SOLAR-POWERED WELLS FOR ATOLL ISLAND WATER SUPPLIES – PART I

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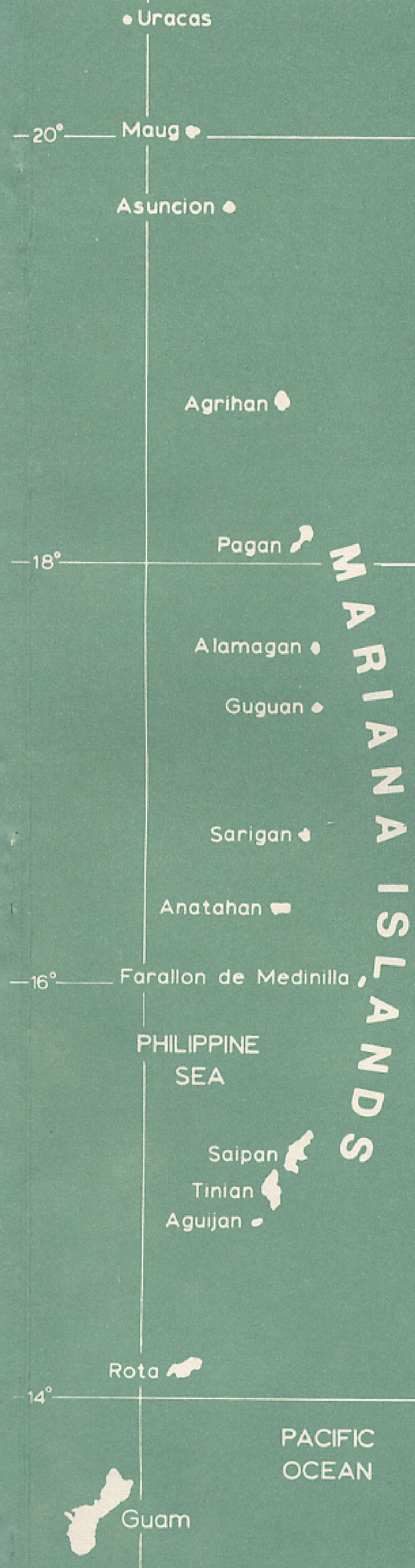

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Partial Project Completion Report

for

Solar Pumping of Groundwater for Irrigation and Village Water Supply
Project No. 06 Grant No. G-837
Project No. 02 Grant No. 14-08-0001-901
Principal Investigator: Stephen J. Winter
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ABSTRACT

This report describes the design, installation, and testing of a solar photovoltaic pumping system on the atoll island of Pis-Moen in Truk State, Federated States of Micronesia. The system uses twelve thirty-watt photvoltaic modules connected directly to a centrifugal pump. The pump draws groundwater from a horizontal well consisting of a length of perforated and screened PVC pipe, twenty feet long. During a noon test at full sun, at five foot head, the pump delivered approximately eighteen gpm. One major problem was encountered during the installation. This was the occurrence of reef rock at the water table at the first site selected. A second site proved to be satisfactory. Test holes should always be dug prior to siting wells on atoll islands.

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INTRODUCTION

Truk State is one of the four states in the Federated States of Micronesia. It consists of all the islands in Truk Atoll (hereafter referred to as Truk), the Mortlock Islands south of Truk, and a number of atoll islands to the west and north of Truk. All of these islands are located in the Eastern Caroline Islands roughly between 148° and 154° east longitude and 5° and 9° north latitude. The only high volcanic islands in Truk State are located within the Truk Atoll lagoon. All the other islands in the State are low and coralline and are generally situated on the reefs defining the various atolls.

Truk enjoys a tropical island climate with an average daily temperature of approximately 81° F. The average annual rainfall for Truk is approximately 145 inches; however, the rainfall is not uniform and distinct wet and dry seasons occur. The rainfall may vary significantly from year to year and droughts are common. The climate on the other islands in Truk State is similar, although accurate weather data are not available.

Recently (1982) a cholera epidemic took place in Truk State. This emphasized the need for safe potable water supplies and, as a result, funds from the U.S.A. became available for assistance with a number of projects:

1. construction of water-sealed toilets

2. construction of ferro cement rainwater storage tanks

3. construction of shallow solar-powered (photovoltaic cell) wells (Winter, S. J., L. D. McCleary, and R. D. Watters, 1983, and Winter, S. J. and L. D. McCleary, 1984).

This program was large in scope such that almost every household was provided with a water-sealed toilet and ferro cement tank. A well was provided in most villages having suitable groundwater resources.

The program emphasized the construction of tanks as it was recognized that properly-maintained rainwater catchment/storage systems produce the highest quality water supplies. However, since the construction of water-sealed toilets greatly increased water needs and since other needs are not always for consumptive activities, groundwater, which is generally lower in quality, also played an extremely useful role.

They served as a natural compliment to rainwater catchment/storage systems since the pumps were powered directly by the photovoltaic modules. Rainwater catchment/storage systems function during cloudy rainy periods; the wells pump during clear dry periods. During extended droughts, by rationing the higher quality stored rainwater for consumtive activities and by making greater use of well water, water of adequate quality would always be available.

These solar-powered wells were designed for household use; that is, their flow rate was rather low, around 1 gpm. Hence, since only a limited number were installed, comparatively few households received the benefits of the dual type water system described above. Because of the number of water-sealed toilets in use and the sometimes difficult problem of placing a well in an area outside the influence of the toilets, consideration was given to the use of fewer larger capacity wells as sources of community water supplies. This report describes a pilot project of this type.

OBJECTIVES

The principal objective of this project was to investigate the feasibility of utilizing photovoltaic modules as the power source for wells serving communities in remote island areas. A second objective was to test on a community level the concept of utilizing the sun as a regulator of water supply systems where water is only required during dry periods as a complementary supply to rooftop rainwater catchment/storage systems. A third objective was to produce a simple design for a shallow well that could be duplicated on a local level.

PUMPING SYSTEM

Design Criteria

A number of criteria were used in arriving at the system design. These included:

1. suitability for use on atoll islands (or on low flat sandy coastal areas of high islands). Atolls are the areas that experience the severest water shortages.

2. utilization of a shallow well capable of being dug by hand. This is the only method available in remote areas.

3. simplicity and ease of maintenance. These factors would hopefully increase the longevity of the system.

4. utilization of a horizontal type well. This would skim the freshest water from the top of the aquifer.

5. direct drive of the pump by the solar modules. No batteries would be used.

6. utilization of a switch so that the pump could be turned off if water is not needed. This would increase pump life and prevent waste of the freshest groundwater.

7. a yield of approximately 10 gpm at a total head of 20 feet (at full sun). This provides 2400 gal per day for 4 hrs full sun. The intent is to provide approximately 10 gal/capita/day.

Schematics of system electrical and hydraulic components based on these criteria are shown in Figure 1.

Site Selection

Truk State was chosen as the general project site because solar modules were available through the Rural Sanitation Program there. These were earmarked for use with solar pumping systems as part of Truk's cholera eradication program. The island of Pis-Moen (Figure 2), located on the barrier reef surrounding Truk Atoll, was chosen as the specific project site because its hydrogeologic characteristics would be similar to other atoll islands and it was still accessible by speedboat from the main island of Moen. Locating the system on Pis-Moen facilitated communication and the transport of construction materials. Pis-Moen is the only permanently inhabited island on the barrier reef. Its population is approximately 400. It is located at the northernmost side of the reef (Figure 3) approximately 15 miles from Moen.

Hardware Selection

A centrifugal pump was selected because the characteristics (good flow at fairly low heads) were appropriate for this location. A ground mounted rather than submersible pump was used because it was thought to be easier to service. Specifically, a model 15030SDS 36 volt D.C. ½ horsepower dual impeller centrifugal pump manufactured by the A.Y. McDonald Company was selected. Referring to the characteristic curves for this pump (Figure 4), the expected flow at 20 feet head was around 22 gpm, using the 30 volt curve, and around 29 gpm, using the 36 volt curve. Also referring to these curves, the power required at 30 volts was around 400 watts and, at 36 volts, around 600 watts. It is noted that, by limiting the power supplied to the pump, the flow would be limited.

Thirty watt solar modules manufactured by the now-defunct Solar Power Corporation were used because of their availability from the Truk State government. The output of these modules in full sun is 1.95 amps at 15.4 volts. Twelve modules were wired 6 in parallel and 2 in series (Figure 5) to produce an estimated 11.7 amps at 30.8 volts (nominal 360 watts). The anticipated operating point of the pump at full sun is shown on the characteristic curves (Figure 4). Thus, the pump was expected to provide around 15 gpm.

PVC pipe was used for both the well components and for electrical conduit primarily because it is so easy to work with.

Construction

A trench 20 feet long was dug for the skimming well. At the first location selected, reef rock was encountered a few inches below the water table (4 feet below ground surface). The second location proved to be satisfactory with reef rock occurring approximately 2 feet below the water table (Figure 6).

A 20 feet long piece of 4 inch PVC pipe was perforated by drilling ¼ inch diameter holes 8 circumferentially and 1 inch apart axially over the entire length of the pipe (Figure 7). The pipe was then covered with a number of layers of fiberglass screen which were secured to it with copper wire (Figure 8). This pipe was laid horizontally in the trench and attached by means of a tee to a vertical price of 6 inch PVC pipe.

It was originally intended that the horizontal portion of the well would drain into a sump (Figure 1). However, since it was impossible to dig through the layer of reef rock, the lower side of the tee connecting the horizontal pipe to the vertical pipe was simply covered with screen as capping the vertical pipe would have raised the horizontal pipe too close to the water table. Even with this arrangement, the tee still caused its end of the horizontal pipe to be around 6 inches closer to the water table than the other end. The top of the vertical pipe was covered with a cap provided with a hole to accept the pump suction line.

The pump was mounted on a concrete slab (Figure 9) and fastened to the slab with stainless steel bolts. A plywood box was provided to protect the pump from rain and vandalism. The suction line was equipped with a foot valve and routed through the pipe cap into the vertical well pipe. Since a storage tank had not yet been constructed, the discharge line was simply routed to an open area for measuring flow rates.

The array was mounted on the roof of a home approximately 100 feet away from the well (Figure 10). The array consisted of 12 modules attached to fabricated aluminum channels. The channels were fastened to the roof with stainless steel lag screws.

Number 12-2 wire was used to connect the array to a heavy duty weather resistant PVC-encased switch located on the side of the house. Number 6-2 wire was used to connect the switch to the pump. It was enclosed in conduit and buried.

Testing

Some difficulty was experienced in priming the pump. After a number of attempts, it was ascertained that the foot valve was not seating properly. In order to prevent this situation from occurring again (when technical personnel would not be available to trouble-shoot), it was decided that the pump discharge line would be routed to the bottom of the storage tank rather than the top. The water in the tank would thus insure that the pump remained primed even if slight leakage through the foot valve occurred. This procedure would have the disadvantage, however, that it would be impossible to hear water being discharged into the tank.

Because of time constraints (and available cloud free weather), it proved to be impossible to conduct extensive tests on the pump. Only one test was conducted at noon at full sun. The total head on the pump was around 5 feet and the measured flow was 18 gpm (Figure 11). Referring again to the characteristic curves, this agrees fairly well with the predicted flow. It was, unfortunately, impossible to conduct drawdown tests.

CONCLUSIONS

Although it is difficult to draw firm conclusions because the system has not been thoroughly tested, many general observations can be made. Groundwater is certainly available on atoll islands in abundant supply and can be reached by means of hand-dug wells. A horizontal well is the logical method of increasing well capacity without increasing the salinity of the water delivered. Even though groundwater may be of lesser quality than water derived from rainwater catchment/storage systems, it serves as a valuable back-up source, especially during dry periods.

Two significant problems were experienced during the course of the project. The first was the encountering of reef rock at the water table. Previous studies (Ayers et al, 1984) indicate that this is most likely to occur on the ocean side of an atoll island. However, a firm answer can only be obtained by digging a few test holes. This is easy in the sandy atoll island soils.

The second problem that occurred was in priming the pump. Two obvious alternatives to the present system exist. One is to use a self-priming pump; the other is to use a submersible pump. Both deserve serious consideration.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Nachsa Siren, Coordinator of the Rural Sanitation Program of the Truk State government, for both logistic support and for providing the solar modules used on this project. Thanks are also due to other members of the Rural Sanitation Program staff who assisted with the construction of the pumping system. Finally, the writers express their gratitude to Mr. Seferin Iasinto, the chief of Pis-Moen, and to other members of the community on Pis-Moen for their hospitality and for their help in constructing the system.

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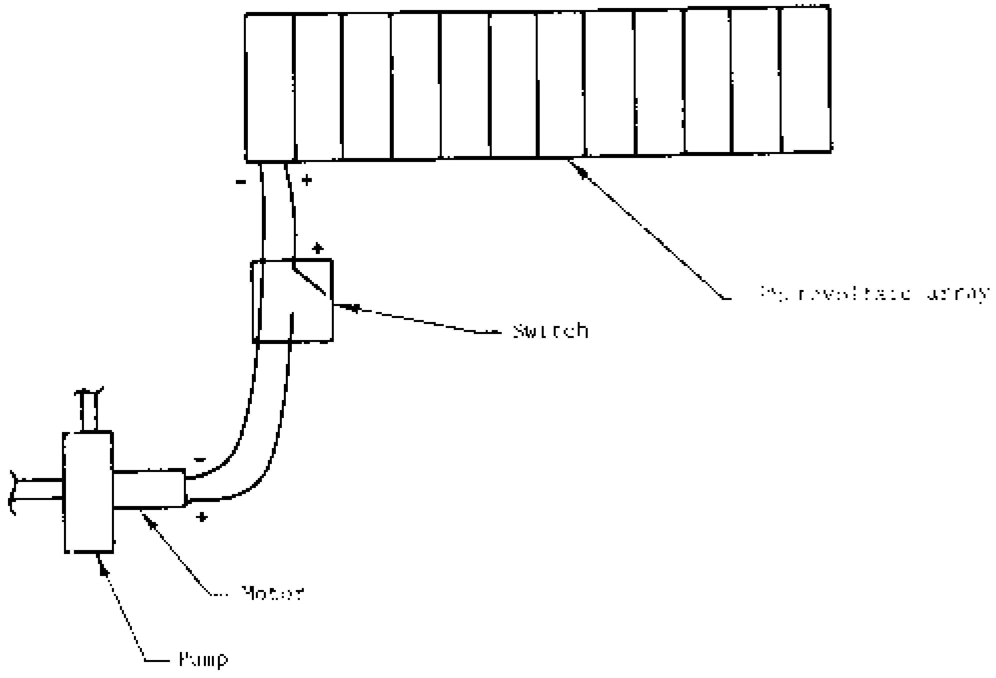

Figure 1a. Schematic of system electrical components.

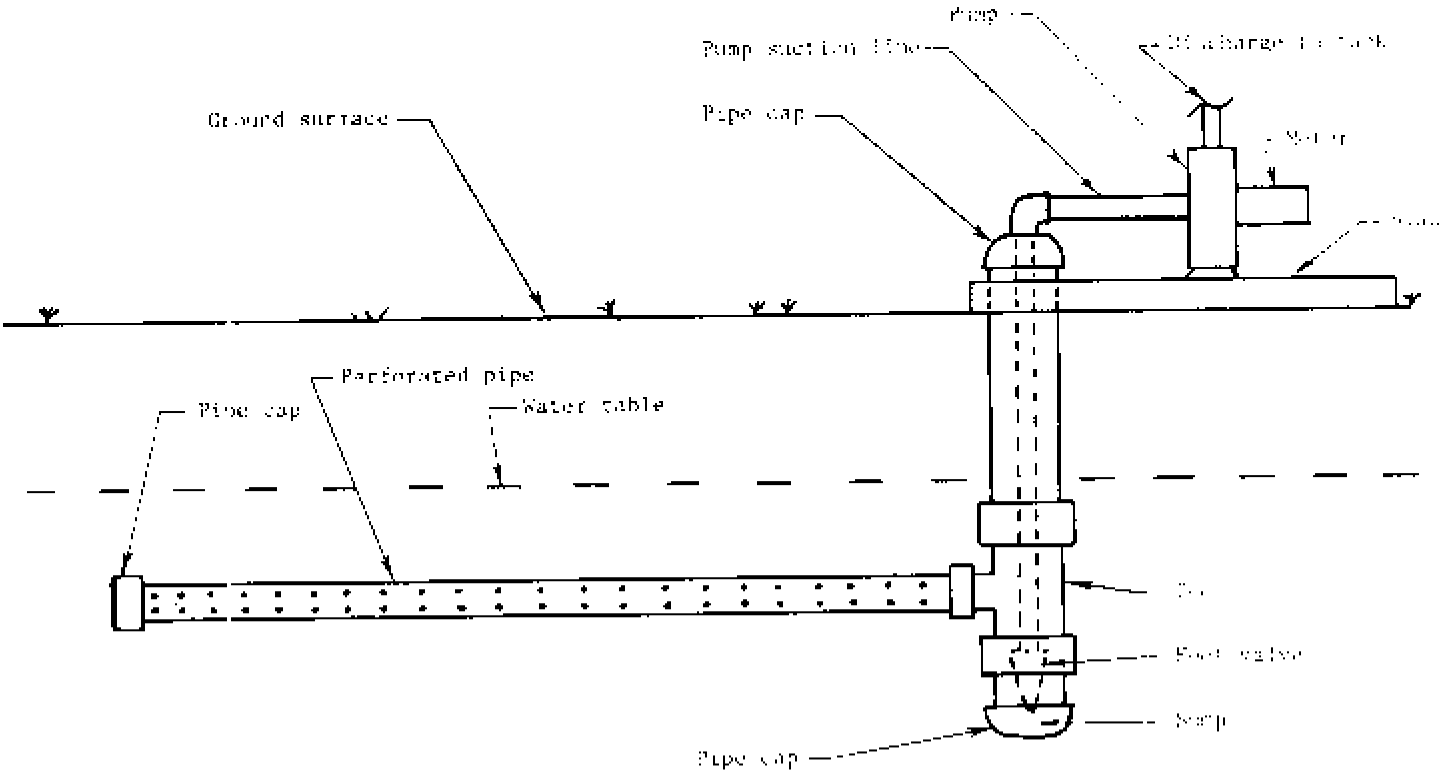

Figure 1b. Schematic of system hydraulic components.

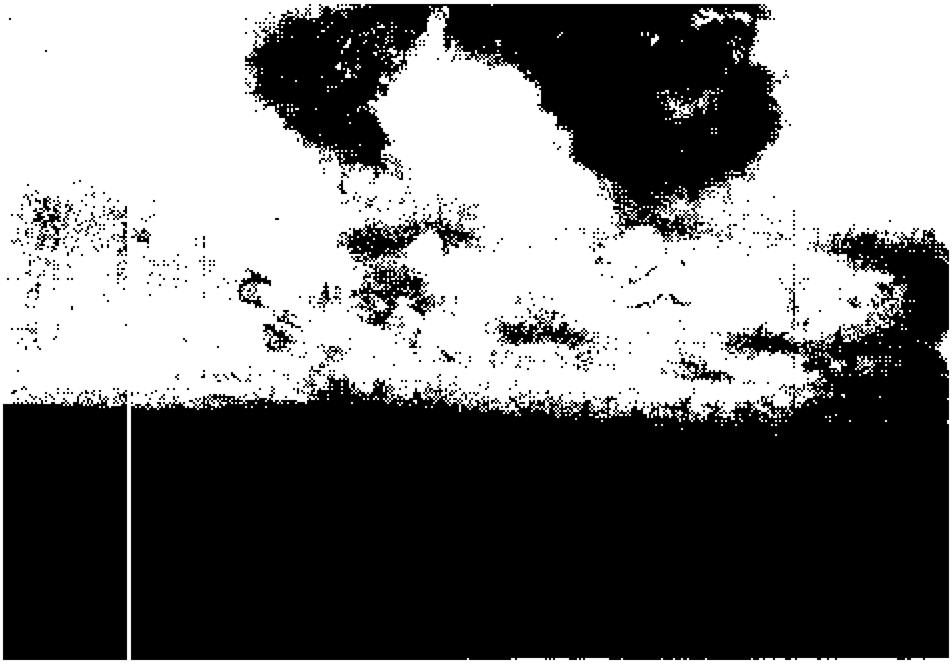

Figure 2. The island of Pis-Moen.

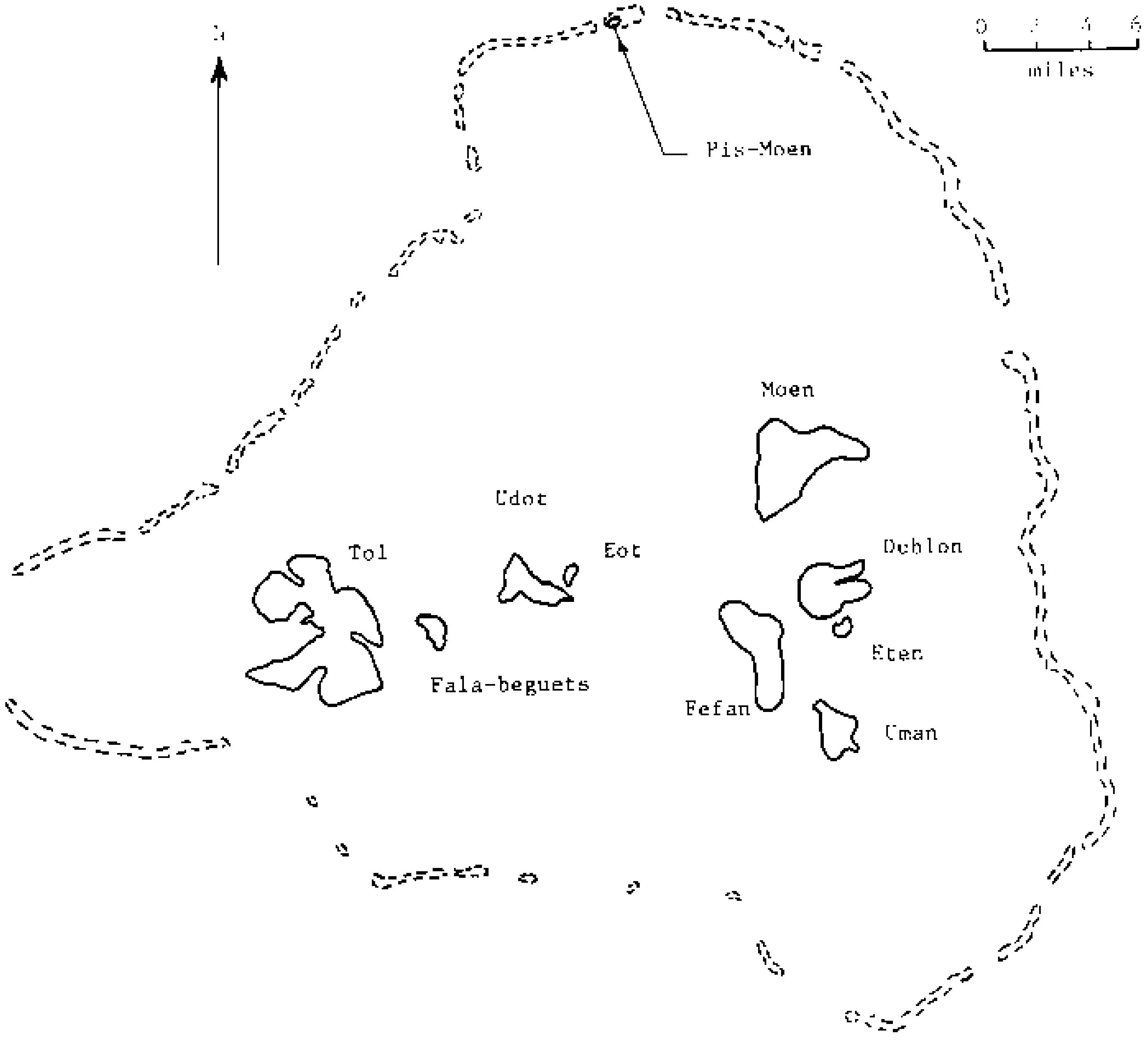

Figure 3. Map of Truk Atoll showing project site.

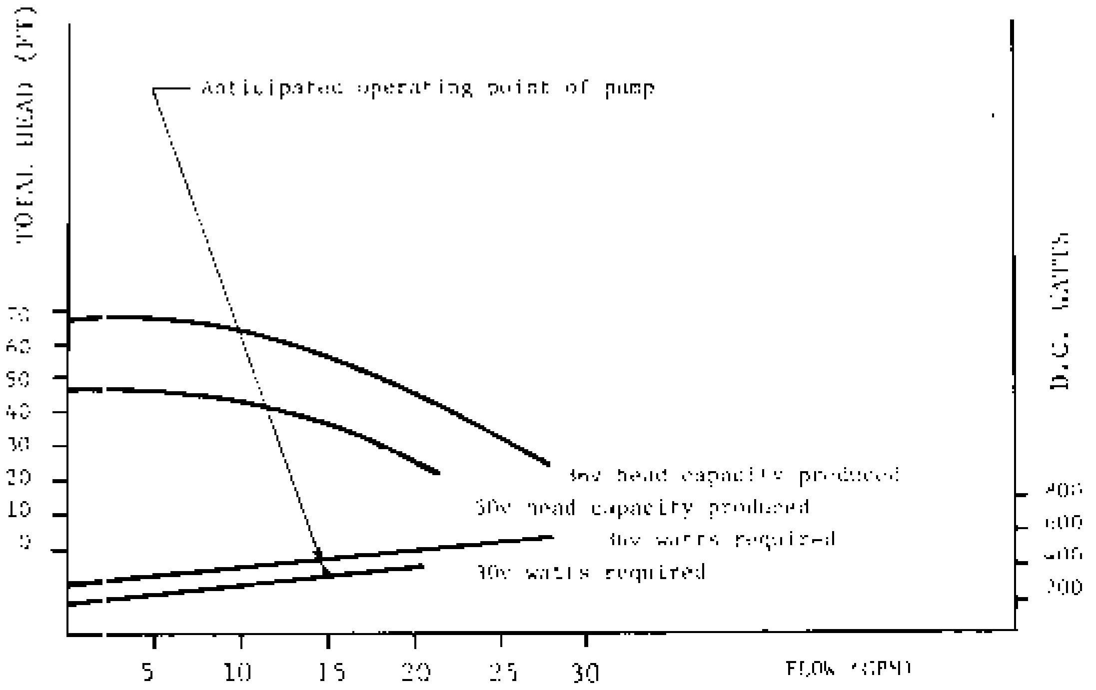

Figure 4. Characteristic curves for A.Y. McDonald model 150305DS centrifugal pump.

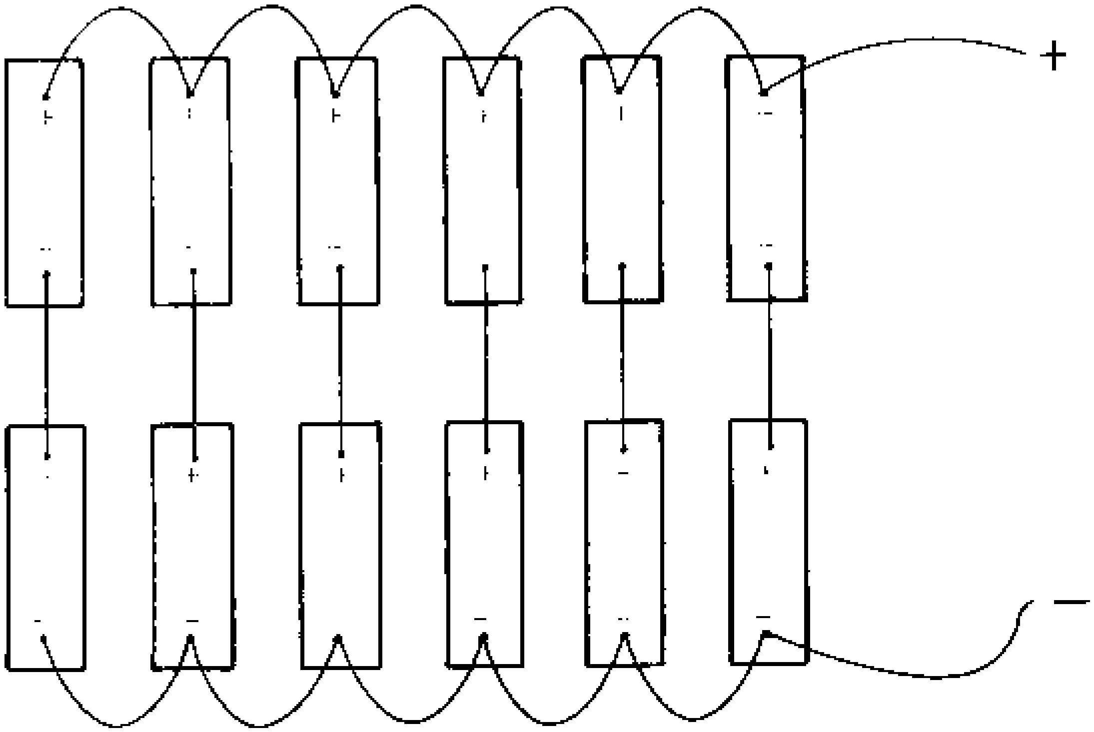

Figure 5. Schematic of array wiring.

Figure 6. Digging the well.

Figure 7. The perforated well casing.

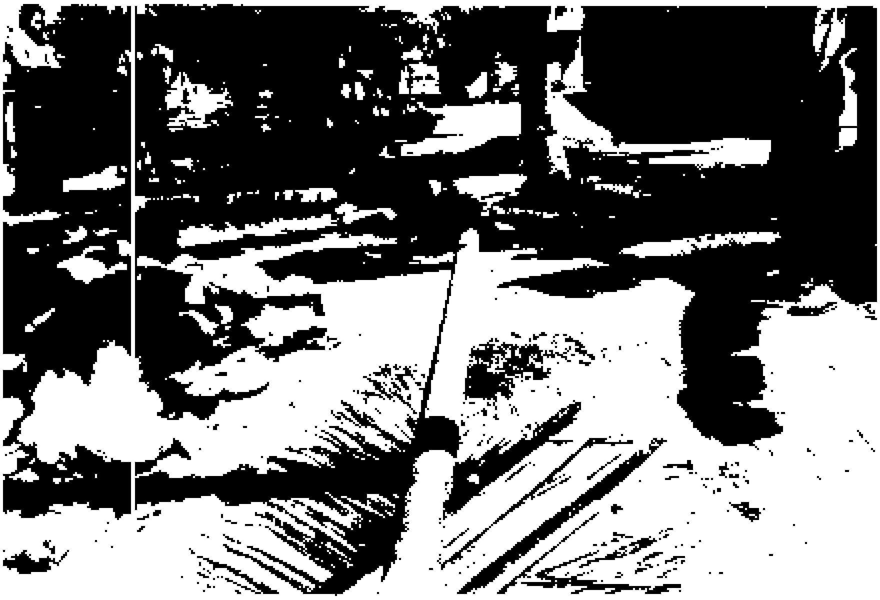

Figure 8. The casing covered with fiberglass screen and attached to the 6" pipe.

Figure 9. The pump installation.

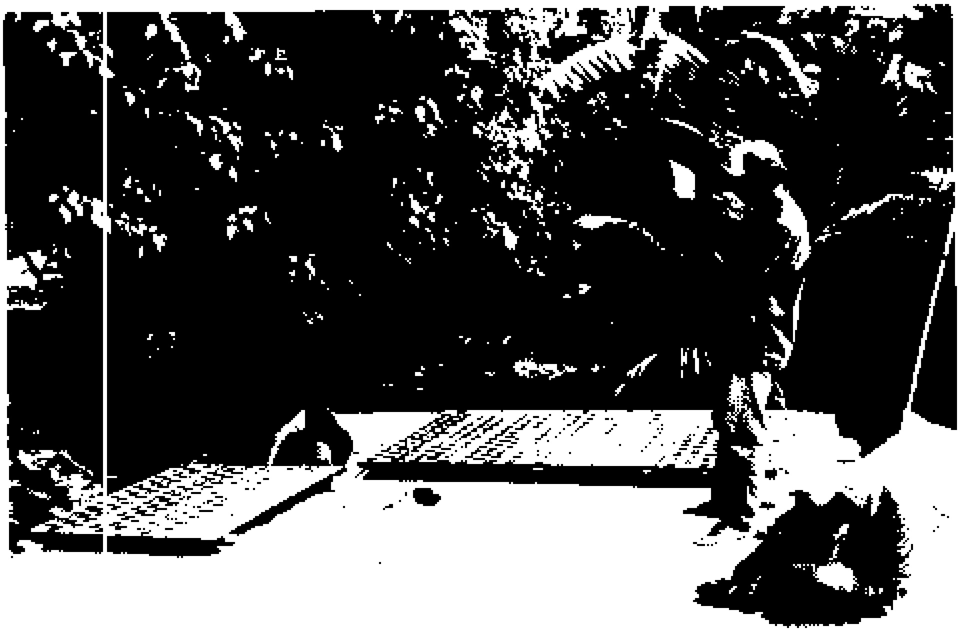

Figure 10. The array.

Figure 11. Testing the pump.