) battery to power a nominal 1W transceiver and the higher price relates to a 70Wp array with a 170Ah (12V) battery to power a nominal 8W transceiver.

D. Economic Analysis

Total procurement proposed requires:

		US$
(i)	11 high power (5-10W) systems	102,000
(ii)	9 low power (1W) systems	75,000
(iii)	Provision for solar power at GPMB at Kaur (assuming 1W system)	1,000
(iv)	Provision for spare batteries to allow rehabilitation of old systems	1,000
(v)	Cross-country vehicle	10,000
(vi)	Two-way mobile VHF radio plus test equipment for vehicle	2,000
	Total budget cost:	191,000

There are two options available; namely to implement 20 new VHF single-channel links plus the GPMB and to implement an additional 8-second priority ones by using rehabilitated existing equipment with new batteries at an estimated cost of US$500 per rehabilitation. Hence:

Number of installations implemented	21	29
Investment per installation	9,095	6,724
Annualised investment cost (10% 15yrs)	1,087	803
Estimated annual recurrent costs	200	200
Annualised total cost	1,287	1,003

Mean cost per call: ($ 0.45)
(Table 3.7) approximate mean duration
per call: 3.5 minutes

Average traffic per day to break-even on above costs: (calls)	7.83	6.11
(time)	34 mins	26 mins

Technical Considerations

1. Each installation requires the following components: exchange VHF transceiver; exchange feeder cable; exchange yagi directional antenna; terminal yagi directional antenna; terminal feeder cable; terminal antenna/array support mast; terminal transceiver; terminal; telephone booth; terminal headset and coin collector; terminal solar array and battery charge regulator terminal; battery pack; and terminal ventilated equipment enclosure(s). It is strongly recommended that suppliers be invited to bid to supply complete, fully integrated, sets of the above equiqment. Although the solar power components can be bought from separate sources, perhaps marginally at a lesser cost, the advantage of 'single-sourcing' the equipment is that there is then a clear responsibility for the correct sizing of the power system and battery pack and any incompatibility between components would be avoided, or at least be covered by the supplier's warranty. One exception to it is the coin collector unit. It may be easier to procure these units from GEC Telephones (Hartlepool, UK) who can supply standard units of the kind used by Gamtel (formerly from Associated Automation Ltd., UK, who no longer trade and whose product line has been taken over by GEC). These units are already available in a form adapted to accept the Gambian coins; other suppliers may find it difficult to offer coin collectors in such small quantities at a reasonable price for the first time if the call for tenders insists on a total system.

2. The transceivers are required to be duplex (identical transceivers are generally used at the exchange and at the village terminal), two frequency VHF units. Even though the existing equipment operates in the 148-174 MHz band, the new equipment is not necessarily tied to using this band. Two power levels of transceiver are generally available from suppliers of equipment. Typically the transmitter can be provided so as to broadcast at a nominal 1W power level for short range duties or as an option, a similar unit can be obtained rated at 5-10 W for longer ranges. The lower rating is desirable whenever it is feasible to use; however, most of the longer range links will probably need the higher powered options. The exact range where low power is no longer adequate cannot be readily defined as it depends on numerous factors. For budgetary purposes 25 km is taken as the upper limit for low powered (nominal 1 W) systems. On this basis, as indicated on Table 2.10, it is necessary to procure nine low powered systems and ten high powered systems, plus a solar array/battery system for the GPMB unit. It also would be useful and add only a marginal extra cost to procure an extra few, (say six), adequately sized batteries to allow redeployment of existing systems.

3. A major associated problem is the lack of suitable facilities to implement the installation and repair of the single channel links. Therefore, it is also proposed to provide a small cross-country vehicle equipped with its own two-way VHF radio to facilitate this work. The cost of the two way radio is marginal in relation to a vehicle (being in the region of US$1,000) but its potential for avoiding unnecessary expenses is quite significant.

SOLAR PHOTOVOLTAIC WATER PUMPS

Introduction

1. The growing demand for energy for water pumping coupled with increasing costs of conventional fuel has, in recent years, prompted considerable interest in the use of solar energy for powering pumping systems. Solar energy can be converted to mechanical energy required for pumping through direct conversion of solar radiation to electricity (by using photovoltaic cells) and then to mechanical energy with a motor/pump unit.

2. Three main uses for solar pumps are: (i) irrigation; (ii) village water supplies; and (iii) livestock water supplies. Water for irrigation purposes is characterized by a large variation from month to month in the amount of water required. This may peak at around 60 m^3/day/hectare and drop to zero. Generally it is not economic to lift the water more than 10 meters because increasing the lift increases the cost and the cost of supplying water for irrigation must not be more than the value of the additional crop that can be grown. Water for rural water supplies (livestock or villages) is characterized by a more constant month by month demand. Consumption is likely to be 20-40 liters per day per capita or per livestock. It is critical to have water available on demand. Hence this type of pumping system must include a storage tank.

The Technology

3. The main components of a PV pumping system include the photovoltaic array pump. Three 'extras' can be inserted between the array and motor, viz. (i) an electronic control system (often called a Maximum Power Point Tracker or MPPT) which maximizes the energy from the array by choosing optimum operating voltages and currents for the array; (ii) a battery which can be used to store electrical energy and hence offer a more constant electrical supply. A controller to prevent overcharging if necessary. Batteries, however, have a number of disadvantages such as extra cost, regular maintenance and decreased system efficiency. In most commercially available solar pumps, batteries are not used, but use of sealed maintenance-free batteries may be feasible for certain applications, such as those requiring some form of storage; and (iii) an invertor for use with cheaper mass produced A.C. motors which converts the D.C. output of the array to A.C. At present most system suppliers favor A.C. permanent magnet motors although recently some manufacturers have introduced brushless D.C. motors. Some larger pumping systems, particularly for high lift borehole applications, incorporate A.C. motors operated in conjunction with D.C.-A.C. inverters. The choice of pump is perhaps the most influential factor in photovoltaic system design. For water lifts up to about 10 m, a single stage centrifugal pump can be

used. The performance of centrifugal pumps is sensitive to changes in head and good design consists of selecting a pump that offers good efficiency over the large range of heads likely to be encountered in practice. For higher head pumping, high speed single-stage centrifugal pumps or multi-stage centrifugal pumps may be used. Alternatively, positive displacement pumps are available although these do not have characteristics that can be well matched to a photovoltaic array and generally some form of power conditioning is required. In general, the efficiency of positive displacement pumps increases with head which means that they are unlikely to be competitive with centrifugal pumps for low head systems.

Predicting the Output of a Solar Pump

4. The annual water pumped per peak watt (wp) of photovoltaic cell can be determined by using equation (1)

Annual output (m^3/Wp) =

$$\frac{0.33 \times \text{sub-system efficiency} \times \text{average daily solar irradiation (kWh/m}^2}{\text{head}} \quad \text{-- (1)}$$

Typical subsystem efficiencies for motor/pump subsystems are 25-30%, 25-40% and 25-40% for 2 m, 7 m and 20 m heads respectively. It should be remembered that all the water pumped may not be useful because of the mismatch between solar energy availability and water requirements.

Sizing a Solar Pump for a Particular Application

5. To size a solar pump to provide a given quantity of water every day requires information on the day-to-day variations in solar irradiation. However, the following approximate procedure can be used if monthly irradiation data is available:

(a) Calculate the monthly hydraulic energy requirements from equation (2). (For water supply this will probably be the same each month whereas for irrigation there will be monthly variations.)

Hydraulic energy required (kWh =
$$0.002725 \times \text{volume reqd. (m}^3) \times \text{system head (m)} \quad \text{-- (2)}$$

(b) Calculate the average daily solar pump hydraulic energy per Wp rating from equation (3).

Hydraulic output ((kWh/Wp) =
$$0.0009 \times \text{subsystem efficiency} \times \text{average daily solar irradiation incident on array (kWh/m}^2 \quad \text{-- (3)}$$

(c) The Wp rating required each month can then be determined from

$$W_p = \frac{\text{hydraulic energy required}}{\text{solar pump hydraulic energy}} = \frac{\text{equation (2)}}{\text{equation (3)}}$$

The maximum value of peak watt rating obtained in the critical month will then be the required solar pump size for the application and location under consideration.

Cost Effectiveness of Solar Pumps

6. Solar pumps have a number of attractive features for small-scale applications in remote areas and can bring benefits out of all proportion to their cost. However, it is of prime importance to consider their economics in comparison with the available alternatives. At present typical solar pumping systems cost in the region of \$50 per peak hydraulic watt (corresponding to \$20 per peak electrical watt). It is anticipated that the cost will be reduced \$15 per peak hydraulic watt within the next five years. Present solar pumps cost effectiveness compared to diesel pumps can be obtained from Figure 1.

7. A m^4 is one m^3 pumped through a head of 1 m. The average m^4 per day can be found by multiplying the system head (m) by the average daily water requirements (m^3 per day) and the cost per m^4 can then be read off for the location under consideration. H* is the effective solar irradiation in the critical month (as determined above) and can be calculated from

H* = (ratio of critical month water demand: average monthly water demand) x critical month solar insolation (kWh/m^2)/water supply efficiency

For <u>rural water supplies</u> with little variation in monthly demand and relatively high supply efficiency, H* will be approximately the worst month solar irradiation. However, for irrigation water with low application efficiencies (50-60%) and peaky water demand, H* will be considerably less than the worst month solar irradiation. The shaded area in Figure 1 represents the present range of diesel pump water costs. To convert from pence per m^4 to pence per m^3 it is necessary to multiply the pence per m^4 by the system head. Although solar pumps are cheaper for some applications one of their major drawbacks is their high capital costs, e.g. US\$13,000 for a 250 hydraulic watt system.

Solar Pump Manufacturers

8. The following list is for information only and does not imply any recommendation or endorsement of the products of any of the suppliers included. Most systems are still under development:

AEG Telefunken, Industriestrasse 29, D-200, Wedel (Holstein), German Federal Republic.
ARCO Solar Inc., 20554 Plummer Street, Chatsworth, California 91311, USA.
Briau SA, BP 0903 Tours Cedex, France.
Central Electronics Ltd., 4 Industrial Area, Sahibabad, 201010, UP, India.
Grundfos, 8350 Bjerringbro, Denmark.
Heliodinamica, Caira Postale 8085, 01000, Sao Paulo, Brazil.
Hindustan Brown Boveri (+), Energy Systems, P.O. Box 204, Baroda 390-001, Gujarat, India.
IDL Chemicals, PB No. 1, Sanatnagar (IE) PO, Hyderabad 500018, AP, India.
Klein Schanzlin & Becker AG, D-6710 Frankenthal, Pfalz, German Federal Republic.
WM Lamb Company Inc., P.O. Box 4185, North Hollywood, CA 91607, USA.
Lowara SPA, 36075 Montecchio Maggiore, Vicenza, Italy.
B P Solar Systems Ltd., Windmill Road, Haddenham, Aylsbury, Bucks, HP17 8JB, UK.
Monegon Limited, 4 Professional Drive, Suite 130, Gaithersburg, MD 20879, USA.
Omera-Segid SA, 49 Rue Ferninand-Berthoud, 9510 Argenteuil, France.
Nolte BV, Postbus 910, 560 Ax Eindhoven, The Netherlands.
Photowatt International Inc., 98 ter Blvd., Heloise, 95102 Argenteuil, France.
Rainbird International Inc., 7045 North Grand Avenue, Glendora, CA 91740, USA.
Sahel SA, 50 Rue JP Timbaud, BP 301, Courbevoie Cedex, France.
Sharp Corporation, 22-22 Nagaiike, Abeno-Ku, Osaka 545, Japan.
Solar Electric International Inc., 31 Queen Anne's Gate, London, SW1H 9BU, UK.
Solarforce, 179 Blvd., Saint Denis, BP 320, 92400 Courbevoie Cedex, France.
Solapak Ltd., Factory 3, Lock Lande, High Wycombe, UK.
Solamat Inc., 885 Waterman Avenue, East Providence, RI 02914-1383, USA.
Solarex Pty. Limited, 5 Bellona Avenue, Regents Park 2143, Australia.
Trisolar Corporation Inc., 10 DeAngelo Drive, Bedford, MASS, USA.
TPK, 149 Bentley Avenue, B-4A, Nepean, Ontario, Canada.

THE GAMBIA

TECHNICAL SUPPLEMENT TO ACTIVITY COMPLETION REPORT

PRELIMINARY

DRAFT TENDER DOCUMENT

This document outlines the essential elements of a detailed draft tender document to be prepared later by the GOTG for inviting bids.

A. 25 photovoltaic vaccine refrigerator & lighting packages

A total of 25 photovoltaic-powered vaccine refrigerators with supplementary lighting, plus spare parts, are to be procured.

The refrigerators should preferably meet WHO specifications and have WHO approval/certification (but this is not mandatory).

The performance requirement for a refrigerator is to be able to sustain a temperature of from +4°C to +8°C in the refrigerator compartment and to sustain 0°C to -15°C in the freezer under a mean daytime temperature of 43°C and a 12-hour (night-time) holdover at an ambient temperature of 35°C.

The load consists of vaccines and at least four, but preferably eight, ice packs. The ice packs are plastic and have external dimensions of approximately 165 mm x 115 mm x 19 mm; each one contains approximately 300 cc of water. The vaccines are inserted cold and therefore do not represent a significant refrigeration load, but the ice packs can be assumed to be at ambient temperature of 30°C when inserted and they may be inserted for freezing and removed no more frequently than every 48 hours.

The minimum refrigerator compartment size is 30 litres and the minimum freezer volume is 34 litres, but 50 litres would be preferred for the freezer.

A photovoltaic power system, consisting of a fixed PV array plus appropriate capacity batteries and a fully automatic battery charge regulator is to be provided. This is to be sized for solar conditions in The Gambia, West Africa (latitude 13°N), to meet the power demand of the refrigerator. It should be sized for 99% availability in the least sunny month (December - mean daily insolation of 4.5 kWh/m^2 on plane of array inclined at 15°). Further details of the solar regime and associated climatic variables are provided in Annex B of this document.

A supplementary lighting package to be powered from the same PV array and battery storage is required. This is to consist of two high-efficiency fluorescent lighting units rated at approximately 20 W each; (13W to 25 W will be acceptable). The lights should be portable with suitable fittings to allow them to be hooked or suspended and should be in a tough enclosure which can be dropped from a height of 50 cm onto a concrete floor without being damaged, i.e., rubber or other impact resistant materials should be used for the enclosure. Each light should be supplied with 10 m of appropriate cable and the cable should terminate in a detachable plug which can be inserted in appropriate sockets provided on or near the refrigerator/battery unit.

The photovoltaic array and battery storage should be sized to allow for an average additional electrical load from the lights sufficient to run them both for up to 4 hours in 24 hours.

The minimum instrumentation to be supplied with the refrigerator/lighting package is as follows:

max-min thermometer in freezer
max-min thermometer in refrigerator compartment
max-min thermometer, external (ambient)
battery voltage indicator
array current (charging current) meter

It would be preferable to have the following additional instrumentation provided:

freezer temperature chart recorder
refrigerator temperature chart recorder
compressor running hours indicator
battery ampere-hour (or watt-hour) meter

B. 25 integrated solar water heater/storage tanks

Twenty-five complete integrated or combined solar water heater/storage units are to be supplied. These should be sized so as to maintain a volume of 30 gallons/day of water at approximately 50 to 60°C under full sunlight conditions at latitude 13 N. (For more accurate sizing, see attached Annex B on climatic data in The Gambia). Each system should be supplied as a stand-alone integrated package, probably standing on a platform about 1-2 m above ground level. The platform is either to be supplied, or detailed recommendations are to be provided on constructing support platforms locally.

Hot water should be drawn off via an appropriately located tap or fawcett. Refilling should be easily carried out.

The system is to be designed to withstand damage resulting from exposure to full sunlight when empty (i.e. stagnation temperatures for an uncooled absorber). It also must be made from high quality, corrosion resistant materials to ensure that the systems have a minimum useful operational life of ten years.

The glazing should preferably be from laminated glass or other damage resistant material.

The suppliers would be required to provide a 5-year warranty on parts.

C. 3 photovoltaic power systems with battery storage and lighting units for UHF radio-telephone repeater stations

Three complete solar PV power systems are required, with appropriately sized battery storage to provide the following power supply:

telecommunications load:	
5A at 24V 24h/day	2.88kWh/day
lighting load:	
3 x 18W sodium SOX security lights (or similar) on 12h/day duty cycle	0.65kWh/day
transmitter room and caretaker's lights on 6h/day duty cycle	0.72kWh/day
total electrical load:	4.25kWh/day

A photovoltaic power system, consisting of a fixed PV array plus appropriate capacity batteries, and an appropriate fully automatic battery charge regulator is to be provided. This is to be sized for solar conditions in The Gambia, West Africa (latitude 13° N), to meet the power demand from the refrigerator. It should be sized for 99% availability in the least sunny month (December - mean daily insolation of 4.5 kWh/m^2 on plane of array inclined at 15). Further details of the solar regime are provided in Annex B of this document.

Security lights amounting to three 18 W SOX (or similar) are to be provided, plus four 20 to 30 W fluorescent lights and fittings. All these lights are to be provided with enough cable to locate them an average of 15 m from the battery bank. It is preferable that they also be supplied with time switches, or photo cell activated switches to ensure they are not left on in daylight or when the battery charge is low.

The array is to supplied with enough cable to locate it up to 40 m from the battery bank.

The preferred type of battery would be 2V lead acid tubular plate cells similar, if possible, to those to be supplied under section D below to reequip telephone exchanges.

D. New batteries for reequipping 7 telephone exchanges

Seven telephone exchanges require complete new banks of batteries with new battery charger units to operate off the mains or off diesel back-up generating sets for their VHF/UHF radio telephone links. The requirements are as follows:

electrical load: 9A at 24V continuous = 5.184 kWh/day preferred time for recharge: under 8h/day

maximum time between recharges: 24h

minimum life at 1 charge/cycle per day: 10 yrs or 3,650 cycles

Therefore, seven sets of batteries, preferably made up of 2V tubular plate cells, are needed to fulfill the above requirements. These are to be supplied complete with appropriate racking and connector links.

In addition, seven battery charger units are to be supplied to operate from a mains supply of nominal 220V 50Hz single-phase and to output at a nominal 24V and appropriate charging current for the above battery requirement. These are to be fully tropicalised, i.e. polyurethane varnished or encapsulated p.c.b.s., etc. It is preferred that the battery chargers include high voltage cut-out to detect and prevent overcharging and gassing of batteries.

E. 20 single channel VHF telephone systems with public pay-phone booths, solar power systems plus spares, etc.

Twenty single channel VHF telephone systems are required, each consisting of the following:

exchange:
- VHF transceiver in ventilated enclosure
- feeder cable
- yagi directional antenna

terminal:
- yagi directional antenna
- antenna/PV array supporting mast
- feeder cable
- VHF transceiver in ventilated enclosure
- telephone booth/shelter
- telephone, handset and coin collector
- solar array and mounting structure
- battery charge regulator
- battery pack

The transceivers need to be duplex, two frequency units, and current practice is to use the 148-174 MHz band, although alternative frequencies can be considered if there are good reasons for doing so. The interface at the exchange requires standard two-wire 48V DC telephone audio frequency input/output.

The transmission ranges (line-of-sight) are up to 50 km. The requirement is for eleven systems between 25 and 50 km estimated to require 5 W (nominal) transmitters, and nine systems for less than 25 km range, which may permit the use of 1 W system.

The power supply in all cases is to be a battery recharged from a solar photovoltaic array. Zero (or minimum) maintenance batteries are necessary. The power supply should provide 99% availability in the least sunny month (December) with a mean insolation approximating 4.5 kWh/m^2 per day on a surface inclined at 15° facing south. (The Gambia is at latitude 13°N). More details of the solar regime for The Gambia appear in Annex B of this document).

These single channel systems are to be provided with an appropriate inventory of spares to anticipate likely maintenance needs for five years of operation.

An additional, associated requirement is for extra zero or low maintenance batteries, preferably of a type similar to those used for the above systems, to rehabilitate existing systems as follows:

quantity	voltage	minimum capacity
5	12V	45 Ah
4	12V	168 Ah

F. Village telecommunication maintenance vehicle

A single light cross-country vehicle equipped with two-way VHF radio is required to undertake the installation of the above equipment and to provide a facility for maintenance and repair work.

This should be preferably a four-wheel drive diesel light truck with an estate-car/station-wagon or van type body.

The vehicle is required to be supplied and fitted with a two-way VHF radio telephone having a range with the vehicle's antenna of 25 km and at least 50 km if connected to one of the VHF telephone link yagi antennae mounted on a mast. It is preferable for this unit to operate at a similar frequency to the VHF telephone network. A portable transceiver for use at the nearest telephone exchange in communicating with the mobile unit is also to be supplied. It is intended to use this radio link among other things for voice communication while optimizing the alignment of the single channel VHF system exchange and terminal antennae.

The vehicle should also be fitted with a small inverter (220V 50Hz) running off its electrical system which is capable of providing up to a nominal 50 W output to power test instruments, etc. It is preferable for the vehicle to have a 24CV DC power supply which could feed two 12V DC power supply units for test purposes.

INSTRUCTIONS TO TENDERERS

Tender Procedure

Tenders shall be prepared in English and submitted in an original marked 'Master' and two (2) copies of all sections required to be completed by the Tenderer at the place, by the date fixed for receipt of Tenderers, in accordance with the letter of invitation.

The original Tender shall be in English and shall be filled out in ink or typewritten and will be made a part of the Contract. Copies shall be identical with the master.

Tenders shall be for a complete solar powered pumping system as described in the Specification.

Tenders shall be bound in loose leaf so that they may be divided for evaluation. Each page of the tender which is to be completed by the Tenderer shall be numbered sequentially and carry the tenderers name.

Alternative Tenders

Tenderers having systems whose performance does not in all respects conform to the Specification may submit a tender in respect of such systems giving full details as to how it is suitable for the required duty. The Government of The Gambia will consider any such systems and those having particularly high merit may be considered for purchase.

Number of Tenders Permissible

Tenderers may submit a tender for any of the systems described in the Specification (item 7 Performance Requirements). If a tender is to be submitted for more than one system, a complete set of Tender Schedules shall be submitted in respect of each system. These shall be headed System A, B, C, F in accordance with the Specifications.

Adjudication Process

Tenders will be primarily considered for:

(i) Performance reliability
(ii) Durability
(iii) Cost effectiveness
(iv) Adequate warranties on labor and parts

The Purchaser will not be bound to award a contract to the lowest or any Tenderer.

Outline Programme for Procurement of Systems

The tentative schedule for the issue and receipt of tenders and the procurement of systems is as follows:*

Tender forms issued August, 1985
Completed tenders returned to Consultants October, 1985
Tender awarded November, 1985
Systems ready for shippingDecember, 1985
Systems arrive at BanjulFebruary, 1986

* Subject to adjustments depending on date of commencement of Project.

SPECIFICATIONS

Scope

This Specification is for the supply and delivery of complete self-contained systems suitable for The Gambia, as described in Section 1.0 above.

The clauses which follow outline the design parameters and other requirements to be observed for the fulfilment of the Contract.

Alterations

The Contractor may propose to deviate from any particular technical aspect of this Specification if he considers it necessary or desirable. Any such deviation shall be clearly and expressly described and the reasons for the deviations explained in the Tender.

Design

The Contractor shall be responsible for the design of the complete system to meet the requirements of this Specification.

The complete system shall be robust, capable of withstanding hard usage in a harsh environment. It shall be resistant to damage from accidental misuse and reasonably resistant to vandalism and the attentions of animals, wild or domestic.

The system shall be designed for assembly, operation and servicing by unskilled personnel under the guidance of a trained technician. The requirement for special tools or instruments to complete the system shall be minimized and any special tools needed for installation shall be supplied with the system. Foundations or other preparatory work shall be as simple as practicable.

The system shall be designed for assembly from small units which can be packed in containers small enough to be easily handled and transported on small vehicles such as landrovers or pickups.

The system shall be designed to operate for a long lifetime with a minimum deterioration of performance. The design life of the whole system shall be at least fifteen years with a minimum need for replacements. Routina maintenance shall be minimized and maintenance work necessary shall be as simple as possible, requiring only a few basic tools for its execution.

Environmental Conditions

The systems shall be designed to operate at a latitude of 13°. As a minimum it shall meet the requirements of this Specification under the following environmental conditions.

(i) Ambient air temperature between 5°C and 45°C.

(ii) Relative humidity up to 90% at an ambient temperature of 45°C.

(iii) Wind speed up to 120 kph (for fixed installations).

(iv) Water resource temperature up to 35°C.

(v) Water containing particles not exceeding 0.3 mm.

(vi) A maximum altitude above sea level of 200 m.

The Contractor shall state the limits of environmental conditions under which the system is designed to operate.

Materials and Workmanship

All materials used shall be of first class quality in accordance with relevant national standards, carefully selected for the duty required, with particular regard given to resistance against corrosion and long term degradation. Workmanship and general finish shall be in accordance with the best modern practice.

Standards

Designs, materials and workmanship shall comply with approximate, approved national or international standards. Such standards shall be the latest issues current at the time of tendering.

Photovoltaic modules shall comply with the test requirements of either 'Specification 501 - Photovoltaic Module Control Test Specifications of the Commission' of European Communities Joint Research Centre - Ispra Establishment or the current 'Jet Propulsion Laboratory Module test Specification'.

Performance Requirement

The Contractor shall guarantee that the performance of the system supplied meets the selected performance requirements and shall supply performance data to demonstrate the performance of the system. In addition, performance data on each of the principal components shall be supplied in sufficient detail to enable the Government of The Gambia and its advisers to check performance under the range of operating conditions specified.

Program and Progress

The Contractor shall submit with his Tender a draft program of design, manufacture and delivery of the equipment included in the Contract. Immediately after award of Contract the Contractor shall confirm and agree on the program with the Government of The Gambia and its advisers.

The Contractor shall submit a progress report at monthly intervals showing the progress achieved related to the overall program.

Bought-in Items

Details of all manufactured components with a value exceeding 5% of the f.o.b. price of the system which the Contractor proposes to buy from other suppliers for incorporation in the system shall be submitted to the Consultants for their approval.

Protective Coatings

All equipment and components shall be provided with suitable protective treatment and paint coatings. Full details of all proposed protective treatments shall be submitted for approval. In general, the dry film thickness of any paint system shall nowhere be less than 200 microns. All protective treatments shall be applied in accordance with the manufacturer's recommendations.

Electrical Equipment

All electrical equipment shall be conservatively rated, present no hazard and be prepared for a tropical climate. Units shall be protected by fuses or other safety devices where necessary. All exposed components and component housings shall be waterproof.

Nameplates

Manufacturers' nameplates including model and serial numbers shall be provided and fixed to all major components for ease of identification and reference to relevant drawings and technical details.

Tests and Inspection During Manufacture

All of the work may be subject to inspection and approval by the Government of The Gambia for compliance with the Specification. The Government of The Gambia shall have access to and may inspect the work at all times at the site of the work, and shall have access to, and may inspect materials and equipment to be incorporated in the work at all times at the place of production or manufacture, including suppliers and sub-contractors, and at the shipping point. Due notice of any inspection will be given to the Contractor.

Material tests required during manufacture shall be in accordance with the appropriate National Standard Specification or as otherwise approved by the Consultants.

Test certificates and test reports in a form approved by the Consultants shall be provided in duplicate by the Contractor in respect of all tests on materials, components and the system as a whole.

Inspection and approval by agents of the Government of The Gambia of any component or test shall not relieve the Contractor of any of his obligations and liabilities under the Contract.

Warranty

The manufacturer/supplier shall provide a warranty to cover replacement at the manufacturer/supplier's expense of any system(s) or component(s) that cause either:

(a) the system to fail to perform within the specification, or

(b) to become faulty, perform erratically or unreliably or malfunction in any significant way

The warranty is to remain valid for one year from date of acceptance of the equipment by the Government of The Gambia so far as all direct replacement expenses are concerned including parts, materials, labor and shipping. Furthermore, a warranty to cover costs of parts and materials is to be provided to extend another four years over and above the initial one year warranty.

The manufacturer/supplier will be required to undertake to respond promptly to any legitimate claims under the warranty. If the replacement is not delivered to Banjul within a period of two months of receiving written notification of a legitimate claim, then the Government of The Gambia reserves the right to charge the manufacturer/supplier for consequential costs arising from the non-availability of the system concerned.

If manufacturers or suppliers can offer other forms of warranty of benefit to the purchaser in addition to the requirements given above, these will possibly be of advantage to the supplier so far as influencing the choice of equipment is concerned.

Packing for Shipment

All equipment shall be carefully and suitably packed for the specific means of transportation to be used, so that it is protected against all weather and other conditions to which it may become subject.

Before despatch all equipment is to be thoroughly dried and cleaned internally. All external unpainted ferrous parts and machined surfaces shall be protected by an approved proprietary preservative, all openings shall be covered and all screwed conditions plugged unless otherwise agreed.

Where moisture absorbants have been used for protection from corrosion during storage or transit, adequate information of their location and warning as to their removal shall be clearly indicated.

As filler material in boxes, paraffin-treated paper strips, plastic balls or similar may be used. Wood wool, hay or straw as filler and for stiffening of the goods shall not be used.

Documentation

Prior to shipment of the equipment the Contractor shall submit to the Consultants the following documents:

(i) A list of components and assemblies to be shipped including all spare parts and tools.

(ii) Assembly instructions.

(iii) Operating instructions.

(iv) Instructions for all maintenance operations and the schedule for any routine maintenance requirements.

(v) Sufficient descriptions of spare parts and components to permit identification for ordering replacements.

(vi) Revised drawings of the equipment as built if different from the approved proposals.

All documents shall be in the English language.

Special Tools

The Contractor shall provide with each consignment two sets of any special tools and other equipment that are required for erecting, operating, maintaining and repairing the equipment.

Technical Support after Shipment

The Contractor shall be prepared to provide advice during the installation and warranty periods of the equipment supplied under the Contract. For this purpose he shall nominate a member of executive or technical staff who may be contacted during normal office hours.

If the Contractor has an agent or representative in The Gambia or Senegal, the particulars shall be advised.

Shipment and Delivery

After packing, the complete system is to be dispatched to Banjul, The Gambia. The shipment may be made by sea provided the delivery to the port of entry within the required schedule can be assured; otherwise the delivery shall be by air freight.

Insurance

The Contractor shall arrange for the equipment to be comprehensively insured for its full value from the time it leaves his premises until clearance from customs at Banjul.

Services by Others

The following sevices after delivery of the equipment will be carried out by the Government of The Gambia and the suppliers will not be held accountable for them:

- Clearance of the equipment through customs;
- Transport to a location specified by the Consultants, including insurance;
- Storage prior to erection if necessary;
- Construction of foundations;
- Erection and setting to work of the equipment;
- Operation of the equipment; and
- Routine maintenance (as distinct from any repairs or maintenance required under the terms of the warranty).
- Full performance testing of the system to confirm compliance with the Specification and identify factors which might limit the useful life of the system when operated under field conditions.

CLIMATIC DATA FOR THE GAMBIA

1. The climatic data which is relevant to the sizing of the solar energy systems includes solar radiation, rainfall, ambient air temperatures, wind speeds and relative humidity. Except for solar radiation, the climatic data in The Gambia are available in a comprehensive form suitable for accurate sizing of solar energy systems. The data on solar radiation is somewhat fragmented, but still better than what is available in many developing countries. With some subjective judgments, however, the solar radiation data too can be interpreted to yield meaningful information. All told, the climatic data in The Gambia can be used to develop fairly accurate sizing of solar energy systems. The data are discussed in the following sections.

Solar Radiation

2. The data on solar radiation is the most important parameter which affects the sizing of solar energy systems. Ideally speaking, one should have access to hourly values of direct and diffuse components of solar radiation for the whole year, which in turn should represent the average of many years of observations, collected with instruments of acceptable accuracy (e.g., Eppley, Kipp and Zonen) which are re-calibrated at proper intervals. However, The Gambia, like nearly all other developing countries, does not possess such data.

3. The only solar radiation data currently available in The Gambia includes: 30-year (1950-79) monthly averages of sunshine hours/day at Yundum airport measured with Campbell Stokes Sunshine recorders; 30-year (1950-79) monthly averages of cloud cover for Yundum airport; 10-year (1970-79) monthly averages of daily solar radiation at Yundun airport measured with relatively inaccurate bimetallic actinographs; and daily values of solar radiation for three locations (Yundum airport, Sapu and Basse), each roughly for over a year, measured in more recent years with newly installed and accurate Kipp and Zonen pyranometers. Whereas individually none of the above data conveys a fully reliable picture of solar radiation in The Gambia, collectively they project a reasonably acceptable view of the situation. Needless to say that owing to the inaccuracies inherent in some of the data, a certain degree of subjective judgment would be needed in its evaluation.

4. Various data as listed above are shown in Tables 1.1 - 1.6.

Ambient Air Temperatures

5. Owing to the country's proximity to the equator and the sea coast, the diurnal and seasonal variations in ambient air temperatures in

The Gambia are limited. This is all the more true of Banjul which is located on the sea coast where the average winter (November-March) temperature is about 24°C and that for the summer (April-October) is around 27°C; similarly the year-round differential between daily maximum and minimum temperatures is about 12°C. The diurnal and seasonal variations become slightly more pronounced -- but not much, as one moves inland in the easterly direction. For sizing the solar energy systems for different locations in The Gambia, it therefore should be accurate enough to use the ambient air temperature data from Banjul (recorded at the Yundum airport). These data are listed in this annex.

6. The annex records three sets of data for Yundum airport: (a) 10-year (1970-1979) monthly averages of the mean, mean maximum, mean minimum, plus extreme maximum and extreme minimum temperatures; (b) 30 year (1950-1979) averages of some parameters as in (a); and (c) for the year 1983 (considered to be a typical year), 3-hourly values of ambient air temperatures for each day of the year. Whereas the former set of data provides an overview of the temperatures for initial sizing of the solar energy systems, the latter furnishes detailed information for their 'dynamic', more accurate, sizing. The three sets of data (a), (b) and (c) are shown in Tables 1.7, 1.8, and 1.9, respectively.

Wind Speed and Direction

7. The diurnal and seasonal variations in wind speeds and direction are more pronounced. For instance, wind speeds vary from about 3 knots (1.5 m/s) in November to around 7 knots (3.5 m/s) in April; also on a daily basis they can vary by a factor of 2-3. However, on a countrywide basis the variations again are not significant. Consequently, for sizing of solar energy systems, the wind speed and direction data for Banjul (i.e., Yundum airport) can adequately represent the whole of Gambia.

8. This annex records two sets of wind data: (a) 30-year (1950-79) data for wind speed, direction and force; and (b) for the year 1983 (considered to be a typical year), 3-hourly values of wind speed and direction for each day of the year. The first set of data would assist in preliminary sizing of the solar energy systems and the latter would lead to their more accurate sizing. These two sets of data are presented in Tables 1.4, and 1.5, respectively.

Relative Humidity

9. The seasonal as well as diurnal variations in relative humidity in The Gambia are quite pronounced. While the winters are relatively dry, the summers are characterized by high humidity; also the diurnal variations are more significant in the winter. In Banjul (i.e., Yundum

airport), for instance, the average relative humidity in January is about 54% while in August it rises to nearly 87%. Also the diurnal variation ranges from 23-81% in January while in August it narrows down to a range of 71-96%. Inland the seasonal and diurnal variations in relative humidity are even more marked. However, given the second order effect of relative humidity on the sizing of solar energy systems, the data at Yundum airport are considered adequate to be representative of the whole country.

10. This annex, consequently, lists for the Yundum airport, three sets of data on relative humidity: (a) 10-year (1970-79) averages of monthly mean, maximum and minimum relative humidity; (b) 30-year (1950-79) averages of mean, maximum and minimum relative humidity; and (c) 3-hourly values of relative humidity for the year 1983 (which was considered to be a typical year). As before, the 10- and 30-year average would assist in preliminary sizing of the systems, while the 3-hourly values are useful in more accurate sizing of the system. The data are listed in Tables 1.12, 1.13 and 1.14.

Rainfall

11. The rainy season in The Gambia is limited mainly to three summer months (July-September) wherein some 85% of the rainfall occurs. Nearly all of the remaining (about 15%) rainfall is experienced in the months of June and October. The rainfall is highest near the coast and decreases somewhat as one proceeds inland. The data on rainfall (except how it influences the incidence of solar radiation) is not directly used in determining the size of solar energy systems. And, since the data on solar radiation for three locations in the country are listed separately, rainfall data for only one location (Yundum airport) is presented in Table 1.15 in this annex.

Table 1.1: TOTAL SOLAR RADIATION IN THE HORIZONTAL PLANE - DAILY VALUES (langleys/day*)

Year: 1983/84
Location: Yundum Airport

	Oct '83	Nov '83	Dec '83	Jan '84	Feb '84	Mar '84	Apr 84
01		1590	1821	1520	1630	-	2508
02		1963	1422	1520	1795	2133	2492
03		2010	1274	3699	1712	2014	2417
04		1866	1279	1438	1976	1842	2264
05		2008	1786	1152	2017	-	2140
06		1968	1703	1778	1986	-	2263
07		1930	0601	1740	1689	-	2214
08		1969	1443	1878	2644	-	2188
09		1716	1557	9957	1992	-	2589
10		1679	1429	1657	1855	2295	2511
11		2085	1904	1912	2158	2350	3110
12		1947	1659	1702	2024	2432	2509
13		1680	1607	1280	2142	2478	2577
14		1899	2100	1453	2121	2119	2588
15		1767	1437	1566	2015	2333	2580
16		1815	1485	0170	2124	2272	2463
17		1368	1626	1520	2368	2519	2424
18		2031	1689	1520	1785	0360	8478
19		1858	1738	1520	2409	1520	2094
20		1730	1763	3736	2377	1520	2327
21		1987	1895	1582	2279	1496	7585
22		2088	1546	1736	2142	1520	4856
23		2152	1878	1909	2177	1198	4892
24		1272	1957	1608	2277	1520	5110
25		-	2780	1350	2325	1520	-
26		-	1936	1719	2299	3281	-
27		1714	2078	1845	2293	2209	-
28		1813	1520	1972	1914	6224	-
29		1521	1520	-	2045	1403	-
30	1885	1553	-	2015	-	0907	-
31	1590	-	1520	1983	-	5564	-

* 1 Langleys/Day = 3.69 Btu/Ft^2 day = 4.19 Joules/Day

Table 1.2: MONTHLY AVERAGE OF CLOUD COVER (OKTAS) AND NUMBER OF SUNSHINE HOURS 10 YEAR (1965-1975) AVERAGED

Month	Mean Cloud Cover (Oktas)	Maximum Recorded	Minimum Recorded	Mean	Possible Sunshine Hours (13° N)	Mean as % of Total
January	2.8	10.4	3.5	8.8	11.4	77
February	2.2	10.5	4.7	9.4	11.7	80
March	2.0	10.5	3.8	9.0	12.1	74
April	1.5	11.2	5.4	9.6	12.5	77
May	2.2	11.3	2.9	8.5	12.8	66
June	3.9	11.0	1.2	7.8	12.9	60
July	5.3	11.0	0.1	6.5	12.4	50
August	5.8	10.7	0.3	5.4	12.6	43
September	5.2	10.5	0.3	6.5	12.2	53
October	3.7	10.3	0.4	7.7	11.8	65
November	2.9	10.2	1.4	8.1	11.5	70
December	3.5	10.4	1.2	7.8	11.3	
Overall Average	3.4	10.7	2.1	7.9	12.1	65.3

Table 1.3: SOLAR RADIATION IN THE HORIZONTAL PLANE - DAILY VALUES
(langleys/day)

Year: 1980
Location: Yundum airport

Date	Month January	February	March
1	-	397	471
2	-	391	431
3	-	408	433
4	-	372	451
5	-	201	421
6	-	172	435
7	-	276	454
8	-	497	513
9	-	473	469
10	-	468	475
11	490	469	471
12	439	416	514
13	429	278	447
14	423	332	423
15	406	421	411
16	287	434	512
17	414	459	-
18	381	481	428
19	386	451	430
20	378	407	419
21	379	280	-
22	432	228	-
23	437	454	-
24	-	435	-
25	-	407	-
26	-	353	-
27	-	394	-
28	390	294	-
29	414	273	-
30	508	xxx	-
31	-	xxx	-
Total	6594	10921	8608
Monthly Mean ly/day	412	376	453

Table 1.4: SOLAR RADIATION IN THE HORIZONTAL PLANE - DAILY VALUES
(langleys/day)

Year: 1980
Location: Sapu

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1	418	482	521	563	320	536	528	526	362	412	484	308
2	404	476	522	571	336	554	575	505	274	452	471	410
3	355	471	517	516	402	559	541	471	297	459	369	388
4	80	339	520	583	601	569	534	535	377	460	383	377
5	364	135	502	578	601	496	488	499	229	455	242	252
6	225	64	516	571	585	401	574	403	314	511	473	548
7	243	209	550	519	595	425	481	425	565	498	407	389
8	158	521	533	451	576	199	382	449	364	406	285	419
9	293	530	565	533	579	553	336	502	386	533	410	440
10	487	523	561	307	581	438	577	491	425	441	394	449
11	446	537	561	583	599	250	547	537	564	344	408	428
12	413	533	560	585	583	420	576	440	503	488	437	281
13	424	272	579	596	575	424	564	525	512	501	471	180
14	402	243	514	563	758	383	540	431	503	511	470	99
15	371	571	515		557	462	527	493	559	453	467	51
16	352	165	467	583	523	380	440	611	533	468	426	214
17	418	551	441	571	474	224	354	452	503	516	457	395
18	409	528	467	588	437	570	236	431	494	478	467	389
19	436	481	555	457	413	535	360	575	429	500	468	438
20	430	384	542	516	258	543	533	511	501	456	444	473
21	430	330	544	473	570	564	548	652	518	438	404	450
22	465	245	565	430	600	511	495	506	571	406	400	352
23	493	489	569	400	504	580	451	423	548	537	411	375
24	480	503	586	405	456	535	486	156	425	520	204	413
25	474	487	562	409	579	392	566	595	542	517	195	339
26	388	477	591	408	552	531	245	471	491	492	387	402
27	421	457	565	430	559	440	553	183	536	471	423	447
28	493	458	521	428	495	450	437	507	421	470	417	449
29	486	341	603	429	499	512	263	557	367	502	398	256
30	486	xxx	510	430	493	548	566	516	429	500	265	223
31	487	xxx	559	xxx	516	xxx	209	345	xxx	498	xxx	259
Total	12231	1802	16683	14476	16156	13984	14512	47624	13542	14693	11936	10903
Monthly Average ly/day	395	407	538	499	521	466	468	475	451	474	398	252

Table 1.5: SOLAR RADIATION IN THE HORIZONTAL PLANE - DAILY VALUES
(langleys/day)

Year: 1981
Location: Sapu

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1	426	444	706	450	460	326			453		225	
2	384	205	491	506	418	375			270		234	
3	423	205	503	511	527	602			269		431	
4	380	308	461	526	549	474			466		343	
5	377	316	425	539	550	597			519		335	
6	365	317	430	583	526	514			455		348	
7	251	331	474	436	249	512			443		412	
8	332	357	502	436	465	567			339		412	
9	421	461	521	170	434	567			541		387	
10	397	453	511	479	459	560			234		342	
11	467	419	540	493	506	527			560		330	
12	432	407	508	473	517	571			415		410	
13	256	350	491	435	510	486			415		416	
14	259	421	485	269	510	391			429		415	
15	213	333	514	270	520	579			509		329	
16	295	482	494	506	393	526			468		362	
17	335	476	531	519	542	549			334		317	
18	302	512	491	475	579	464			529		390	
19	395	511	483	506	601	557			546		339	
20	353	509	510	549	496	304			521		337	
21	418	518	526	567	557	609			452		312	
22	431	523	350	543	569	465			519		394	
23	455	521	443	515	547	336			251		400	
24	336	268	566	514	239	506			526		328	
25	341	506	521	548	621	496			521		422	
26	232	511	557	528	574	519			566		343	
27	295	481	561	531	541	582			483		363	
28	467	481	565	510	580	555			431		419	
29	459		561	455	582	528			543		443	
30	476		514	517	585	544			551		455	
31	499		325		381							
Total	11472	11626	15560	14359	16459	15088			13898		10967	
Mean	370	413	502	479	531	503			463		366	

Table 1.6: METEOROLOGICAL SERVICE

Year: 1980
Location: Basse

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1	435	454	546	596	442	218	554	498	282	486	505	297
2	412	478	561	583	541	574	584	433	335	475	477	380
3	369	459	525	467	562	595	580	299	401	469	316	357
4	221	281	535	602	577	613	545	453	353	495	400	387
5	267	98	552	608	563	555	428	511	337	526	343	392
6	421	44	562	562	578	310	606	587	527	530	468	95
7	278	233	563	562	514	300	544	254	585	514	411	-
8	167	410	574	517	355	427	447	491	474	511	346	-
9	268	556	-	578	580	565	379	499	417	545	407	-
10	485	556	-	581	582	483	580	553	540	449	420	239
11	440	565	-	588	580	586	508	432	590	407	428	399
12	422	568	582	595	590	581	643	355	527	459	418	407
13	439	268	582	590	555	487	533	582	552	558	452	219
14	393	152	550	599	623	546	563	454	575	524	438	150
15	349	541	526	582	551	552	578	466	575	460	418	98
16	297	548	514	581	618	671	546	586	413	440	388	164
17	399	571	511	588	625	227	419	514	479	532	410	423
18	406	570	523	572	583	559	194	496	485	491	448	421
19	436	495	571	555	563	577	420	588	414	483	450	406
20	432	419	591	485	557	567	534	478	494	528	413	482
21	430	408	609	581	615	550	418	606	557	480	382	457
22	462	304	603	493	618	509	473	407	604	482	367	378
23	485	205	585	419	616	577	-	415	513	527	362	357
24	491	534	612	473	625	549	-	270	415	586	212	449
25	488	456	629	508	575	521	556	522	587	603	324	421
26	354	541	593	382	629	539	301	425	490	335	388	440
27	426	542	587	522	536	375	501	221	578	486	410	461
28	483	479	641	468	483		531	454	439	457	376	468
29	472	314	558	494	392	538	204	467	402	510	369	366
30	481	xxx	564	511	524	431	598	478	489	485	212	250
31	495	xxx	583	xxx	548	xxx	314	442	xxx	495	xxx	205
Total	12,403	12,049	15,932	16,242	17,100	15,051	14,081	14,236	14,429	15,328	11,758	9,557
Monthly Mean 1 yr/day	400	415	569	541	551	502	485	459	481	494	392	341

a/ Record of rainfall measured at 09 G.M.T. (9 a.m. in Gambia and Sierra Leone, 10 a.m. in Nigeria) and entered against day preceding that on which read, in accordance with the instructions on Nigerian Form 508.

Table 1.7: AMBIENT AIR TEMPERATURE - 10-YEAR AVERAGES (1970-1979)
(Degree °C)

Location: Yundum Airport

Month	Mean	Mean Maximum	Mean Minimum	Extreme Maximum	Extreme Minimum
January	23.3	32.0	16.0	35.9	11.3
February	24.0	33.7	16.2	37.9	12.2
March	25.1	33.7	17.6	39.2	13.6
April	24.8	33.0	19.3	28.9	16.0
May	25.0	31.6	19.8	27.1	17.0
June	27.1	31.9	22.9	35.5	19.9
July	26.7	30.2	23.4	32.8	20.0
August	26.7	30.0	23.0	31.8	19.9
September	26.5	30.6	22.7	32.8	20.4
October	26.7	31.7	22.2	34.3	19.0
November	25.4	32.5	18.9	35.7	14.7
December	24.0	31.7	17.1	35.2	13.1
Overall Average	25.4	31.9	19.9	35.6	16.4

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.8: AMBIENT AIR TEMPERATURE - 30-YEAR AVERAGES (1950-1979)
(Degree °C)

Location: Yundum Airport

Month	Mean	Mean Maximum	Mean Minimum	Extreme	
				Maximum	Minimum
January	23.4	31.8	15.2	35.5	10.7
February	24.5	32.9	15.2	37.9	12.0
March	25.5	33.9	17.2	39.4	13.4
April	25.6	32.7	18.5	38.9	15.5
May	25.9	31.7	20.0	37.5	17.2
June	27.2	31.7	22.7	35.4	19.8
July	26.7	30.2	23.3	32.7	20.5
August	26.3	29.7	22.9	31.6	20.7
September	26.5	30.4	22.6	32.6	20.3
October	26.8	31.5	22.1	34.1	19.3
November	25.5	32.3	18.8	35.2	14.6
December	23.7	31.2	16.1	24.7	11.5
Overall averages	25.6	31.8	19.6	35.5	16.3

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.9: THREE HOURLY VALUES OF AMBIENT AIR TEMPERATURE (Degree °C)

Year: 1983
Month: January
Location: Yundum Airport

Date	Hours							
	00	03	06	09	12	15	18	21
1	17.2	15.8	14.9	18.4	25.2	31.1	26.8	20.2
2	19.8	16.3	16.1	21.5	28.0	30.5	28.5	20,4
3	20.3	18.5	19.4	20.0	25.0	28.8	26.5	22.9
4	20.4	21.5	19.4	20.5	26.8	30.5	28.1	23.8
5	20.9	18.8	17.3	19.9	27.4	32.1	29.5	21.7
6	19.3	17.9	17.8	19.8	25.7	29.5	27.5	18.1
7	20.0	19.0	18.2	19.0	24.5	28.4	27.5	16.6
8	18.7	16.8	18.5	19.5	25.6	30.3	29.6	19.0
9	15.7	13.5	12.8	16.3	27.2	31.3	29.4	16.4
10	18.0	12.7	10.9	17.7	28.8	33.0	30.5	20.5
11	19.2	18.6	17.1	20.9	27.5	32.6	29.5	21.3
12	21.2	19.0	16.5	20.6	28.0	32.7	31.0	17.7
13	20.3	17.0	19.0	20.5	27.7	31.2	29.6	21.9
14	19.5	19.4	18.5	20.0	26.4	30.5	27.6	20.5
15	19.7	19.0	18.4	20.2	26.9	28.1	27.8	18.3
16	17.0	17.5	16.0	19.5	26.9	31.6	30.0	21.7
17	20.0	21.0	21.8	20.4	29.0	33.6	32.1	23.2
18	22.0	21.9	20.0	21.4	30.4	34.5	33.1	19.3
19	19.8	18.9	19.7	23.0	31.5	35.2	33.8	21.5
20	18.3	16.0	17.0	21.8	31.0	35.1	31.7	21.7
21	19.5	19.8	18.0	20.0	30.1	35.0	26.8	20.2
22	18.2	16.1	13.3	19.8	28.4	35.0	29.5	20.8
23	19.6	18.5	17.3	19.5	31.0	35.9	34.5	20.5
24	18.2	19.5	13.5	21.0	31.8	36.3	31.8	21.9
25	16.9	19.8	20.0	21.1	30.6	35.6	33.6	19.9
26	21.6	16.7	17.5	21.0	29.5	34.5	32.5	23.1
27	25.5	20.8	19.5	21.1	28.4	32.0	31.1	19.4
28	23.0	22.6	21.5	21.2	27.5	30.9	29.4	21.0
29	21.8	21.6	20.9	21.7	23.9	27.3	26.8	19.7
30	20.0	20.5	19.5	20.3	26.5	30.6	29.5	18.3
31	20.7	19.3	18.4	20.3	28.2	31.9	30.4	21.2

Table 1.9: Cont'd
Month: February

Date	Hours 00	03	06	09	12	15	18	21
1	18.6	14.4	13.3	17.6	28.7	33.5	31.0	22.8
2	21.7	21.8	17.8	20.0	30.0	34.9	32.9	22.1
3	19.8	20.5	17.6	19.2	30.3	35.6	32.4	22.5
4	19.4	21.0	17.3	20.0	31.5	35.3	31.1	22.0
5	20.3	20.5	18.0	21.7	31.7	35.5	31.9	23.2
6	20.4	18.0	20.8	21.4	26.5	33.0	30.4	22.1
7	20.8	17.5	15.7	19.0	30.6	33.0	29.2	21.7
8	18.9	14.8	14.5	19.1	25.9	30.3	25.4	21.2
9	20.9	20.4	18.5	21.2	25.0	27.9	24.3	21.6
10	19.7	18.0	16.3	18.4	24.1	28.5	24.5	21.2
11	19.6	18.9	16.9	19.3	24.9	27.7	24.4	20.9
12	21.3	21.0	19.7	19.7	25.1	29.4	25.5	21.5
13	21.3	19.5	18.0	19.5	25.0	28.3	24.8	21.3
14	20.0	19.2	17.0	19.3	26.0	28.2	24.6	21.5
15	20.5	19.7	19.4	21.1	26.5	20.9	27.5	21.2
16	21.2	19.8	19.5	21.2	28.5	31.7	27.0	22.9
17	23.3	21.5	20.4	21.5	29.6	33.9	29.0	23.5
18	24.4	22.0	20.6	23.4	33.3	37.0	30.0	23.4
19	25.0	23.8	22.6	24.2	33.1	39.0	31.3	25.6
20	21.5	20.9	17.5	24.9	35.3	40.0	30.8	23.7
21	19.3	19.1	18.6	22.4	33.4	36.5	29.5	23.2
22	21.5	19.0	17.1	25.2	35.8	39.6	34.3	25.9
23	22.0	21.8	21.0	24.0	33.0	38.5	32.7	24.5
24	21.6	19.8	20.3	23.7	34.5	39.7	38.1	24.7
25	22.4	21.3	15.5	23.5	35.4	38.5	35.5	25.0
26	22.0	19.6	19.1	22.0	32.8	39.5	30.4	23.3
27	21.6	19.8	20.5	21.7	32.5	33.8	30.4	23.5
28	22.4	21.0	21.0	21.7	37.3	37.0	36.0	26.4

Table 1.9: Cont'd
Month: March

Date	Hours 00	03	06	09	12	15	18	21
1	24.4	23.5	22.4	23.1	32.0	36.0	32.9	24.2
2	22.7	19.6	18.3	22.8	33.2	35.5	29.5	22.8
3	20.2	19.4	19.0	21.1	29.7	32.5	30.4	23.0
4	21.8	21.4	21.2	23.6	28.5	35.0	34.3	24.5
5	24.5	22.4	21.7	26.0	29.6	35.7	27.8	24.0
6	24.7	21.8	21.4	23.6	30.4	36.4	27.0	23.6
7	22.6	21.2	19.0	23.1	31.0	34.6	31.4	24.1
8	24.8	22.7	24.0	25.6	35.6	39.0	38.5	27.6
9	21.5	18.9	17.2	25.4	36.2	40.1	38.6	25.9
10	27.3	27.8	27.9	28.8	34.5	38.0	35.5	26.2
11	25.0	25.8	27.5	28.6	33.5	35.0	35.0	26.2
12	23.8	25.2	26.4	26.0	28.0	30.0	28.8	24.5
13	22.5	21.4	21.1	23.6	28.7	32.5	26.2	22.0
14	21.2	21.0	19.8	22.0	27.0	26.7	24.3	21.0
15	20.6	19.8	20.3	21.5	26.5	30.5	25.0	21.8
16	20.7	19.6	19.6	21.6	28.1	30.0	25.7	21.5
17	20.7	19.6	19.0	22.8	30.4	34.3	20.2	21.9
18	20.7	19.6	19.3	23.8	31.9	30.7	25.4	21.9
19	21.2	20.1	19.2	21.6	30.4	29.5	26.4	21.7
20	20.7	20.1	20.1	21.1	32.7	34.0	33.3	23.2
21	21.8	21.0	20.0	21.6	35.2	39.1	29.5	24.3
22	24.0	22.2	20.8	22.9	32.5	33.0	29.5	23.0
23	21.6	21.6	21.0	22.0	31.7	33.6	29.5	23.3
24	22.9	22.5	22.0	23.4	29.0	32.0	26.7	23.1
25	22.0	22.0	22.0	23.7	27.1	30.0	27.6	24.2
26	23.2	22.4	22.3	26.6	38.0	41.2	40.0	31.0
27	30.0	27.0	27.8	30.5	37.5	40.0	30.7	27.1
28	26.2	23.3	23.9	26.5	33.0	35.5	27.2	23.0
29	21.8	21.5	20.4	22.7	28.2	30.2	26.0	20.9
30	20.2	18.9	19.7	22.0	27.0	29.5	25.2	21.6

Table 1.9: Cont'd
Month: April

Date	00	03	06	09	12	15	18	21
	Hours							
1	19.4	18.5	18.0	21.8	27.4	30.0	25.0	20.0
2	19.1	19.0	19.3	21.2	24.6	25.8	23.4	20.5
3	19.9	19.1	18.8	21.1	24.6	24.8	23.0	20.6
4	20.2	19.0	18.2	21.5	25.5	28.5	25.5	21.7
5	21.4	20.5	20.5	22.4	25.5	32.2	26.8	25.1
6	24.7	23.7	23.4	25.7	34.8	38.0	29.1	24.6
7	25.9	24.0	22.6	26.1	35.2	40.6	31.4	24.8
8	25.6	24.0	24.7	28.5	36.0	41.1	31.4	24.8
9	22.9	20.8	20.2	26.9	33.8	36.2	29.4	24.7
10	20.0	17.5	17.5	25.4	31.1	36.2	26.6	21.1
11	20.1	19.1	19.3	21.0	27.9	26.8	24.2	21.2
12	20.5	20.1	20.0	22.0	31.7	28.8	25.1	21.5
13	20.9	20.0	18.8	21.4	28.5	30.0	26.6	21.6
14	20.9	20.7	19.5	21.0	29.6	30.0	26.2	22.0
15	21.3	21.0	20.5	23.3	29.5	32.0	26.6	22.4
16	21.9	20.9	20.7	23.0	28.7	29.5	24.9	22.0
17	20.7	20.2	19.6	22.0	26.8	29.7	27.0	21.9
18	20.5	19.7	19.0	22.5	27.5	30.0	25.4	21.2
19	20.2	19.5	19.0	22.4	26.6	30.2	24.2	21.2
20	20.7	20.2	20.2	22.4	25.9	27.5	24.9	22.0
21	21.3	21.1	20.5	23.7	28.0	30.7	26.5	22.0
22	20.6	20.1	20.3	24.3	27.6	26.8	25.7	22.4
23	21.9	21.5	21.3	22.5	25.8	30.1	24.5	21.5
24	20.9	19.8	19.6	22.4	29.5	28.7	23.9	21.0
25	20.4	19.6	19.2	22.0	26.4	26.9	24.3	20.6
26	20.1	19.8	19.6	21.7	25.7	25.8	23.4	21.0
27	20.4	20.0	19.5	22.8	28.0	27.8	24.1	21.8
28	20.9	20.1	20.0	23.8	28.1	30.8	25.4	22.2
29	21.5	20.6	20.2	24.3	31.4	33.8	28.8	24.5
30	24.4	23.8	24.0	26.1	31.3	36.6	31.5	25.2

Table 1.9: Cont'd
Month: May

Date	Hours 00	03	06	09	12	15	18	21
1	25.0	24.5	23.5	28.1	32.3	33.2	30.5	29.3
2	29.5	29.9	30.3	32.1	37.2	36.0	27.9	24.2
3	22.5	21.4	21.5	24.3	29.8	28.5	25.0	23.8
4	25.4	25.1	26.0	27.1	30.9	35.1	29.8	29.0
5	28.2	27.4	25.8	27.0	29.8	31.0	25.5	23.0
6	23.0	22.3	21.6	24.5	28.4	28.0	24.0	21.9
7	21.5	20.9	20.9	23.3	28.6	28.8	24.2	21.8
8	21.3	21.0	20.5	23.4	27.7	30.7	25.3	23.1
9	22.4	21.5	21.3	23.2	30.0	29.0	26.1	23.7
10	21.7	20.7	20.8	23.7	28.9	33.3	26.1	22.5
11	21.9	21.1	21.2	23.3	26.3	27.6	24.9	22.5
12	22.1	21.5	21.1	22.9	27.0	27.3	25.2	22.0
13	21.4	21.5	21.4	23.3	28.0	28.0	25.6	22.3
14	21.8	21.6	21.4	23.5	27.0	29.0	25.5	23.5
15	23.8	21.8	21.6	23.5	30.9	29.5	27.8	24.0
16	22.5	21.6	21.4	24.5	30.8	37.8	29.0	23.2
17	22.8	21.6	21.1	24.3	29.6	30.7	26.4	23.1
18	23.0	21.8	20.7	26.8	36.0	37.0	28.4	24.2
19	23.2	21.7	19.4	25.4	30.5	31.8	28.8	24.0
20	23.8	23.0	22.0	25.0	29.5	29.9	27.3	23.0
21	22.5	21.7	21.1	23.6	27.7	25.3	24.6	22.3
22	22.6	21.8	20.9	25.4	27.0	28.5	26.1	23.2
23	23.2	22.0	22.5	25.5	29.2	30.2	26.3	23.0
24	22.7	23.0	21.5	25.0	28.6	32.3	26.8	24.0
25	23.3	22.5	22.3	24.9	28.2	29.4	27.0	23.3
26	22.4	21.5	21.0	24.8	31.3	28.7	27.6	25.5
27	25.0	24.5	24.5	25.5	30.4	33.0	29.2	25.2
28	24.5	24.0	23.4	27.2	31.7	34.0	30.0	25.5
29	26.0	25.6	24.3	26.0	28.5	30.5	29.0	25.5
30	24.5	23.2	22.8	26.0	33.0	37.5	30.0	25.2
31	23.0	23.0	22.1	27.1	32.6	32.5	29.0	25.2

Table 1.9: Cont'd
Month: June

Date	Hours 00	03	06	09	12	15	18	21
1	24.4	23.3	23.8	26.7	31.5	31.4	28.0	25.5
2	25.1	24.8	24.8	26.8	31.5	32.5	29.0	26.5
3	25.9	24.3	23.9	28.0	31.6	31.0	29.0	27.0
4	26.5	26.3	26.0	27.8	32.0	31.7	28.9	26.8
5	25.6	25.0	24.6	27.7	32.0	32.0	29.6	26.5
6	25.5	25.2	25.0	27.4	31.7	32.3	30.0	26.3
7	26.0	25.0	23.4	26.6	31.0	31.0	28.5	26.4
8	26.0	25.3	24.6	27.0	31.5	32.8	30.6	27.8
9	26.9	26.4	25.4	27.6	32.0	33.9	30.0	27.0
10	26.0	26.8	25.2	28.9	33.9	33.0	29.4	27.1
11	26.2	25.5	25.0	28.0	31.5	31.9	29.1	26.0
12	25.5	24.8	23.8	26.6	30.0	30.2	27.4	26.0
13	24.8	24.3	24.2	25.5	27.9	31.2	28.4	26.5
14	26.0	25.0	25.1	26.8	32.5	24.0	29.4	27.4
15	27.0	26.5	26.3	27.8	30.0	31.5	29.1	26.9
16	26.5	26.3	26.2	28.3	31.6	32.9	30.0	27.3
17	26.6	25.8	25.5	28.6	33.3	33.8	30.0	27.5
18	27.0	26.8	25.7	28.5	31.4	31.5	29.2	27.0
19	26.5	26.0	25.5	25.0	30.4	26.0	31.0	27.8
20	27.5	26.0	25.8	27.8	30.9	31.1	28.6	23.8
21	24.0	23.8	23.1	26.5	30.1	32.1	30.5	27.8
22	27.2	22.9	23.2	25.5	29.9	31.2	29.8	27.2
23	26.7	26.0	25.5	28.0	31.0	31.5	29.8	26.9
24	26.0	26.0	25.4	27.4	30.2	32.1	29.3	26.6
25	25.7	23.8	22.7	27.4	31.0	32.0	29.5	26.5
26	26.2	24.5	25.3	29.0	32.5	32.9	29.6	27.7
27	26.3	25.3	25.2	28.4	30.1	28.8	26.5	24.9
28	25.6	25.4	24.8	26.4	29.2	31.3	29.7	27.4
29	27.4	26.8	26.4	28.7	31.8	32.0	29.5	27.5
30	27.0	26.2	24.7	27.8	31.0	30.5	28.8	26.6

Table 1.9: Cont'd
Month: July

Date	00	03	06	09	12	15	18	21
	Hours							
1	25.0	24.6	22.5	27.8	31.5	33.0	30.7	27.7
2	27.1	26.6	25.0	26.0	27.0	31.0	29.3	27.0
3	26.5	26.8	26.2	28.2	30.8	31.8	29.5	27.6
4	26.6	26.1	26.4	28.6	31.4	32.0	23.4	23.7
5	24.2	24.3	23.8	27.7	29.9	31.2	30.1	27.0
6	26.5	25.3	25.7	28.3	29.4	22.8	23.8	23.0
7	22.5	22.3	22.7	26.7	30.7	33.0	23.5	24.1
8	23.3	23.0	22.5	26.6	30.0	29.9	28.3	27.2
9	27.0	26.3	24.2	27.8	30.1	25.5	24.6	24.6
10	24.3	23.5	22.7	28.2	30.8	33.1	31.1	28.2
11	27.2	26.9	26.7	29.0	30.8	22.9	26.0	26.0
12	24.5	26.5	25.0	28.0	31.4	32.0	30.0	27.8
13	26.8	25.7	24.7	28.1	31.0	32.0	29.7	27.6
14	23.0	23.2	23.4	24.8	29.0	30.5	30.0	27.0
15	25.7	25.6	25.7	28.2	30.8	31.7	30.5	27.3
16	27.1	26.4	24.3	28.0	31.0	31.9	30.3	27.3
17	26.3	25.6	25.1	28.4	30.4	31.8	30.0	27.5
18	27.2	26.3	26.6	28.5	30.6	31.2	29.6	26.5
19	25.8	26.0	24.8	26.2	30.8	31.6	29.8	27.7
20	26.0	21.7	22.5	25.4	29.6	30.5	29.5	26.9
21	26.5	26.6	26.0	24.5	27.0	30.0	28.4	27.2
22	26.7	25.9	25.3	28.0	30.1	30.8	29.7	26.7
23	25.6	23.9	23.7	27.5	30.8	31.6	30.0	27.8
24	26.6	26.0	25.0	28.2	30.6	31.1	28.9	27.2
25	26.6	26.3	27.0	28.4	30.2	30.2	29.0	27.0
26	26.9	25.3	24.9	27.4	29.3	30.2	28.4	25.7
27	25.2	25.2	25.0	27.5	30.0	30.7	28.9	26.0
28	25.3	24.7	24.6	28.0	29.8	30.0	30.0	27.3
29	26.8	26.1	26.1	28.0	30.5	31.0	29.8	27.1
30	24.7	23.5	22.6	28.5	30.4	32.7	30.5	27.4
31	26.7	26.6	25.7	27.8	31.0	31.3	29.6	27.2

Table 1.9: Cont'd
Month: August

Date	Hours 00	03	06	09	12	15	18	21
1	26.4	24.8	25.0	28.5	31.5	28.0	28.6	26.5
2	26.0	25.3	25.5	28.0	30.5	30.5	27.1	26.6
3	25.0	25.5	25.4	27.4	29.3	30.4	29.0	27.1
4	27.0	26.4	26.1	28.2	30.7	31.6	30.0	27.5
5	26.3	25.8	25.1	28.6	31.5	31.3	29.6	26.9
6	27.2	26.9	26.8	27.8	29.2	30.0	28.0	26.4
7	25.0	23.9	22.0	27.3	30.3	30.4	29.2	26.5
8	25.4	24.4	23.6	26.7	30.4	23.0	24.5	24.4
9	23.6	23.8	24.0	25.5	29.0	30.5	24.5	24.5
10	24.7	23.9	23.6	25.4	26.2	25.8	25.9	25.3
11	24.9	24.6	24.5	26.5	28.9	30.8	29.0	26.3
12	25.5	24.6	25.3	27.8	29.8	30.0	29.5	27.3
13	26.6	25.6	25.3	28.1	30.2	31.1	29.4	26.7
14	26.4	25.3	24.0	25.0	30.2	27.5	27.8	25.3
15	24.5	23.1	22.5	26.7	30.5	30.5	29.6	27.0
16	26.4	26.3	25.5	28.5	31.0	31.0	29.5	27.1
17	25.5	25.7	24.3	27.5	30.7	30.0	29.6	26.7
18	26.0	25.0	23.6	28.2	31.2	31.2	29.7	27.5
19	27.2	27.1	26.5	27.6	29.7	31.2	27.9	25.4
20	24.6	23.4	22.8	26.0	30.5	31.5	29.2	26.3
21	25.0	24.0	24.0	27.7	26.3	23.9	24.5	23.0
22	22.2	22.8	23.5	26.5	29.5	30.7	29.6	27.0
23	25.8	25.3	24.5	27.7	29.7	30.3	28.1	23.5
24	24.7	23.2	22.4	26.1	30.2	31.6	24.2	24.3
25	23.3	23.5	24.5	26.8	29.3	30.5	28.7	27.0
26	27.1	26.7	26.1	28.4	30.0	30.4	29.1	26.8
27	26.5	25.6	24.7	27.0	30.1	31.0	29.4	26.8
28	25.5	24.8	24.3	27.1	31.2	29.5	30.0	26.5
29	25.2	23.0	22.8	26.8	30.5	27.4	23.0	22.8
30	23.0	22.9	23.7	27.5	30.5	30.6	26.5	23.0
31	23.3	23.0	22.5	26.8	31.0	31.9	30.3	26.5

Table 1.9: Cont'd
Month: September

Date	Hours 00	03	06	09	12	15	18	21
1	25.2	23.0	23.4	24.9	29.7	28.1	27.4	25.3
2	24.5	23.9	23.9	27.1	30.3	31.4	30.2	27.3
3	25.7	25.7	26.1	28.3	30.5	31.0	29.5	27.0
4	26.6	26.2	25.2	27.2	28.0	28.4	27.7	24.6
5	23.7	22.7	22.4	25.6	30.5	32.0	30.0	26.4
6	23.8	23.3	23.3	21.5	30.3	30.9	28.9	26.9
7	25.5	25.2	25.0	27.9	30.4	31.5	29.6	27.0
8	24.9	24.4	24.3	28.2	31.5	33.2	30.0	26.7
9	24.8	21.8	23.0	26.7	30.0	30.6	29.8	26.6
10	26.3	26.3	25.6	28.5	30.1	30.0	27.2	25.5
11	24.8	24.5	23.4	23.6	27.3	30.1	25.5	24.4
12	24.0	23.4	24.3	22.2	26.0	28.9	27.0	25.0
13	25.0	23.8	23.6	28.3	31.0	31.0	29.4	27.4
14	26.7	25.0	24.5	27.5	30.3	31.3	28.9	26.6
15	25.6	24.2	24.5	28.0	28.7	24.3	26.6	22.6
16	22.2	22.5	22.6	27.4	30.4	30.5	28.9	26.0
17	26.0	25.4	24.9	27.4	30.0	30.5	28.8	26.2
18	25.8	24.5	23.6	27.7	31.8	29.6	28.5	26.5
19	24.6	24.5	23.6	28.3	31.1	31.5	29.0	22.6
20	22.9	23.0	22.5	25.8	30.1	31.4	30.8	26.5
21	25.7	24.4	23.3	27.1	30.8	31.7	29.2	27.0
22	26.0	25.7	25.1	23.1	28.9	29.5	28.6	25.5
23	25.7	22.9	22.3	25.2	30.5	30.2	29.0	26.0
24	25.0	24.6	21.7	24.6	30.7	32.2	29.3	25.6
25	22.8	23.2	23.0	36.3	31.3	31.6	30.0	23.5
26	25.4	24.0	23.4	27.7	31.0	31.3	30.0	26.4
27	25.0	25.4	25.1	27.9	31.5	32.0	29.0	26.0
28	24.5	23.9	23.7	27.2	28.5	30.0	26.0	23.2
29	22.8	22.2	21.8	25.6	30.0	32.2	30.4	24.3
30	24.3	22.7	22.6	27.8	31.8	33.5	29.8	26.9

Table 1.9: Cont'd
Month: October

Date	Hours 00	03	06	09	12	15	18	21
1	26.7	27.2	22.2	23.5	28.6	31.0	29.5	27.0
2	25.1	25.6	26.0	28.5	30.5	31.3	29.2	27.0
3	25.3	24.6	23.7	28.0	31.2	32.3	29.5	26.5
4	25.5	25.5	26.0	28.3	31.0	31.6	29.5	25.7
5	25.2	24.7	23.6	26.9	30.0	31.6	30.5	25.0
6	25.1	25.0	23.6	25.7	29.0	31.4	30.4	25.0
7	25.0	23.5	24.3	27.8	27.0	31.3	28.3	24.5
8	25.5	24.2	25.5	28.5	32.0	25.0	30.9	26.9
9	25.0	24.5	24.0	28.0	32.4	33.5	30.0	27.0
10	25.9	25.7	25.7	28.8	31.4	32.4	25.6	24.5
11	24.5	24.0	23.4	27.5	31.4	32.2	30.0	26.6
12	25.5	24.8	24.8	27.8	31.6	31.9	29.6	25.8
13	24.8	25.0	24.8	28.0	31.4	31.5	29.7	26.0
14	25.6	23.8	24.0	28.1	31.0	32.4	30.4	25.7
15	24.4	23.1	22.9	27.2	31.6	32.4	30.1	25.5
16	25.4	24.5	23.6	27.0	32.3	32.5	30.0	26.3
17	25.3	24.4	23.2	28.0	31.3	31.5	28.9	24.6
18	24.9	23.1	23.6	28.2	31.8	32.2	29.9	26.5
19	26.0	25.5	25.6	28.3	32.0	32.9	30.0	26.2
20	26.2	25.4	23.0	27.6	31.7	31.5	29.4	25.1
21	24.7	23.8	21.6	27.5	31.6	33.0	30.0	26.2
22	24.9	24.7	23.0	28.0	31.6	32.7	30.3	26.0
23	24.8	24.0	22.5	26.6	33.2	32.0	29.2	26.0
24	24.6	25.3	24.8	28.0	32.4	30.4	29.1	26.0
25	25.4	25.3	23.2	27.7	31.5	32.0	29.5	26.2
26	25.4	23.1	22.3	27.0	32.7	33.2	31.0	24.5
27	23.4	24.0	21.7	26.8	33.9	34.0	30.9	26.1
28	25.5	24.0	24.2	28.0	32.1	33.9	29.5	26.8
29	26.3	24.8	24.5	27.7	30.9	32.3	29.0	23.5
30	23.0	21.4	21.0	26.9	31.5	32.5	29.5	25.8
31	24.0	22.4	22.4	25.8	32.0	33.6	30.2	26.6

Table 1.9: Cont'd
Month: November

Date	Hours							
	00	03	06	09	12	15	18	21
1	23.4	22.8	22.6	27.9	31.8	32.5	30.0	26.5
2	24.8	23.5	22.8	27.8	33.0	24.0	30.5	26.5
3	24.7	23.5	24.3	27.6	32.3	33.5	29.9	26.0
4	24.8	23.1	21.6	27.3	31.7	32.3	29.5	26.7
5	24.0	21.6	23.1	26.3	30.6	33.2	30.0	27.1
6	25.5	23.5	22.0	25.5	30.5	33.5	29.1	26.5
7	26.5	25.1	21.5	25.3	29.1	31.7	29.2	26.6
8	24.8	23.9	22.0	25.6	29.8	31.9	28.4	25.9
9	25.5	23.2	18.5	24.8	29.5	32.0	27.3	25.7
10	22.7	19.0	18.2	25.5	29.5	34.0	30.2	24.6
11	22.2	20.6	17.2	24.2	36.5	40.0	30.6	24.5
12	23.2	22.8	19.5	24.2	33.8	35.0	29.1	25.3
13	24.3	24.1	23.5	26.0	31.0	31.8	28.0	23.0
14	21.5	22.2	22.1	25.4	31.4	32.7	29.0	25.4
15	24.3	23.0	20.0	23.8	31.0	34.8	27.4	22.6
16	20.5	21.0	21.5	25.3	31.8	33.0	27.9	24.1
17	23.6	20.6	20.6	25.5	27.1	31.4	30.9	24.2
18	23.0	22.5	19.9	24.0	33.5	39.5	31.7	24.5
19	22.8	22.7	22.4	24.5	32.0	34.7	28.3	25.2
20	24.0	23.0	21.3	25.9	31.0	33.0	29.8	24.5
21	23.0	22.5	21.5	26.4	31.8	34.6	31.0	24.3
22	22.5	20.0	18.7	24.0	36.6	39.1	34.6	24.1
23	20.8	19.6	18.9	25.5	35.0	37.7	34.4	23.5
24	21.4	22.7	18.3	23.2	31.4	32.5	27.4	25.0
25	23.0	20.5	19.3	24.1	32.0	37.0	31.4	23.5
26	20.8	21.4	19.4	24.0	33.7	38.0	32.1	24.0
27	22.0	23.2	20.9	25.1	32.5	36.2	31.1	25.0
28	21.6	20.7	19.7	22.8	33.8	35.5	30.4	21.5
29	26.0	22.4	17.5	24.6	32.2	34.4	31.0	24.0
30	21.0	18.8	20.4	23.0	31.3	35.0	29.4	25.0

Table 1.9: Cont'd
Month: December

Date	00	03	06	09	12	15	18	21
	Hours							
1	23.8	22.2	20.9	25.7	32.2	36.0	30.2	24.8
2	23.1	22.6	21.1	22.7	29.5	33.4	32.1	24.8
3	22.3	24.3	22.2	23.8	29.0	33.4	30.2	23.7
4	23.7	23.7	33.3	25.5	27.4	32.8	30.3	25.2
5	22.7	19.0	21.7	24.5	31.8	26.1	29.6	23.8
6	19.5	19.5	19.5	24.2	32.8	34.5	30.4	24.2
7	24.4	22.8	23.2	24.4	27.3	29.4	27.0	23.8
8	22.9	21.6	21.5	24.0	33.0	34.7	32.4	26.9
9	26.7	24.6	23.1	25.3	31.7	34.2	31.7	24.8
10	24.5	24.1	23.2	23.9	27.9	32.5	30.5	24.6
11	22.4	22.1	20.9	22.5	28.6	31.7	29.3	23.1
12	22.2	21.5	19.6	21.0	27.0	30.3	27.5	22.5
13	16.6	18.5	19.1	20.8	26.5	29.5	26.3	20.4
14	17.6	17.5	16.6	20.4	28.6	32.2	26.3	21.4
15	20.8	17.6	19.3	21.9	29.0	33.5	30.0	22.7
16	20.4	16.7	18.0	21.2	29.0	32.2	28.7	21.0
17	20.6	19.1	19.5	21.5	29.6	33.2	26.3	21.3
18	21.0	19.4	18.5	22.2	29.1	33.0	29.5	19.2
19	16.3	18.9	19.1	23.0	29.2	33.6	30.5	21.6
20	19.7	23.0	19.6	22.7	30.3	33.6	30.4	21.7
21	23.0	17.9	17.9	22.2	29.0	33.1	31.0	21.1
22	21.2	20.0	18.4	21.7	28.9	30.8	28.3	20.2
23	20.0	17.5	13.0	18.8	30.0	33.9	29.5	21.2
24	19.5	18.4	17.8	21.8	28.3	33.3	26.2	21.9
25	20.7	19.9	19.9	21.4	28.5	31.8	27.3	21.5
26	21.0	19.0	18.0	20.2	27.4	31.5	26.0	20.6
27	18.5	17.0	16.0	18.0	26.3	31.0	25.4	21.2
28	19.8	17.8	18.0	19.6	29.9	24.0	30.5	21.7
29	21.1	14.3	17.0	20.6	29.7	33.6	30.0	20.7
30	16.8	17.4	20.5	21.5	29.5	33.0	31.7	22.0
31	20.5	20.7	19.5	19.8	24.4	30.4	29.2	20.7

Table 1.10: WIND, SPEED AND DIRECTION - 30-YEAR AVERAGES (1950-1979)

Location: Yundum Airport

Month	Mean Speed (kts)	Calm	NE	E	SE	S	SW	W	NW	N	Maximum Force Beaufort	0	1-3	4-5	6-7	8
January	5.3	21	21	15	3	0	0	2	16	22	5	21	71	8	0	0
February	6.1	17	16	9	2	0	1	5	24	26	5	17	72	11	0	0
March	6.8	13	11	6	2	0	2	10	31	25	5	13	71	16	0	0
April	7.0	10	6	3	1	1	3	13	41	22	5	10	72	18	0	0
May	6.4	12	3	1	1	1	6	24	41	11	5	10	72	18	0	0
June	4.9	29	2	2	3	8	10	23	19	4	6	29	61	10	0	0
July	4.9	29	2	2	3	8	10	23	19	4	6	29	61	10	0	0
August	4.6	33	2	2	4	9	14	20	12	3	5	22	59	8	0	0
September	3.7	40	3	4	7	7	8	13	13	5	6	40	55	5	0	0
October	2.9	47	5	5	3	3	4	11	14	8	5	47	51	2	0	0
November	2.7	47	10	7	2	0	2	6	12	14	4	47	52	1	0	0
December	4.5	28	23	15	3	0	0	2	11	19	4	28	65	7	0	0
Overall averages	5.0	27.2	8.7	5.9	2.8	3.1	5.0	12.7	21.1	13.6	5.1	26.6	63.9	9.5	0	0

Table 1.11: THREE HOURLY VALUES OF WIND DIRECTION AND SPEED
(Knots)

Year: 1987
Month: January, 1983
Location: Yundum Airport

Day	Hours 00	03	06	09	12	15	18	21
1	NW/02	NW/03	NW/04	NW/05	NE/07	NE/05	NW/06	W/03
2	NW/04	W/03	NE/08	NE/06	NE/10	NE/04	N/04	NW/05
3	N/06	N/06	N/07	N/09	N/16	N/11	N/10	N/07
4	N/08	N/12	N/10	NE/10	N/10	NE/10	NE/05	N/10
5	N/07	N/08	N/05	N/10	N/18	NE/09	NE/06	NW/04
6	N/06	NE/09	N/07	NE/10	NE/18	N/10	N/04	N/04
7	N/08	N/06	NE/06	NW/10	E/15	NE/10	N/08	N/05
8	N/04	N/08	N/08	N/10	3/18	NE/11	E/03	SE/05
9	NW/08	CALM	CALM	NE/03	E/07	E/07	CALM	NW/03
10	N/08	CALM	N/03	N/06	E/10	N/06	N/04	N/08
11	N/07	NE/05	E/06	NE/10	N/10	W/10	W/08	W/06
12	W/06	NW/07	N/02	NE/06	NE/10	NE/09	NE/03	CALM
13	NE/08	NE/03	NE/18	NE/15	NE/15	E/09	N/05	N/03
14	N/06	N/05	NE/07	NE/10	NE/10	NE/08	NW/05	N/07
15	N/06	NW/07	N/06	N/10	E/08	N/08	CALM	NW/02
16	CALM	N/05	NE/07	N/05	NE/12	E/08	N/02	N/08
17	NW/05	N/10	NE/10	NE/08	NE/12	E/07	NE/04	NW/07
18	NW/08	NE/05	NE/09	N/10	NE/12	NE/15	E/04	NE/06
19	NW/07	NE/05	E/09	NE/08	NE/08	NE/10	CALM	NW/02
20	NW/05	N/08	N/04	NE/10	E/12	E/06	NW/05	NW/09
21	CALM	NW/07	N/02	N/06	NE/12	NE/04	NW/09	NW/08
22	W/05	CALM	N/05	N/10	N/10	NE/07	NW/07	NW/05
23	NW/07	NW/05	N/06	N/03	NE/10	E/09	N/02	NW/08
24	W/04	NW/02	N/02	N/08	E/08	E/08	NW/06	NW,02
25	CALM	N/02	N/09	N/06	NE/12	E/10	N/05	CALM
26	E/03	N/03	NE/08	N/05	E/14	NE/10	NE/06	N/07
27	NE/11	NE/08	N/06	N/10	NE/16	N/10	NE/08	N/07
28	N/08	NE/10	NE/13	NE/08	E/18	E/09	E/02	N/08
29	N/10	NE/06	NE/05	E/10	N/18	NE/09	NE/05	N/06
30	N/07	NE/07	N/08	E/12	NE/11	E/13	NE/05	N/05
31	NE/05	NE/07	NE/05	NE/08	E/12	E/08	N/09	NW/05

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd

Month: February, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	NW/03	CALM	CALM	NE/02	NE/08	NE/05	NW/06	CALM
2	NW/05	NE/05	N/05	NE/04	E/12	E/10	N/04	W/05
3	N/06	NW/08	N/08	N/06	NE/08	E/07	NW/05	W/05
4	NW/04	NW/06	N/06	N/08	E/07	NE/08	N/05	N/05
5	SE/04	S/07	SE/04	S/09	SW/05	SW/07	SE/08	NW/10
6	E/02	CALM	N/07	E/05	E/08	SW/09	NE/08	W/03
7	NW/03	CALM	CALM	CALM	E/05	SE/05	E/07	NE/06
8	NW/02	SE/04	NW/03	N/06	N/08	NE/07	NW/08	NW/07
9	NW/05	N/07	N/05	N/08	NE/08	E/09	NW/10	N/07
10	N/05	N/10	N/10	NE/09	N/09	NW/09	W/14	NW/09
11	NW/09	NW/10	N/8	N/10	N/10	N/15	NE/15	W/08
12	NW/06	N/08	N/10	N/10	NE/10	N/08	NW/10	NW/10
13	SW/05	NW/04	N/04	N/10	N/10	NE/09	NW/09	NW/10
14	NW/05	N/10	N/05	NW/11	E/10	N/06	N/10	NW/03
15	NW/06	N/04	N/10	N/08	N/11	N/05	NW/08	NW/06
16	NW/06	N/05	N/12	N/10	N/10	NW/10	NW/10	NW/05
17	NW/09	N/11	NW/08	NE/08	E/10	NW/06	NW/13	NW/08
18	NW/09	N/08	N/08	NE/06	NE/05	N/12	W/10	NW/10
19	NE/10	N/09	N/10	N/10	N/10	NW/15	W/10	W/08
20	N/04	N/05	N/03	N/02	N/15	SE/10	W/15	W/07
21	S/08	S/05	NW/02	S/05	N/07	N/04	SW/10	S/09
22	S/05	CALM	CALM	NE/08	NE/15	N/15	W/06	NW/08
23	W/02	N/02	NW/03	NE/09	N/09	NW/14	W/10	W/05
24	S/05	W/05	NW/08	NE/07	E/15	E/10	E/12	S/04
25	SW/04	W/05	CALM	NE/10	E/09	NE/06	W/09	S/06
26	W/05	CALM	NW/05	N/03	E/04	E/08	SW/10	S/09
27	SW/03	S/02	CALM	S/02	NW/03	W/11	W/11	W/09
28	CALM	NW/03	CALM	NW/05	N/11	NE/10	E/05	SW/10

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: March, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	S/10	S/05	S/04	W/05	NE/08	CALM	NW/10	NW/07
2	NW/07	CALM	CALM	CALM	S/05	S/08	S/10	W/02
3	CALM	W/03	CALM	W/05	NW/08	NW/05	NW/12	W/06
4	W/03	W/02	SE/08	NW/08	NS/10	N/09	N/09	W/05
5	NW/10	W/09	N/06	NE/06	N/12	N/10	NW/13	NW/07
6	N/10	N/06	N/08	N/10	NE/10	E/06	NW/12	N/10
7	NW/08	NW/05	NE/06	N/08	N/12	NW/07	W/10	W/08
8	N/10	N/12	N/07	N/12	N/11	NE/10	E/19	E/09
9	S/04	CALM	CALM	N/09	SE/18	NE/10	N/10	N/06
10	NE/08	N/06	N/08	N/10	NE/14	N/13	N/10	CALM
11	NW/02	N/05	N/10	N/08	NE/18	E/11	CALM	W/04
12	CALM	NW/05	N/12	NW/08	NW/05	NW/05	N/10	W/10
13	CALM	SW/06	CALM	CALM	SW/12	NW/10	NW/10	W/09
14	W/09	W/12	NW/03	NW/08	N/08	W/10	W/12	NW/10
15	NW/10	NW/10	NW/10	N/08	N/06	NW/08	NW/16	W/08
16	W/07	W/08	NW/02	NW/10	NW/05	W/16	W/12	W/09
17	NW/06	NW/06	CALM	N/12	NE/09	NW/05	W/12	W/12
18	W/09	NW/06	N/04	NW/08	NW/06	W/15	W/12	W/10
19	W/10	W/05	NE/03	W/04	E/06	W/10	W/15	W/08
20	W/03	W/03	W/08	W/10	N/04	W/09	SW/12	SW/10
21	SW/05	SW/06	CALM	CALM	NE/12	SW/10	SW/18	S/10
22	W/08	SW/08	S/06	SW/09	W/10	SW/10	SW/10	SW/02
23	W/02	W/08	SW/06	SW/04	NW/05	W/09	E/11	E/10
24	NE/10	N/09	NE/10	NE/11	E/06	NE/08	E/15	E/06
25	NE/05	N/08	E/04	E/10	E/02	E/09	E/08	E/08
26	E/03	W/03	CALM	NE/07	SW/18	SW/10	S/13	S/08
27	S/10	CALM	NE/08	S/10	E/12	S/10	E/15	NE/08
28	NW/07	NE/02	NE/06	E/09	E/12	SE/12	SE/13	NW/07
29	W/06	N/07	N/10	E/12	SE/12	E/12	W/10	E/12
30	SE/06	E/05	SE/10	S/18	NE/10	N/10	NW/12	NW/10
31	NW/10	S/10	NW/06	NE/10	N/13	NW/11	W/15	NW/08

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: April, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	W/08	NW/07	N/05	N/14	E/05	W/09	W/16	S/10
2	W/08	W/09	NW/07	W/14	NW/07	NW/15	W/18	W/10
3	W/08	NW/10	W/06	NW/06	NW/09	W/15	N/15	NW/[illegible]
4	NW/10	N/08	N/04	NE/09	NE/05	N/09	W/14	NW/10
5	NW/05	N/05	E/08	NE/11	E/10	W/12	NW/10	N/10
6	N/10	NE/09	N/09	E/09	E/12	N/10	NW/10	N/06
7	N/10	N/09	E/07	NE/10	E/12	E/12	NW/14	N/09
8	calm	calm	NE/06	N/07	E/08	E/11	W/11	W/08
9	W/08	W/08	NW/07	NE/10	NE/10	W/10	W/10	W/09
10	W/04	calm	calm	N/10	N/12	N/10	N/12	NW/15
11	NW/10	W/05	NW/08	NW/09	W/06	W/15	NW/10	W/10
12	W/10	N/09	N/10	calm	N/02	W/12	W/15	W/10
13	W/10	W/10	SW/10	W/04	SW/15	W/12	W/10	SW/07
14	W/08	NW/07	calm	NW/01	W/08	NW/10	NW/12	W/08
15	W/12	W/10	NW/08	NE/10	NE/10	NW/11	W/15	N/10
16	N/10	N/10	W/06	N/10	N/10	NW/15	W/10	N/13
17	N/08	N/08	N/10	NE/05	N/13	NW/15	W/14	W/10
18	N/10	NE/10	NE/05	W/11	NE/08	N/10	NW/12	W/10
19	N/08	N/05	Nw/05	N/04	E/10	NW/10	NW/12	N/10
20	N/10	N/08	N/10	N/13	NE/11	W/11	W/15	NW/10
21	N/08	N/12	N/10	NE/11	N/10	NW/11	NW/13	W/14
22	NW/10	N/10	NE/05	NE/08	N/10	N/18	N/18	N/10
23	N/10	N/05	NW/07	NW/05	NE/06	NW/08	NW/12	NW/10
24	N/10	NW/06	NW/05	NW/08	N/04	W/11	W/16	NW/12
25	NW/08	W/05	calm	W/09	W/14	W/13	W/15	W/14
26	W/13	W/08	NW/05	N/08	W/11	NW/18	NW/18	W/15
27	NW/10	W/07	W/05	N/10	NE/05	NW/10	N/12	NW/10
28	NW/08	N/02	N/05	NW/10	N/08	W/14	W/13	W/10
29	NW/12	NW/06	NW/06	NW/07	E/09	W/10	S/15	W/05
30	W/10	W/04	W/02	calm	E/02	SE/05	NW/10	SW/08

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: May, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	S/04	CALM	CALM	SW/02	NE/12	NW/12	NW/10	N/12
2	N/10	NE/05	E/06	E/10	E/10	W/14	NW/11	W/09
3	W/08	NW/10	NW/02	CALM	N/13	N/08	NW/11	N/10
4	NE/20	NE/05	NE/11	N/10	NE/15	NE/10	N/12	N/10
5	N/10	N/07	N/05	NE/09	NW/10	NW/10	N/12	NW/07
6	NW/02	NW/08	NW/04	NW/05	NE/07	NW/06	NW/11	NW/10
7	W/08	N/10	NW/06	NW/08	NW/04	NW/12	NW/15	NW/11
8	NW/04	NW/10	NW/06	NW/09	NW/07	W/09	NW/12	W/19
9	NW/12	W/10	W/09	NW/09	W/05	W/12	W/10	NW/05
10	W/04	W/02	W/05	W/08	W/10	W/15	W/13	W/08
11	NW/06	NW/05	NW/10	NW/14	NW/12	W/12	W/10	W/06
12	W/07	W/07	W/08	W/10	W/03	NW/15	N/10	NW/10
13	N/07	N/05	W/04	W/06	W/09	NW/10	NW/15	NW/09
14	NW/10	W/12	W/10	NW/10	NW/10	NW/07	W/10	NW/10
15	NW/06	N/08	W/06	CALM	CALM	W/13	W/13	W/04
16	W/04	W/03	W/06	NW/06	NW/03	E/10	NW/12	W/09
17	W/07	NW/08	NW/05	NW/10	NW/02	W/10	W/15	W/08
18	NW/06	W/06	W/06	N/10	NE/10	W/10	W/14	W/10
19	W/09	W/06	CALM	W/06	W/08	NW/11	W/09	W/08
20	NW/06	NW/06	NW/05	NW/07	W/11	W/15	W/10	W/07
21	NW/05	NW/06	N/05	W/12	NW/12	NW/10	NW/12	NW/10
22	NW/08	NW/04	NW/06	NW/10	NW/15	W/14	W/13	NW/10
23	W/05	NW/02	CALM	NW/04	N/08	W/11	NW/17	W/09
24	SW/04	W/06	CALM	NW/05	W/10	W/13	W/15	W/10
25	W/08	NW/06	W/07	W/09	W/08	NW/15	W/12	W/11
26	NW/06	SW/04	CALM	SE/10	CALM	W/10	W/10	W/12
27	W/08	E/06	SW/06	CALM	E/10	W/18	W/18	W/12
28	W/06	W/06	W/07	N/10	W/08	W/11	W/17	W/08
29	NW/10	NW/09	N/06	N/10	W/07	NW/10	W/11	W/05
30	W/08	W/02	CALM	W/05	S/05	SW/18	SW/19	W/11
31	CALM	CALM	CALM	W/08	N/05	NW/11	NW/13	NW/10

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: June, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	NW/07	S/05	NW/08	W/07	NW/08	N/15	NW/15	W/10
2	NW/07	NW/05	W/14	W/10	SW/08	W/10	W/10	SW/12
3	W/05	CALM	CALM	W/10	NW/10	W/15	W/12	SW/11
4	W/08	NW/09	N/05	CALM	W/11	W/22	NW/18	W/12
5	NW/05	W/09	W/05	W/09	W/08	SW/14	SW/15	NW/05
6	W/05	NW/07	NW/06	CALM	SW/09	W/15	W/10	NW/07
7	NW/04	NW/07	CALM	W/05	W/05	W/15	W/14	W/06
8	W/05	W/05	W/02	W/06	W/02	W/10	W/10	W/10
9	W/05	W/08	W/04	NW/06	W/04	W/12	W/10	W/10
10	W/07	W/07	W/06	N/12	S/20	W/11	W/11	W/10
11	W/10	W/09	W/05	W/12	W/13	W/11	W/15	W/12
12	W/09	NW/07	W/06	W/08	W/05	W/12	NW/10	W/07
13	CALM	CALM	NW/03	NE/09	S/03	W/06	NW/10	NW/03
14	N/03	CALM	N/04	W/07	NW/09	NW/06	W/18	NW/12
15	NW/09	NW/11	NW/05	W/12	SW/10	W/10	W/13	W/10
16	W/08	W/08	W/08	E/15	W/10	W/20	W/12	SW/10
17	NW/08	W/05	W/08	SW/10	W/12	W/15	W/18	W/10
18	W/11	W/08	CALM	W/10	W/10	W/12	W/15	W/08
19	W/02	W/03	CALM	SE/10	CALM	NE/05	W/08	W/10
20	W/08	W/04	CALM	N/06	W/11	N/10	S/28	N/08
21	CALM	NE/09	CALM	N/07	S/04	E/08	NW/09	N/05
22	N/04	S/09	W/05	CALM	NW/06	W/10	NW/09	W/07
23	W/07	W/06	NW/02	W/11	W/14	W/18	NW/15	NW/11
24	NW/13	W/10	W/07	W/07	SW/10	W/13	W/12	W/06
25	W/04	CALM	CALM	W/08	W/12	W/09	W/11	NW/07
26	W/04	CALM	N/11	CALM	W/02	W/15	NW/09	W/07
27	CALM	CALM	CALM	E/04	E/05	W/15	SW/06	CALM
28	CALM	W/05	CALM	W/09	NW/10	NW/12	N/15	W/10
29	NW/10	NW/06	W/06	W/06	NW/10	W/20	W/12	NW/10
30	W/10	CALM	W/07	W/18	W/20	NW/10	NW/10	NW/10

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: July, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	NW/06	W/04	calm	W/09	W/10	W/11	W/12	W/08
2	W/06	W/02	calm	N/05	N/02	W/07	W/11	W/08
3	W/08	W/09	W/07	N/02	W/05	NW/20	W/10	W/05
4	W/06	NW/02	calm	W/03	S/05	NW/09	S/07	calm
5	W/05	calm	calm	calm	NW/03	W/13	W/10	W/03
6	W/08	NW/06	calm	NW/11	NW/02	W/05	SE/05	calm
7	calm	calm	S/02	S/06	calm	W/07	E/10	W/11
8	calm	S/02	calm	calm	NW/10	S/10	W/12	W/09
9	W/08	W/05	calm	calm	W/10	S/14	calm	calm
10	W/03	SW/05	calm	E/05	SE/05	E/10	NW/13	W/06
11	W/04	NW/05	NW/02	NW/10	NE/06	calm	W/09	calm
12	W/03	NW/07	W/04	W/06	W/10	W/18	W/18	W/08
13	W/06	W/08	W/02	W/10	W/18	W/13	W/12	NE/22
14	E/06	calm	calm	E/07	E/04	W/07	W/08	W/04
15	W/05	NW/05	calm	NW/08	NW/12	W/05	W/10	W/08
16	W/10	W/03	calm	calm	W/05	W/08	W/15	W/05
17	W/06	W/04	W/02	NW/12	NW/14	W/13	W/15	W/08
18	W/05	W/07	NW/08	W/15	W/16	W/13	W/15	W/05
19	W/02	W/04	calm	S/08	SW/08	W/08	W/10	W/03
20	W/05	calm	calm	calm	W/05	W/09	W/11	W/03
21	W/06	calm	NE/08	W/06	W/10	W/10	NW/10	NW/09
22	W/10	W/06	NW/05	W/10	W/08	W/11	W/10	W/04
23	calm	calm	calm	calm	W/08	NW/08	W/10	W/08
24	S/05	calm	calm	W/08	W/10	NW/10	NW/12	W/09
25	NW/06	W/02	W/08	NW/08	NW/12	W/16	NW/12	NW/05
26	NW/09	NW/04	W/04	NW/06	NW/10	NW/10	NW/10	calm
27	W/04	W/03	NW/02	N/09	NW/10	NW/08	N/12	NW/09
28	NW/09	N/03	N/06	N/10	W/12	W/10	W/12	W/10
29	NW/10	W/05	W/05	W/05	NW/10	W/11	W/10	W/07
30	calm	calm	calm	W/08	W/10	W/13	W/13	W/04
31	W/05	W/08	W/04	SW/04	SW/10	W/16	W/10	W/10

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: August, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	W/05	calm	S/02	S/05	W/09	NW/08	W/08	NW/08
2	SW/03	S/02	calm	W/08	W/05	W/06	W/10	W/08
3	calm	W/04	N/02	NE/06	E/04	N/12	NW/10	NW/09
4	NW/04	NW/06	NW/08	E/06	W/05	NW/08	W/15	W/10
5	W/06	NW/06	W/05	W/10	W/10	W/15	W/18	W/12
6	W/12	W/15	W/10	W/09	NW/13	NW/10	N/13	NW/10
7	NW/03	NW/02	calm	calm	W/09	NW/09	NW/10	W/08
8	NW/04	calm	calm	calm	NE/05	SE/03	calm	calm
9	calm	SE/05	calm	N/04	SE/02	W/10	W/04	calm
10	calm	S/03	S/02	W/06	calm	W/08	W/15	W/09
11	W/05	W/03	W/05	W/10	W/10	W/12	W/11	W/05
12	W/04	W/06	W/10	W/10	W/18	NW/15	W/12	W/08
13	W/05	W/09	W/07	W/06	W/18	W/12	W/12	calm
14	SW/05	S/05	SE/05	S/02	S/05	W/10	W/11	W/06
15	S/04	calm	S/02	W/09	W/09	W/15	W/13	NW/07
16	NW/05	NW/05	calm	W/10	NW/12	NW/04	NW/04	W/05
17	W/04	W/02	W/02	W/04	W/03	W/05	W/03	W/03
18	W/04	W/02	calm	W/04	W/02	W/04	W/04	W/03
19	W/03	W/05	W/05	W/05	W/07	W/12	W/05	S/04
20	S/05	S/03	SE/02	SW/05	W/03	SW/05	W/10	NW/05
21	W/05	W/02	W/02	W/05	NW/33	W/02	calm	calm
22	calm	calm	NE/05	N/05	NE/08	N/03	W/07	W/02
23	NE/03	SW/04	W/04	S/03	W/10	W/12	S/12	calm
24	S/10	S/03	S/03	S/05	W/07	NW/10	W/06	W/04
25	SW/02	calm	calm	N/04	N/05	W/08	W/14	NW/08
26	NW/06	NW/03	N/03	NW/06	W/10	NW/10	NW/08	W/05
27	calm	W/04	S/03	S/07	SW/08	W/10	W/08	N/02
28	calm	S/02	S/02	S/02	S/05	SW/18	SW/03	calm
29	W/10	calm	S/02	W/05	NW/03	SE/25	calm	calm
30	calm	calm	calm	SE/05	N/03	NW/08	NW/03	W/02
31	calm	calm	calm	calm	calm	N/05	NW/05	calm

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: September, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	SW/15	W/03	calm	NW/02	SE/02	S/10	SE/04	W/06
2	calm	calm	calm	calm	W/08	W/05	W/03	NW/05
3	W/03	W/06	W/04	NW/03	W/08	W/11	NW/09	W/03
4	W/05	W/07	calm	calm	S/04	S/04	SW/02	SW/02
5	calm	calm	S/02	calm	calm	W/02	W/05	W/02
6	NW/02	W/05	W/04	calm	NW/03	NE/03	NW/05	calm
7	calm	W/05	calm	W/05	NW/05	W/10	W/07	calm
8	S/05	calm	calm	calm	S/05	W/08	W/08	W/03
9	S/03	NE/04	S/06	calm	NW/06	N/06	NW/05	calm
10	calm	N/05	N/05	N/10	N/09	NW/04	SW/05	W/05
11	W/03	calm	S/05	NE/02	NE/05	E/04	W/05	calm
12	S/05	S/03	E/06	E/07	W/10	W/15	W/06	calm
13	calm	calm	NW/05	W/08	NW/06	NW/08	NW/10	calm
14	W/05	calm	calm	W/03	W/05	SW/14	W/05	W/03
15	W/05	calm	calm	W/05	E/20	NW/03	S/03	NW/05
16	calm	calm	calm	W/08	NW/12	NW/11	NW/10	W/02
17	NW/08	NW/07	NW/05	N/04	N/08	N/08	NW/10	NW/02
18	calm	calm	calm	W/05	calm	W/06	W/10	W/06
19	W/03	calm	N/02	NW/05	NW/09	NW/10	SW/07	SW/05
20	SE/05	calm	SW/02	calm	N/05	E/06	S/03	SW/08
21	SW/05	calm	S/03	SE/06	W/06	W/10	W/08	W/05
22	W/04	calm	calm	W/05	NW/08	W/05	W/05	calm
23	SE/08	SW/03	calm	W/02	W/04	NW/07	W/05	W/04
24	calm	calm	calm	calm	SE/03	calm	W/07	W/05
25	N/04	calm	calm	calm	N/05	W/10	NW/10	W/06
26	NW/09	calm	calm	SW/05	W/12	NW/10	NW/05	W/04
27	W/03	W/05	W/04	S/02	W/05	W/10	W/10	W/02
28	calm	W/04	SE/03	SE/13	W/05	W/06	S/02	S/02
29	S/08	calm	SE/03	E/05	NE/05	W/03	W/10	calm
30	W/02	calm	calm	calm	E/03	S/06	W/05	NW/05

Source: Department of Water Resources, Department of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: October, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	SE/08	NE/10	SW/03	W/02	NE/02	N/06	N/08	W/03
2	W/02	NW/03	W/05	NW/10	W/10	W/12	W/10	W/03
3	S/02	W/02	S/04	W/05	W/08	W/12	W/12	W/06
4	W/05	W/05	NW/03	N/04	W/04	W/10	W/04	W/06
5	W/03	E/05	W/03	S/04	E/05	E/06	NW/03	NW/03
6	CALM	CALM	NE/02	E/04	E/02	E/02	NW/03	N/02
7	SW/05	CALM	CALM	CALM	NE/02	NE/04	NW/03	NW/02
8	N/02	N/03	CALM	N/06	NE/03	W/04	W/04	W/03
9	W/03	CALM	CALM	SW/05	W/05	SW/05	W/09	W/08
10	W/06	W/04	N/03	NW/06	NW/10	N/08	N/07	SW/08
11	W/03	SW/02	CALM	N/02	SW/04	NW/08	W/06	CALM
12	W/04	W/03	N/05	N/04	W/10	SW/04	N/05	W/04
13	N/05	NW/04	W/02	N/03	W/06	NW/10	W/07	W/06
14	W/06	CALM	SW/05	NW/03	NW/07	N/03	N/05	W/06
15	CALM	CALM	CALM	W/05	W/08	N/04	W/06	SW/05
16	SW/06	CALM	W/03	SW/05	W/06	N/08	N/06	W/02
17	W/03	W/03	W/02	N/05	NE/03	NW/10	NW/08	N/05
18	N/04	N/04	CALM	N/05	N/10	W/05	NE/12	SW/08
19	W/08	W/08	N/10	N/05	NW/05	W/05	W/05	W/06
20	W/05	W/05	CALM	W/04	W/10	N/10	W/08	W/02
21	W/06	CALM	CALM	CALM	W/05	W/05	W/10	W/05
22	W/03	N/-3	N/02	N/04	W/06	NW/06	W/10	W/05
23	NW/06	SW/03	W/02	S/04	W/10	SW/10	W/11	SW/05
24	CALM	NE/02	W/03	N/05	NW/06	N/12	W/06	W/02
25	CALM	CALM	CALM	CALM	NE/06	NW/09	NW/06	W/04
26	N/02	CALM	CALM	N/06	W/06	W/08	W/10	CALM
27	W/05	W/08	CALM	CALM	CALM	W/04	W/04	SW/04
28	W/06	CALM	W/05	W/03	N/09	W/07	W/14	W/08
29	W/13	W/03	W/04	N/05	W/12	W/10	W/10	W/08
30	CALM	CALM	CALM	NW/05	NW/05	NW/06	W/05	W/05
31	N/05	CALM	CALM	CALM	N/06	NW/10	W/05	N/07

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: November, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	W/02	CALM	CALM	W/02	N/14	NW/05	W/03	W/05
2	W/03	CALM	W/02	NW/03	NW/05	NW/09	W/10	W/10
3	CALM	CALM	W/04	W/08	NW/08	W/02	W/10	W/08
4	W/05	W/04	CALM	W/05	NW/08	N/05	NW/06	W/06
5	W/05	N/02	N/06	NW/05	NE/06	NE/05	W/10	N/06
6	N/12	N/06	CALM	N/02	E/06	N/03	NW/08	NW/04
7	W/05	NW/04	W/02	W/08	SE/05	NW/08	NW/10	NW/08
8	W/05	N/10	N/06	N/12	W/08	N/09	NW/06	NW/06
9	N/10	N/10	CALM	N/04	NE/06	NE/04	NW/08	NW/06
10	N/02	CALM	N/02	N/07	NE/06	NW/03	NW/03	W/04
11	CALM	N/04	CALM	E/03	E/10	E/06	W/10	W/05
12	W/05	W/05	CALM	CALM	CALM	W/13	W/15	W/10
13	W/05	CALM	CALM	N/05	NW/08	W/07	NW/05	W/06
14	N/05	N/03	N/04	NE/05	NE/08	N/10	W/10	W/04
15	W/04	NW/04	CALM	NW/04	NW/01	W/08	NW/05	W/02
16	NW/04	N/06	N/08	N/10	NE/05	N/08	NW/07	W/05
17	NW/05	CALM	N/02	NE/10	NE/05	CALM	NW/06	W/05
18	N/05	N/02	CALM	NE/05	E/05	E/08	W/08	W/05
19	SW/03	W/03	W/03	W/03	W/08	W/05	W/10	W/10
20	SW/10	W/05	W/02	NW/05	W/09	W/05	NW/08	W/08
21	W/06	W/02	W/03	W/08	NW/05	NW/08	W/06	W/06
22	W/04	NW/05	CALM	E/03	E/10	SE/10	N/04	CALM
23	W/03	SE/02	W/03	NE/05	E/05	E/10	NW/05	W/05
24	SW/06	W/08	NW/08	CALM	CALM	W/06	W/10	W/05
25	W/05	CALM	CALM	W/04	N/03	NE/04	W/06	W/08
26	W/03	CALM	W/03	CALM	NE/04	E/08	W/10	W/02
27	W/02	W/03	CALM	CALM	NE/02	S/06	W/10	W/07
28	NW/05	N/04	N/08	E/10	SE/08	E/06	NW/08	W/05
29	N/05	N/04	CALM	NE/10	E/08	NE/04	NW/05	W/10
30	W/05	SW/04	S/06	S/02	E/02	S/06	W/10	W/04

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.11: Cont'd
Month: December, 1984

Day	Hours 00	03	06	09	12	15	18	21
1	W/02	N/02	CALM	N/02	NE/08	S/05	W/08	W/07
2	CALM	W/06	NW/05	N/06	NE/07	SE/06	CALM	CALM
3	CALM	N/08	N/06	E/13	E/08	E/03	N/02	W/07
4	NW/05	N/05	N/02	E/02	CALM	E/07	NW/03	CALM
5	CALM	CALM	CALM	E/02	E/10	E/07	N/06	N/03
6	N/03	N/04	NE/07	NE/10	E/11	E/08	N/05	N/02
7	N/05	N/05	NE/04	NE/08	NE/06	N/03	CALM	N/05
8	NE/03	NE/04	N/02	NE/05	E/08	E/08	NE/10	E/03
9	NE/08	NE/10	NE/08	E/12	E/10	E/08	E/06	NE/08
10	NE/08	E/08	NE/15	E/13	NE/12	E/10	NE/09	NE/06
11	NE/08	E/06	E/06	NE/10	E/15	E/15	NE/08	NE/05
12	N/08	NE/15	NE/15	E/11	E/12	NE/03	N/04	N/03
13	CALM	N/03	NE/10	NE/08	NE/08	NE/08	N/05	N/02
14	N/08	N/05	N/05	NE/03	NE/02	E/05	N/05	NW/08
15	NW/06	N/05	NE/08	NE/08	E/08	E/05	CALM	N/05
16	CALM	N/04	CALM	E/06	NE/06	NE/05	N/05	E/07
17	CALM	N/05	NE/04	E/07	E/08	N/07	NW/05	NW/06
18	N/09	NE/06	NE/10	E/10	E/12	E/08	MW/07	NW/07
19	N/03	N/05	NE/09	NE/10	E/07	S/07	N/02	NW/02
20	N/02	E/12	NE/08	E/08	E/12	E/07	N/05	N/04
21	N/05	CALM	NE/03	NE/08	NE/08	E/08	NW/04	N/03
22	NE/06	NE/06	E/07	NE/08	NE/07	E/02	N/06	NW/08
23	N/02	N/03	CALM	N/03	NE/05	NE/03	NW/04	W/09
24	N/04	N/05	N/05	N/05	NE/05	N/06	NW/06	NW/06
25	N/05	N/10	N/10	NE/08	NE/11	N/06	N/06	N/04
26	N/08	N/08	N/10	E/05	E/07	N/10	NW/08	NW/08
27	N/07	N/07	NE/04	NE/03	E/05	E/02	NW/06	W/06
28	NW/02	N/02	N/03	CALM	E/12	SE/05	N/04	N/02
29	N/04	CALM	CALM	E/05	E/10	N/12	N/05	N/04
30	N/05	NE/10	NE/13	E/08	E/10	NE/11	NE/05	NE/08
31	NE/07	NE/11	E/08	E/15	E/14	E/12	E/08	E/07

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

Table 1.12: RELATIVE HUMIDITY (%)
10 YEAR (1970-79) MONTHLY AVERAGES

Location: Yundum Airport

	Maximum	Minimum	Mean
January	81	23	54
February	80	21	54
March	80	25	57
April	85	33	64
May	90	44	71
June	91	54	76
July	92	66	83
August	96	71	87
September	94	70	87
October	95	62	83
November	93	40	74
December	87	28	61
Overall averages:	88.5	44.8	78.0

Table 1.13: RELATIVE HUMIDITY - 30-YEAR (1950-1979) MONTHLY AVERAGES
(percent)

Month	Maximum	Minimum	Mean
January	80	23	54
February	80	25	54
March	84	26	57
April	87	34	64
May	91	45	71
June	91	56	76
July	93	68	83
August	96	73	87
September	95	70	87
October	96	63	83
November	91	41	73
December	88	29	61
Overall Averages	89.3	46.1	70.8

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia

Table 1.14: THREE HOURLY RATES OF RELATIVE HUMIDITY
(percent)

Year: 1983
Month: January, 1983
Location: YUNDUM AIRPORT

Day	Hours 00	03	06	09	12	15	18	21
1	96	92	88	70	37	29	54	73
2	87	98	71	34	29	25	44	73
3	66	55	41	38	20	17	28	33
4	42	29	32	30	23	22	30	35
5	41	48	48	35	23	22	31	55
6	61	44	40	33	26	21	32	63
7	41	42	39	33	25	21	41	73
8	44	49	34	29	23	17	33	63
9	80	94	97	75	23	19	29	76
10	76	90	82	56	23	18	34	54
11	74	51	48	36	23	17	35	58
12	62	72	81	41	18	20	23	69
13	47	60	40	31	21	20	32	45
14	55	45	41	32	21	23	30	61
15	78	76	65	47	23	31	36	68
16	75	71	69	49	22	22	29	66
17	84	36	31	39	20	18	33	59
18	59	39	41	33	16	15	26	57
19	78	64	37	23	15	11	30	71
20	85	82	67	29	16	11	20	62
21	74	56	58	44	13	12	40	83
22	88	84	87	53	21	16	35	83
23	92	97	77	68	23	13	20	56
24	80	72	89	45	18	11	24	71
25	90	59	49	47	19	16	26	66
26	70	85	73	5	15	14	20	34
27	18	35	35	26	19	16	18	56
28	31	28	25	26	20	22	27	48
29	43	37	30	25	20	20	24	48
30	50	35	39	30	20	19	27	57
31	44	41	42	33	25	21	32	69

Table 1.14: Cont'd
Month: February, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	83	95	99	65	26	19	34	51
2	72	49	65	52	30	22	28	85
3	79	65	76	62	32	19	21	62
4	77	74	72	58	26	20	32	81
5	75	65	72	58	26	20	32	81
6	82	90	59	65	49	25	48	87
7	91	100	98	79	48	49	54	82
8	97	96	89	67	39	34	56	87
9	86	71	76	61	33	31	54	72
10	68	63	77	74	43	28	55	70
11	58	59	76	67	41	37	62	77
12	71	55	64	64	37	26	41	72
13	67	64	69	62	43	29	49	75
14	79	74	80	63	33	30	53	74
15	81	73	59	55	37	27	42	77
16	76	73	63	54	28	27	47	64
17	58	50	51	45	24	22	39	68
18	56	57	55	43	23	21	42	70
19	53	50	54	48	26	18	41	61
20	75	67	81	47	23	22	43	63
21	88	88	96	80	35	30	47	72
22	92	100	97	48	22	20	34	66
23	74	68	66	53	28	23	33	66
24	82	96	84	55	30	20	21	78
25	84	87	97	74	22	17	23	66
26	78	87	85	85	30	19	50	72
27	90	96	95	97	35	34	44	88
28	92	98	98	98	35	18	22	66

Table 1.14: Cont'd
Month: March, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	76	83	88	85	28	18	17	63
2	62	63	77	60	27	24	43	82
3	93	98	86	84	33	27	31	78
4	87	75	82	84	33	27	31	78
5	62	88	73	53	36	20	62	75
6	56	70	65	52	37	25	59	77
7	70	64	76	59	33	36	40	72
8	53	57	45	40	20	15	18	55
9	81	89	96	56	16	14	16	56
10	53	44	28	27	15	22	22	59
11	59	48	30	20	26	30	23	50
12	54	39	22	31	39	34	40	67
13	79	78	90	79	56	32	62	89
14	95	92	90	85	56	61	68	86
15	88	92	91	82	63	42	61	73
16	81	90	93	90	47	49	61	79
17	84	93	85	60	34	28	40	80
18	85	86	82	59	32	41	62	78
19	81	87	83	85	47	53	62	88
20	93	96	99	95	35	42	39	85
21	93	98	97	96	17	25	48	89
22	94	95	99	86	24	26	45	84
23	93	98	100	92	30	37	50	84
24	88	93	95	90	58	45	64	86
25	91	91	91	81	60	59	61	78
26	85	88	90	62	14	13	11	31
27	29	49	31	22	17	13	44	54
28	48	64	56	42	19	26	50	69
29	76	68	70	67	40	44	56	77
30	79	89	69	63	57	44	60	75
31	77	59	70	60	49	42	55	80

Table 7: Cont'd
Month: April, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	87	90	77	64	48	37	63	89
2	94	96	93	78	67	53	71	86
3	87	91	91	77	59	59	66	80
4	87	79	84	68	51	45	55	71
5	73	73	69	59	50	33	49	49
6	52	58	60	49	22	21	46	63
7	59	61	66	51	27	17	41	64
8	66	59	46	37	23	20	36	59
9	73	82	86	44	26	26	43	63
10	80	91	87	47	32	27	55	84
11	93	94	97	86	53	61	77	89
12	93	97	96	86	87	57	72	90
13	90	90	95	86	48	41	85	90
14	94	97	96	90	34	50	67	90
15	95	97	94	80	42	39	58	77
16	82	92	94	82	54	52	69	82
17	89	80	85	74	56	47	56	75
18	82	81	87	71	52	49	60	78
19	89	95	96	83	57	41	70	87
20	93	93	94	84	64	57	62	76
21	81	76	74	64	48	43	54	44
22	84	92	92	63	54	60	59	76
23	81	82	84	75	56	38	67	80
24	83	90	91	76	48	55	71	85
25	89	91	95	82	60	64	71	87
26	90	92	94	85	64	66	76	89
27	90	90	95	72	49	54	67	80
28	90	94	95	75	55	50	66	84
29	90	93	95	71	43	44	51	72
30	67	69	71	67	46	35	48	68

Table 1.14: Cont'd
Month: May, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	70	75	80	58	37	37	44	52
2	40	37	35	29	22	36	56	71
3	78	83	83	75	51	53	69	69
4	50	52	46	44	31	22	41	41
5	48	50	55	57	46	46	61	71
6	73	79	82	66	52	54	71	83
7	86	89	90	75	57	55	69	80
8	80	80	83	67	51	43	57	71
9	78	86	84	76	50	48	57	67
10	81	87	88	74	52	37	58	77
11	80	85	87	76	64	59	75	79
12	81	82	87	80	59	60	71	85
13	86	86	89	81	57	58	64	81
14	84	86	87	75	60	54	66	72
15	70	79	83	86	49	54	55	71
16	76	80	82	70	42	19	45	74
17	74	79	83	67	48	47	57	76
18	77	80	84	49	21	28	55	72
19	80	85	92	62	38	38	47	69
20	74	80	85	64	48	46	54	83
21	86	91	93	82	64	68	75	86
22	86	88	94	69	58	55	65	76
23	77	82	83	65	56	53	66	83
24	86	90	95	76	59	42	67	85
25	86	86	91	79	56	57	63	82
26	85	90	94	84	49	60	61	74
27	83	87	88	82	61	49	63	86
28	92	91	94	72	48	43	58	86
29	80	86	88	73	60	53	55	81
30	89	94	95	76	47	49	59	83
31	91	96	95	69	44	42	64	87

Table 1.14: Cont'd
Month: June, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	87	92	88	73	47	52	70	84
2	87	89	88	78	60	48	64	80
3	85	95	94	74	65	66	72	84
4	90	88	86	77	50	57	70	82
5	75	85	87	69	50	55	63	77
6	84	87	89	78	59	56	62	88
7	82	85	94	80	57	57	74	83
8	84	85	89	81	61	57	62	76
9	83	88	93	80	58	49	62	76
10	80	86	88	72	43	50	65	80
11	83	85	87	75	57	55	67	80
12	84	85	88	75	59	58	67	76
13	83	86	88	83	73	59	74	81
14	85	91	89	73	43	45	65	71
15	78	84	84	76	65	63	74	85
16	87	87	86	75	60	55	65	78
17	84	83	85	71	49	50	62	76
18	81	87	88	74	63	60	65	76
19	80	84	88	90	65	80	63	78
20	86	90	89	78	63	60	78	97
21	96	94	96	88	64	60	68	79
22	73	88	97	92	75	66	75	92
23	92	93	92	80	71	62	65	84
24	91	88	92	85	75	72	80	91
25	94	99	98	78	65	68	68	87
26	85	94	91	78	61	65	85	88
27	93	95	98	82	80	92	96	95
28	99	98	98	94	83	76	82	93
29	92	81	95	85	73	76	85	89
30	89	92	99	85	72	76	79	88

Table 1.14: Cont'd
Month: July, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	94	95	100	79	69	68	78	89
2	92	94	98	99	92	82	87	96
3	98	94	96	88	83	80	76	86
4	91	92	92	79	66	70	98	98
5	96	99	98	88	76	76	81	100
6	96	97	99	88	85	100	97	100
7	100	100	100	81	70	71	96	97
8	98	99	99	93	79	78	87	90
9	90	92	98	86	73	92	98	98
10	98	99	100	80	73	66	81	90
11	95	96	94	85	80	98	92	97
12	100	96	98	87	62	70	77	86
13	89	94	96	82	75	73	83	90
14	97	96	97	93	72	67	68	85
15	92	91	91	80	69	61	65	78
16	83	88	95	85	70	70	73	87
17	93	95	96	83	76	73	78	88
18	89	93	88	83	77	76	82	92
19	92	92	99	98	76	69	76	86
20	96	99	97	91	73	72	78	85
21	90	87	92	96	98	78	84	88
22	89	90	91	81	78	75	78	90
23	94	100	100	83	72	73	74	84
24	92	92	98	86	73	71	80	87
25	91	91	88	82	78	77	81	86
26	85	99	92	80	74	73	78	89
27	90	91	92	83	77	67	75	85
28	87	90	91	78	67	71	75	82
29	85	91	90	81	74	75	81	90
30	98	99	99	80	70	66	75	85
31	90	90	95	88	79	[illegible]	80	91

Table 1.14: Cont'd
Month: August, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	93	98	100	87	69	92	85	94
2	96	98	99	88	76	80	94	91
3	97	94	96	85	76	71	76	87
4	88	90	91	87	77	74	78	86
5	90	95	98	83	71	70	79	96
6	92	94	89	86	81	72	78	84
7	89	91	98	77	66	74	78	88
8	93	95	99	90	79	99	95	95
9	98	98	98	95	78	71	98	98
10	99	98	98	94	91	96	90	93
11	96	96	92	86	80	70	72	87
12	92	94	83	80	76	77	75	85
13	87	96	95	86	70	68	76	88
14	91	95	96	90	72	87	80	96
15	96	97	98	90	68	69	73	85
16	88	85	90	81	68	72	73	87
17	94	91	94	82	70	68	69	85
18	89	96	97	83	68	65	70	81
19	82	82	89	75	67	62	82	90
20	91	95	98	87	68	68	74	87
21	91	95	95	84	94	91	89	93
22	97	97	91	90	73	72	78	86
23	96	93	94	87	73	73	80	95
24	97	97	98	90	72	75	98	97
25	98	99	95	91	77	72	81	86
26	88	88	96	83	82	76	74	87
27	91	94	97	81	75	71	75	91
28	96	98	96	88	70	75	71	84
29	94	98	97	89	76	86	99	97
30	97	97	98	90	75	75	82	96
31	97	97	97	91	65	69	67	95

Table 1.14: Cont'd
Month: September, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	85	98	98	91	74	69	72	85
2	95	96	96	90	76	75	74	88
3	96	96	95	86	75	72	79	90
4	91	90	96	90	79	78	79	94
5	95	99	99	93	66	62	71	84
6	85	96	98	85	70	68	81	93
7	93	96	95	85	73	68	74	87
8	97	97	98	87	69	64	72	90
9	95	98	95	71	65	66	69	83
10	87	94	92	82	71	71	84	94
11	96	98	96	98	86	71	92	98
12	98	98	98	96	89	75	87	96
13	98	99	99	77	74	73	79	88
14	92	97	98	90	77	65	76	92
15	94	98	99	88	70	82	80	98
16	97	97	98	86	76	75	78	89
17	88	88	90	80	67	66	76	88
18	92	96	97	84	63	73	78	88
19	94	96	96	85	72	72	78	99
20	97	98	97	92	76	71	67	91
21	94	96	96	88	70	68	74	87
22	93	93	95	96	66	78	84	96
23	97	92	95	91	72	75	79	96
24	98	98	98	94	72	67	76	87
25	95	98	99	93	61	69	76	85
26	77	93	96	84	71	69	72	89
27	96	96	95	89	70	65	75	92
28	96	96	95	89	70	65	75	92
29	98	98	98	91	68	56	67	97
30	94	98	97	88	67	59	81	91

Table 1.14: Cont'd
Month: October, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	94	90	98	92	85	69	78	87
2	94	93	94	85	73	72	80	92
3	96	97	98	86	71	65	75	90
4	94	95	94	85	66	67	74	91
5	94	97	95	80	69	57	66	91
6	91	90	93	80	67	61	64	89
7	88	93	91	81	77	64	75	91
8	91	90	91	81	57	53	74	90
9	96	96	96	89	67	65	75	86
10	93	93	94	86	70	67	91	91
11	93	96	98	89	70	68	76	92
12	96	97	97	91	69	71	78	94
13	97	96	97	87	66	66	71	91
14	91	95	96	85	67	62	72	92
15	92	96	97	90	71	64	71	93
16	92	89	87	87	63	60	70	87
17	89	96	97	82	65	63	73	93
18	92	96	97	86	63	62	70	89
19	90	92	92	84	66	61	70	90
20	88	89	90	84	63	63	73	92
21	93	97	96	84	61	59	64	86
22	92	92	96	85	63	60	62	87
23	93	96	98	90	57	62	77	90
24	95	93	92	80	59	66	74	88
25	92	92	96	83	62	59	71	86
26	86	95	97	84	45	37	44	79
27	90	88	96	92	60	58	69	91
28	92	93	95	87	62	56	73	88
29	90	93	92	83	65	58	71	92
30	96	96	97	87	61	57	66	85
31	91	96	95	93	41	36	55	73

Table 1.14: Cont'd
Month: November, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	93	97	99	84	56	58	68	86
2	93	97	98	85	57	53	63	92
3	97	98	98	90	56	57	58	85
4	89	94	98	84	58	60	72	87
5	92	93	84	71	52	41	58	80
6	88	81	87	61	54	37	61	80
7	77	71	87	71	53	43	62	81
8	82	77	77	64	51	43	70	84
9	76	77	92	59	43	44	66	80
10	81	94	95	59	43	35	54	90
11	93	96	97	74	21	13	57	88
12	96	99	97	97	44	39	70	93
13	95	97	98	96	48	44	65	89
14	95	95	85	71	45	44	65	84
15	85	90	97	88	45	36	67	90
16	95	99	83	69	39	37	66	84
17	93	87	87	62	57	38	50	89
18	95	96	99	78	29	17	48	87
19	97	99	98	96	49	35	73	94
20	98	96	97	94	62	45	60	82
21	93	98	97	90	52	30	58	92
22								
23	98	98	99	83	23	29	28	81
24	92	98	98	94	18	17	17	76
25	96	94	96	98	52	38	75	90
26	97	97	97	84	42	29	46	80
27	94	97	97	93	34	21	43	83
28	94	96	97	98	59	30	57	87
29	96	98	78	54	17	16	38	79
30	46	67	87	60	21	25	33	87

Table 7: Cont'd
Month: December, 1983

Day	Hours 00	03	06	09	12	15	18	21
1	95	97	97	94	50	28	56	88
2	94	96	93	66	27	20	29	74
3	81	70	72	67	33	17	32	74
4	79	88	80	48	40	17	35	69
5	88	93	46	43	19	20	36	77
6	92	78	61	38	17	14	30	71
7	73	63	56	36	24	19	47	59
8	65	61	49	58	19	15	25	48
9	41	37	45	21	22	23	27	40
10	34	26	25	27	17	15	22	34
11	32	25	27	24	14	14	14	42
12	34	27	29	30	48	16	22	42
13	86	57	39	35	21	19	42	78
14	88	75	81	53	20	15	43	74
15	81	72	60	35	15	16	30	57
16	74	72	44	30	21	12	25	69
17	80	62	36	32	18	15	36	73
18	57	50	37	18	11	12	27	78
19	90	59	32	19	16	13	27	64
20	53	23	38	29	19	13	24	67
21	42	59	52	29	19	17	26	68
22	48	39	40	37	21	16	29	74
23	80	88	94	77	26	15	28	77
24	84	82	82	63	34	26	52	75
25	83	80	56	50	24	27	46	77
26	63	75	77	63	30	25	42	95
27	90	84	90	78	36	30	44	71
28	87	95	81	83	19	14	24	62
29	57	83	54	40	21	14	23	62
30	87	55	30	28	24	13	18	41
31	42	32	30	27	20	16	17	52

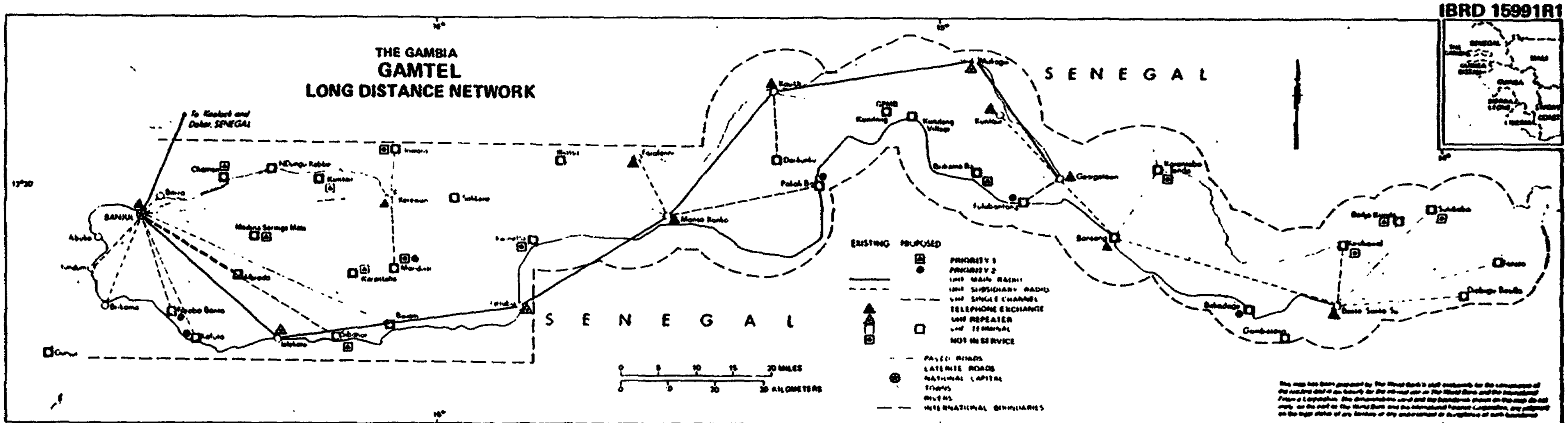
Table 1.15: RAINFALL - 30-YEAR (1950-79) MONTHLY AVERAGES

Location: Yundum Airport

Month	Monthly Total	Most in a day	Number of Days >0.3	Number of Days >1.0	Number of Days >10.0
January	1.1	0.9	0	0	0
February	0.8	0.6	0	0	0
March	TR	TR	0	0	0
April	TR	TR	0	0	0
May	4.7	4.1	0	0	0
June	73.0	28.4	6	5	3
July	269.4	69.9	16	15	8
August	439.5	92.0	22	19	12
September	295.6	68.0	18	16	9
October	97.4	40.0	8	7	3
November	7.2	5.2	1	0	0
December	0.8	0.5	0	0	0
Yearly total	1189.5		69	62	35

Source: Department of Water Resources, Government of The Gambia, Banjul, Gambia.

IBRD 15991R1



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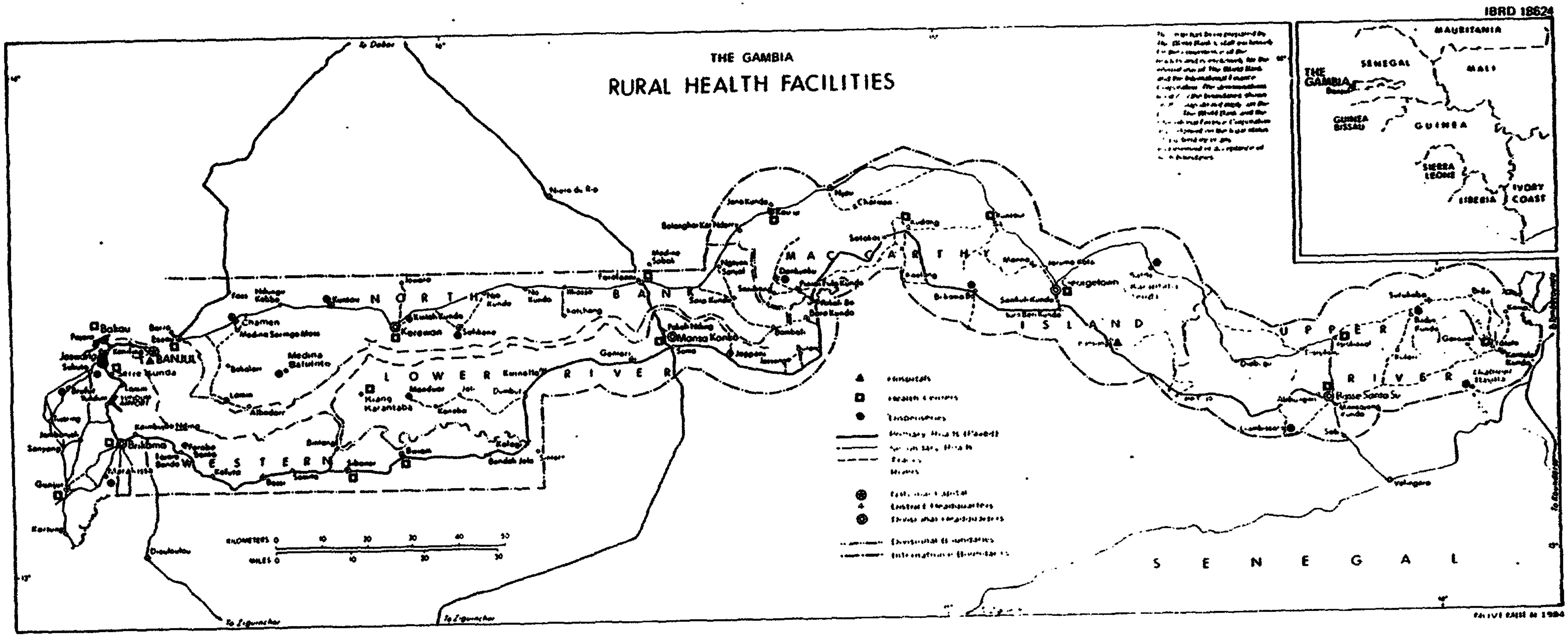
IBRD 18624
THE GAMBIA
RURAL HEALTH FACILITIES
MAURITANIA
SENEGAL
MALI
THE GAMBIA
GUINEA BISSAU
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
NORTH BANK
MAC CARTHY ISLAND
UPPER RIVER
LOWER RIVER
WESTERN
S E N E G A L
BANJUL
Georgetown
Mansa Konko
Kerewan
Basse Santa Su
Brikama
Bakau
Medina Sabakh
Kuntaur
Bansang
Farafenni
Soma
Chamen
Medina Sarmgo Mass
Medina Salunto
Essau
Barra
Kiang Karantaba
Bwiam
Sibanor
Serrekunda
Fajara
Jeswang
Gunjur
Kartung
Diouloulou
Nioro du Rip
Velingara
KILOMETERS 0 10 20 30 40 50
MILES 0 10 20 30
Hospitals
Health Centers
Dispensaries
Primary Roads (Paved)
Secondary Roads
Tracks
District Headquarters
Divisional Headquarters
Divisional Boundaries
International Boundaries
FEBRUARY 1984