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ASSESSMENT OF SMALL HYDROELECTRIC POTENTIAL IN CAPE VERDE

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ASSESSMENT OF SMALL HYDROPOWER POTENTIAL IN CAPE VERDE

I. INTRODUCTION

Background

In February 1981, a statement of interest in small hydropower assistance initiated from the National Institute for Technological Research (NITR) in Cape Verde, and was directed to the NRECA through the U.S. AID Mission to Cape Verde. A continuing correspondence between NRECA and Cape Verde resulted in an NITR request for a visit to Cape Verde by a team of experts in order to assess the countrywide potential for small hydroelectric power, and the feasibility of undertaking a program aimed at developing this potential.

In addition, suggestions were made by the NITR for investigating the possibility of exploiting small-scale hydropower in a hybrid system with either a wind or solar pond system.

This study represents an initial NRECA response primarily to the first of the two requests presented by the Government of Cape Verde, i.e. the country-wide assessment for small-scale hydropower potential. The second issue, i.e. the feasibility of a wind- or solar pond-hydro hybrid system is not addressed in this study due to paucity of detailed site-specific data which is necessary for this type of analysis. Our recommendations suggest steps to proceed

if the Government of Cape Verde is interested in pursuing this further.

Summary

This study concludes that there is insufficient surface water in Cape Verde to economically develop small scale hydropower as part of Cape Verde's overall energy development program. This conclusion is based on the economic analysis of a hypothetical site in Cape Verde, Sao Tiago Island, which receives most of the rainfall and where 50% of the archipelago's total population resides. This conclusion was reached based on information available from several study sources that have been involved in water resources in Cape Verde. It is therefore deemed unnecessary and financially unwise to assemble and commission a study team to perform a first-hand small hydropower assessment in Cape Verde.

Conclusions

1. The surface water resources in Cape Verde are insufficient to justify the undertaking of an aggressive small-scale hydropower component as part of an overall energy development program. This conclusion is based on an economic analysis performed for a representative site using the best available data.

2. Without some site specific information, an in-country assessment by a team of experts is not warranted. This is based on the results of the analysis, which indicate that the costs to develop a representative site exceed the economic benefits by a factor greater than 2.

3. There may very well be hydropower sites in Cape Verde that could be developed. The results of this study suggest that if such sites do exist, they are not in sufficient number to justify investing a large amount of time or money into setting up an infrastructure in order to exploit them. Isolated sites, however, may justify development on an individual basis.

Recommendations

1. If site-specific projects can be identified, information should be supplied to the Washington NRECA/SDH staff for a similar at-desk study to be carried out. If the results of such a study verify that the project merits further consideration, then arrangements can be made to conduct on-site pre-feasibility or feasibility studies. The type of information required for a site-specific study includes:

   a.) general local characteristics
      i. present water uses,
      ii. existing electrical services, access roads
      iii. local community infrastructure and economy

   b.) hydrology
      i. the daily or monthly stream flows recorded at the site or nearby sites
      ii. the minimum and maximum flows occuring historically

c.) the available head (elevation drop between the intake and the powerhouse)

2. U.S. AID is currently involved in a wind energy and renewable energy development project in Cape Verde. The NRECA/SDH staff feels it prudent not to duplicate efforts by conducting a simultaneous analysis of a hybrid system. If the renewable energy project develops to the point that a hydro hybrid project looks reasonable, we recommend that detailed economic and technical studies be conducted.

3. NRECA/SDH recommends that the Cape Verde AID Mission coordinate request for small hydro assistance through the Africa Bureau and ST/EY Offices of AID/Washington.

This study is organized as follows:

Section II provides the terms of reference, which describes how country assessments are normally carried out and defines the guidelines followed for this study.

Section III presents a general description of the Cape Verde archipelgo, focusing particularly on their critical energy and water situation.

Section IV outlines the methodology employed for the economic analysis of a representative hydro site.

Section V performs an economic analysis for a representative hydro site in Cape Verde. Due to a lack of

specific data, basic assumptions have been made based on the best available information for average head, available surface water and cost per installed kilowatt of the system.

II. TERMS OF REFERENCE

Determining the role of SDH in a country's overall energy development program normally involves assembling a team of experts to identify and visit specific representative sites in-country. Based on their assessment of the technical, economic and social feasibility of developing these sites, the host country government can then decide whether or not to proceed with a small hydropower program. Representative sites are chosen according to certain characteristics (e.g. stream flow, head, ease of access, proximity to energy consuming centers, etc.) that are typical of a large percentage of the sites throughout the country.

The process of identifying representative sites in Cape Verde involved consulting information sources in the United States and correspondence with organizations and individuals in the host country. Preliminary information provided to the NRECA indicates that, due to the nature of the streamflow in Cape Verde, the waterways do not lend themselves to economic hydropower development. Based on this information, the NRECA felt that a "desk" study be made a necessary prerequisite and determinant of an in-country visit by a team of experts. This decision stems from the limited financial resources available for small hydro development.

Nature of Information Used In The Study

The type of information that is required in order to perform this study includes: demographic information, current energy consumption statistics according to location and end-use, current energy supply according to source, projected energy supply and demand, energy costs, streamflow data, hydrologic and climatic data and topographic information.

In some cases the information is only available in Cape Verde, in some cases it doesn't exist at all.

The information used for this study varies in degrees of accuracy. Some of it is current, some is slightly out of date. If the reader is aware of any new or more current information than that found in this report, the NRECA would appreciate being informed so that appropriate adjustments can be made.

Information Sources

Information, taking the form of reports, studies, articles and private conversations, was obtained from the following U.S. based organizations:

- World Bank
- United Nations
- United States Agency for International Development
- Embassy of Cape Verde
- United States Man and the Biosphere Program
- United States Department of State

- Private consultants

A complete list of the specific references used is provided at the conclusion of this report.

III. GENERAL DESCRIPTION OF CAPE VERDE

The Cape Verde islands are located in the central Atlantic approximately 620 kilometers (385 mi.) off the west coast of Africa. The archipelago consists of 10 islands and 5 islets, which are divided into windward and leeward groups. The six windward islands are Santo Antao, Sao Vicente, Santa Luzia, Sao Nicolau, Sal, and Boa Vista. The four leeward islands are Maio, Sao Tiago, Fogo, and Brava.

Although the islands are of volcanic origin, the only active crater is on Fogo (its most recent eruption was in 1951). Three islands, Sal, Boa Vista, and Maio, are somewhat level and lack natural water supplies. Mountains over 1,280 meters (4,200 ft.) are found on Sao Tiago, Fogo, Santo Antao, and Sao Nicolau.

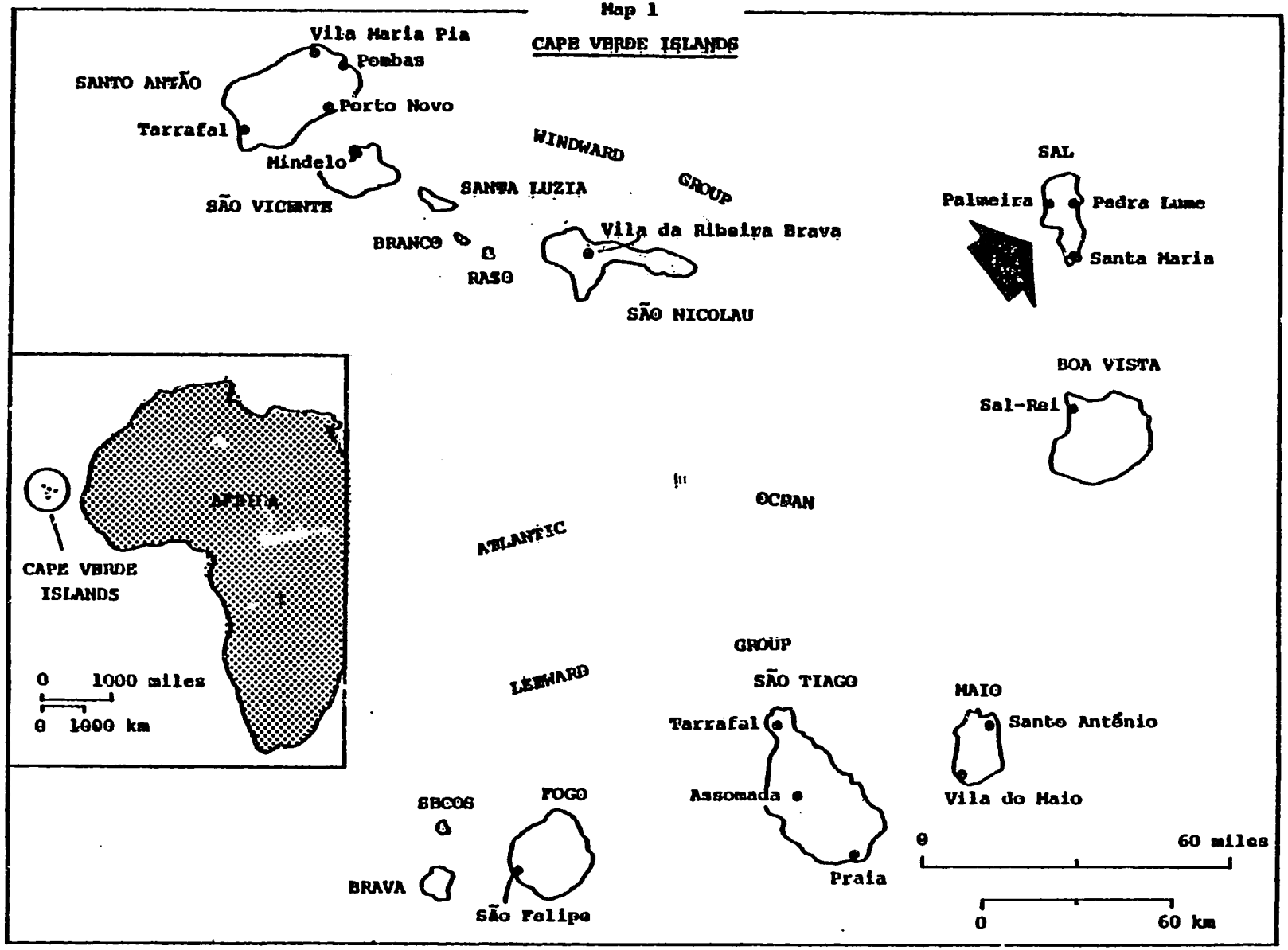
All of the islands, but particularly the windward, have been eroded by sand carried by high winds. On several of the mountainous islands, sheer, jagged cliffs rise almost vertically from the sea. Generally the uplands and coasts are devoid of natural vegetation, which is largely confined to the valleys in the interior.

Energy and Water

Cape Verde is faced with two critical resource scarcities: energy resources and water.

Map 1

CAPE VERDE ISLANDS



Although the archipelago is rich in sunshine and wind, these renewable resources are only beginning to be explored from a comprehensive perspective. Almost all of the rural population (approximately 80% of the entire population) rely on extremely scarce fuelwood for domestic energy supply. The balance of the rural demand is provided by animal dung. Electricity in Cape Verde is generated exclusively by Diesel engine-generators (using imported Diesel fuel), and form the most part, is confined to the urban centers, the international airport at Sal, and water desalinization plants.

The lack of adequate water supplies for domestic consumption and on-farm use (which includes livestock and irrigation) is a continuing source of concern. Cape Verde has been described as being the exact antithesis of an oasis, a desert surrounded by water. Yet the opposite is true, fresh water is an extremely scarce resource. Rainfall is very irregular, and its periodic failure causes droughts and famines. Most of the rain falls between July and October, during which time erratic torrential rains may account for half of the year's rainfall in a single storm. When these rains do occur, the steep topography, impervious geology and poor soil cohesion result in almost vertical wave fronts that wash out to sea in a relatively short period of time. Little surface water or soil is left behind in the wake of this flood, and as a result, the archipelago is heavily dependent on foreign sources for

basic necessities such as food.

In response to these circumstances, U.S. AID, the United Nations and other international organizations have undertaken watershed management, irrigation and desalinization projects. Such activities, however, require substantial energy inputs which demand precious foreign exchange.

IV. METHODOLOGY

The methodology followed for this at-desk overview study involves the following: (a) matching stream flow information with the appropriately sized hydropower system to determine the amount of power that could be produced on an annual basis; (b) comparing the cost of electricity produced based on various assumptions concerning system costs, debt service, system lifetime and operation and maintenance cost, with the most economic alternative; (c) performing such analysis for one theoretical site representative of the majority of the sites which may be possible to exploit.

In the case of Cape Verde, there are no known instances of rivers or streams that flow for more than a few months throughout the year. Year round water availability is almost always a necessary requisite for firm power production, which in turn is often relied upon to prove financial viability of a hydropower installation. However, based on available information, a representative site has been selected, and due to the lack of specific stream flow data, water availability for hydropower production has been estimated from catchment basin size information, topographic maps and rainfall data. Thus, even though year round electric power will not be available from the hydropower installation, electricity will be available throughout part of the year, dependent upon the ability to successfully capture the water during the rainy season. The value of

the electricity produced in this site can be calculated and compared with the present and projected cost of the current method of electricity supply, a diesel electric generator. In this manner, the most economic alternative can be determined.

V. ECONOMIC ANALYSIS

Assumptions

The following assumptions were used in order to perform the economic analysis of a representative site:

A. Since the rainfall in Cape Verde is concentrated in a relatively small number of storms during a four month rainy season, a run-of-river scheme is assumed to be unfeasible. As was pointed out in Section IV, there are no known streams that flow continuously throughout the year. The Draft Environmental Report on Cape Verde prepared by the U.S. Man and the Biosphere Program states that, "There are no permanent streams or lakes anywhere in the archipelago."[1] U.S. AID Mission discussions with the National Institute for Technological Research revealed that, ". . . there is no permanent source of water to generate hydroelectric power."[2]

Hence, our theoretical site will employ a dam for retaining the rainfall and allowing it to flow through a turbine/generator unit in a controlled manner.

B. It is assumed that the island of Sao Tiago has a total of 16 million cubic meters of developable surface water and an average catchment basin of 30 square kilometers. The Project Paper for the

U.S. AID Cape Verde Watershed Management Project (655-006)[3] stated that the catchment basins are between 10 and 50 sq. km. and has estimated the surface runnoff for Sao Tiago Island to be approximately 110 million cubic meters per year. Also, it stated that the paucity of data makes estimation of the potential development of this runoff difficult, but that perhaps 16 million cubic meters may ultimately be supplied. The Draft Environmental Report on Cape Verde[1] estimates a total surface runoff for the entire archipelago as being 330 million cubic meters annually. Therefore, Sao Tiago Island, with only one-fourth of the total land area of the archipelago, accounts for one-third of the total surface water runoff.

C. This study will assume a head value of 70 meters, which is admittedly ambitious, but will be suitable for our purposes.

Due to the extremely small catchment basins on almost all of the inhabited islands, the reservoirs will have to be located at a relatively low elevation. Therefore, the maximum head can be expected to be under 70 meters.

D. The cost of the hydro system is assumed to be approximately $2,000 U.S. per installed kilowatt of generating capacity. This is to include equipment cost; installation cost; cost of the civil works for dam construction; and cost of distributing the power to the energy

consuming centers. The system lifetime is assumed to be 30 years, and the discount rate is assumed to be 15%.

E. It is assumed that the turbine-generator size will be in the 50 KW - 100 KW range.

The appropriate system size must be selected based on energy requirements of the end users, as well as on resource availability. Both the modest energy requirements as well as the modest water availability tend to be driving forces for a relatively small system. If the system is too large, the capital costs are high, the power output will be excessive, and the stored water will be depleted within a period of weeks, not to be replenished until the following rainy season. However, if the system is too small, the costs of the supporting structures (i.e. dam, distribution systems, etc.) will by far outweigh the value of the generated energy. In addition, the water evaporation rates in Cape Verde are very high due to the strong winds and excessive solar insolation. Therefore an unnecessarily large percentage of the water will evaporate from an under-sized reservoir.

F. The hydroelectricity will replace Diesel engine produced electricity at a rate of $0.25 U.S. per kilowatt hour.

G. The annual operation and maintenance costs for the hydro system will be on the order of 3% of the initial capital outlay.

Analysis

Based on the above assumptions, the cost calculation for a representative site in Cape Verde is as follows:

$$P = (\eta)(10)(Q)(H) \quad \text{where}$$

P = Power in kilowatts (KW), assumed to be 100 KW

η = System efficiency, assumed to be 70%

Q = Waterflow in cubic meters per second (cms)

H = Head in meters, (m), assumed to be 70m

We will solve for Q by using the assumed values for P, η, and H.

$$Q = 100/((7)x(70)) = .2\text{cms}$$

Based on the estimate of 16 million cubic meters of annual recoverable surface water for the entire Island of Sao Tiago (996 square kilometers), a 30 square kilometer catchment basin will collect (30/996) x (16 million) = 482,000 cubic meters of water per year.

Therefore, the system will produce full power for 482,000/.2 = 2,400,000 seconds = 669 hours per year. Multiplying this by the power output results in 669 x 100 = 66,900 kwh per year.

The value of this electricity will be 66,900 x $0.25 = $16,800 on an annual basis, based on an assumed cost of Diesel engine electricity of $0.25 U.S. per kilowatt hour.

Using a uniform annual capital recovery factor with discount rate (r) equal to 15%; system lifetime (n) equal to 30 years; initial outlay (P) equal to ($2,000 per installed kilowatt) x (100 KW) = $200,000, we can calculate the equivalent annual costs (R) of the system:

$$R = P \left(\frac{r}{(1+r)^n - 1} + r \right)$$

$$= \$30,500$$

We must add the annual operation and maintenance costs of (.03) x ($200,000) = $6,000. This results in a total annual cost of $36,500.

Comparing the annual value of the electricity produced by the system ($16,800) with the annual cost of procurring, operating and maintaining the system ($36,500), indicates that the development of such a site would not be cost effective.

Discussion

From the above analysis of the data, the following comments can be made:

1. An analysis that is based on assumptions concerning water resource availability as opposed to reliable information can always be improved by such information.

2. Each one of the assumptions made was purposefully slanted in the direction of making the project more attractive. The head of 70 meters is probably higher than the average site. In order to gather as much water as possible, the reservoir should be situated at a relatively low elevation. (This is actually called for by the extremely steep terrain characteristic of several of the islands.) Therefore, an additional 70 meters of vertical elevation from the reservoir to the power house may not be available.

3. The estimate of 16 million cubic meters of surface water with development potential for Sao Tiago Island may very well be higher than the rest of the archipelago, since Sao Tiago Island receives more total rainfall and more rainfall per square kilometer than the rest of the islands.

4. Evaporation losses, which are reported to be high due to strong and constant winds and solar insolation levels,[3] were not entered into the calculation.

5. Reservoir capacity would most certainly be diminished due to excessive soil runoff during the rainy season. The Draft Environmental Report on Cape Verde reports that, "Flash floods with nearly vertical wave fronts carry large loads of rocks, gravel, sand and finer sediments," and "The steep terrain makes dam sites scarce and reservoir would be subject to rapid filling with erosional debris."[3] This would result in either

decreased power production due to decreased water storage capacity, or increased costs due to dredging of the reservoir.

6. As a result of the constant abrasion from the high rock and silt content of the water, the lifetime of the turbine, penstock and intake will be decreased. Similarly, the operation and maintenance costs of the unit, and dam, will increase.

7. Since the unit would sit idle for a large part of the year (according to the calculations, it could operate at full load for only 27 days of the year), the system would not displace any diesel capacity. An argument could not be made, then, for entering the costs of additional diesel capacity into the calculations. Cape Verde would still require that additional capacity throughout the other 11 months. The hydro system would only serve to reduce fuel consumption.

APPENDICES

APPENDIX 1 - Correspondence AID - NRECA

APPENDIX 2 - NRECA's SDH Program

APPENDIX 1

UNITED STATES GOVERNMENT

memorandum

DATE: February 4, 1981

REPLY TO ATTN OF: Hugh I. Smith, AID/Praia, Cape Verde

SUBJECT: Small Decentralization Hydropower Program (SDH) with the National Rural Electric Cooperative Association (NRECA)

TO: Jack Fritz, DS/EY, Room 306 SA-18

REF: AAA/AFR/DR, John W. Koehring memo dated January 23, 1981

The Government of Cape Verde has recently established the National Institute for Technological Research which is primarily involved in energy research, including hydropower activities. The above-mentioned entity has expressed interest on in-country assessment of their potential for mini hydro activities in Cape Verde. We would like to know when you are available to carryout this assessment. In the interim, we would appreciate additional information on this program.

HIS/lb

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

OPTIONAL FORM NO. 10
(REV. 7-76)
GSA FPMR (41 CFR) 101-11.6
5010-112

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APPENDIX 1

DEPARTMENT OF STATE
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523
Praia, Cape Verde

Mr. Clark
Training and Information
Specialist
Small Decentralized Hydropower
NRECA
1800 Mass. Avenue, NW
Washington, D.C. 20036

June 18, 1981

JUL 20 1981

Dear Mr. Clark,

This is in reference to your letter of March 13, 1981 regarding the Government of Cape Verde's request to conduct an in-country assessment of the country's potential for mini-hydropower.

With respect to your request for more information, inter alia, about the existance of hydroelectric activities in Cape Verde, the National Institute for Technological Research has reported that there is no permanent source of water to generate hydroelectric power. However, they are exploring the possibility of utilizing small turbines, associated with renewable energy projects (solar pond, wind energy, etc.), to generate such power from sea water.

The National Institute for Technological Research welcomes your sending a pre-feasibility team to Cape Verde to assess the country's potential for mini-hydro activities. Please advise us when such a team is prepared to visit Cape Verde.

Sincerely yours,

Hugh I. Smith

Hugh I. Smith
Program Officer

HIS/at

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NRECA'S SMALL DECENTRALIZED HYDROPOWER PROGRAM

In May of 1980, the International Programs Division of the National Rural Electric Cooperative Association (NRECA) entered into an agreement with the Agency for International Development (AID) to enhance NRECA's technical capabilities in the area of small (1 MW or less) decentralized hydropower and to make this expertise available to developing countries. The SDH Program provides a broad range of technical assistance to AID, foreign governments, and private organizations in the identification, design and implementation of small-scale decentralized hydroelectric power projects.

In order to facilitate the application of SDH technology throughout the world, teams of specialists are assembled which can provide in-country consulting services in areas such as plant siting, project design, economic and technical feasiblity studies, environmental/social impact analysis, and institutional development. A wide variety of informational and institutional programs is being developed by the SDH/Washington staff.

Specific SDH program activities include, but are not limited to the following:

1. Project Identification: identification of potential hydropower sites in developing countries, determining the role of SDH in a country's overall energy development program, examination of technical, economic, sociological, institutional and environmental aspects of SDH projects.

2. Site Selection and Project Design: development of analyses and designs of new projects or of the SDH component of renewable energy projects including evaluation of hydrologic potential, demand forecasting, preliminary design of generation and distribution facilities, technical feasibility studies, sociological inquiries, and environmental analyses.

3. Training and Information: development of training programs, workshops, and conferences of SDH for engineers, planners, and technicians from developing countries. These activities include classroom as well as hands-on training.

4. SDH Data Base: surveying of existing SDH facilities in both developed and developing countries to provide descriptions of system performance, economics, implementation procedures and management. The SDH staff is also identifying and evaluating equipment manufactures; developing a "skills bank" of qualified SDH specialists and compiling a library on SDH technology.

Since its inception, the SDH Program has provided a wide variety of services to countries in literally all corners of the globe.

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REFERENCES

1. Draft Environmental Report on Cape Verde prepared by the Arid Lands Information Center, Office of Arid Lands Studies, University of Arizona, of the United States National Committee for Man and the Biosphere. August, 1980.

2. Personal correspondence from Hugh I. Smith, Program Office of the U.S. Agency for International Development Mission in Praia, Cape Verde, to Mr. Paul Clark, Training and Information Specialist for the NRECA/ Small Decentralized Hydropower Program.

3. Project Paper for the U.S. AID Cape Verde Watershed Management Project 655-0006. July 30, 1979.

4. Project Identification Document for Cape Verde Renewable Energy 655-0009. U.S. AID. December 1979.

OTHER SOURCES

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4. Background Notes: Cape Verde U.S. Department of State September, 1978.

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