N83 19264 D33

THE 80 MEGAWATT WIND POWER PROJECT AT KAHUKU POINT, HAWAII

R.R. Laessig
Vice President-Engineering
Windfarms, Ltd.
San Francisco, CA 94111

Windfarms Ltd. is developing the two largest wind energy projects in the world. Designed to produce 80 megawatts at Kahuku Point, Hawaii and 350 megawatts in Solano County, California, these projects will be the prototypes for future large-scale wind energy installations throughout the world.

80 MEGAWATT WIND POWER PROJECT AT KAHUKU POINT, HAWAII

Location

The site for this project is the Kahuku Area on the northern tip of Oahu, Hawaii (Fig. 1). This location receives consistent northeast trade winds approximately 80% of the year.

Although Oahu is not the largest of the Hawaiian Islands, it contains over 90% of the state's population and has the highest electrical consumption. The state's largest city, Honolulu, is located on the south side of Oahu, which is on the opposite side of the island from the project area.

The site comprises about 2,100 acres, including three ridges which slope upward from the coast toward Mt. Kawela to an approximate elevation of 1,000 ft. These slopes increase the velocity of the prevailing

PRECEDING PAGE BLANK NOT FILMED

688

trade winds. Due to the wind's intensity, this area of Oahu is sparsely populated and contains less than 3% of the island's inhabitants.

Currently, Hawaiian Electric Company's (HECO) 1300-megawatt system is almost totally dependent on oil-fired generating plants. The annual fuel consumption is approximately 10 million barrels of oil. Having no petroleum deposits in the State of Hawaii, all oil must be imported at considerable expense adding substantially to the state's electricity costs.

Energetic winds, the high cost of fossil fuel, the support of the state government and the Hawaiian people make the northeast coast of Oahu one of the most desirable locations for the development of a major wind energy installation.

Project Description

Twenty machines with a nameplate capacity of 4 megawatts each will be placed on the Davis, Opana, and the Waialee Ridges. This area is owned by the Campbell Estate, and part of the Waialee Ridge by the State of Hawaii. It is presently used for training purposes by the U. S. Army which has a long-term lease that will expire in 1983. The renewed lease will contain provisions to permit the coexistence of the wind farm and the military training range.

The site map (Fig. 2) shows the arrangement of the machines and the road system that will be built for installation and maintenance of these machines.

The project will be developed in two phases:

The first phase includes six machines on Davis Ridge. Installation is expected to start by the middle of 1983 with commercial operations starting near the end of the same year. The transmission line used to transmit power to the HECO system will be the existing 46 kV transmission line on the north shore of Oahu. This line has a capacity of 22.5 megawatts and, therefore, is not large enough to take the 80 MW production of the entire wind farm.

The fourteen machines in the second phase will be installed in the beginning of 1984 with all machines expected to reach commercial operation by 1985. Upon completion of the two phases, the power of the entire project will be carried by a newly installed 20-mile long 138 kV transmission line from the existing Kuilima Substation on the north portion of Davis Ridge to the Wahiawa Substation.

The Wind Turbine Generator

The WTG used in this project will be the Hamilton Standard WTS-4, a machine that will be installed later this year in the Medicine Bow Project and in Sweden. This machine has a rating of 4 megawatts at 34 mph with a rotor diameter of 260 ft. and a tower height of 250 ft. The machine is equipped with a downwind rotor and its characteristics are shown in Fig. 3.

A step-up transformer is used on each machine which increases the voltage of the generator (4160 volts) to an intermediate voltage of 46 kV. The 46 kV line from each ridge will be brought into a switchyard located near the present Kuilima Substation where all the switching and safety equipment is located. For phase I, the power will be transferred directly to the existing 46 kV transmission line, while the 138 kV transmission line will be used for phase II.

All wiring within the wind farm will be underground. This assures that the local environment will be disturbed as little as possible and may also increase local acceptance of the project.

Land Acquisition

In July of 1980, Windfarms entered into a detailed agreement with the Campbell Estate, the owner of the land. Under the terms of this agreement, Windfarms is granted exclusive prospecting rights over the Estate's 2,100 acres. This allows Windfarms to conduct wind measurements and other meteorological work to determine the best sites for locating the turbine generators. It also allows Windfarms to select sites and do preliminary meteorological and topographical work at the sites. After all sites have been clearly established, the Estate has agreed to grant Windfarms a separate lease of 2 acres for each generator site and easements for the ingress and egress and auxiliary buildings.

Many negotiations were necessary with the Campbell Estate and the U.S. Army which presently uses this area as a training ground. The U.S. Army has taken a very positive view of this wind power plant and a mutually acceptable way has been found to install the machines at the best wind location without impairing the U.S. Army's field training area.

Power Purchase Agreement

In July of 1980, Windfarms Ltd. and HECO entered into a Power Purchase Agreement in which HECO agrees to purchase all energy generated by the Project during the next 25 years. The price paid by HECO per kilowatt hour generated will be equal to its average cost per kilowatt hour during the preceding two month period. In addition, the Power Purchase Agreement specifies voltage and frequency requirements. Stability criteria are also an important factor, and preliminary calculations have been made to show that 80 megawatts on the present Hawaiian grid does not affect the stability of the grid. Final stability analyses will be presented in a future paper.

Meteorological Work

A comprehensive meteorological program has been launched by Windfarms to accurately determine the area's wind resource and the resulting energy output of the completed wind farm. After the installation of the 107-meter and 80-meter wind towers on the Davis Ridge, two extensive field services were conducted using kites and mobile equipment which allowed the project meteorologists to categorize each ridge and correlate it with the long-term measurements gathered by the Opana Ridge instrumentation and the Livermore Laboratories data.

Two additional towers will be installed at the Opana and Waialee Ridges as soon as the permitting process is completed.

Maintenance and Control Building

The switchyard and the maintenance and control facilities will be located near the Kuilima Substation. The control building will house the control center of the wind farm and will be the single interface point of the HECO system dispatcher and the wind farm. All parts required for routine and emergency maintenance will be stored in the maintenance building.

Transmission of Electric Power

The power from the first phase of the project will be carried by a 46 kV power line which presently connects the north shore of Oahu to the HECO grid. This transmission line is large enough to take 22.5 megawatts (26 MVA). The Kuilima Substation will be used as a tie-in point to this transmission line.

For the second phase of the project, a 138 kV transmission line, approximately 20 miles long, is planned which will connect the Kuilima Substation with the Wahiawa Substation. Several routings have been proposed for this line. Minimizing the environmental impact and interferences with the training area of the U.S Army were the two determining factors for the final routing of this line (Fig. 4).

The transmission line begins at the Kuilima Substation, and will be routed through a gulch to avoid visibility from the highway. It then proceeds in an approximately southern direction through inaccessable mountain territory, and then runs to the west, terminating at the Wahaiwa Substation. The transmission line towers that are located in the southern mountain range are not accessable by road and will have to be placed and maintained by helicopter.

In order to establish a back-up line, the 46 kV line connections at the Kuilima Substation will be made permanent. The control system will limit the output of the wind farm to 22.5 MW at times when the 138 kV line is not operational or during maintenance periods.

This power line has been surveyed and tower locations have been selected. April 1984 is the anticipated completion date.

The Hawaiian Electric Company will build and maintain this power line as a subcontractor for Windfarms.

The metering devices used to determine the power delivered from the wind farm to the HECO grid will be located at the Wahiawa Substation, while the power delivered during phase I will be measured at the Kuilima Substation.

Environmental Impact Statement

In addition to selecting the locations of the machines and planning for the 138 kV transmission line, the current activity includes the preparation of the Environmental Impact Statement. For this purpose, several local experts were hired to study the archeological, botanical, zoological, socio-economic, and the electro-magnetic interference impacts of the wind farm and transmission line to the area. This work is being conducted by the Bechtel Power Corporation in Norwalk, California, and a first environmental assessment was filed in June 1981. It is hoped that, by the beginning of 1982, all permits will be obtained to start site preparation, road construction, power lines, switchyards, and control maintenance buildings.

A list of required permits and issuing agencies is shown in Fig. 5.

Costs and Schedule

Negotiations about the final cost of the project are underway and it is still too early to publish a final figure. Currently it is expected that the project cost will be in excess of $250 million. Several cost items will be discussed that are usually not carried in present projections.

A major expense is the cost of interest during construction. This cost for the present project is approximately $80 million. A further substantial expense item is the cost of the transmission line. It is estimated that the cost of the transmission line will be in excess of $500,000 per machine, or over $10 million for this project.

Furthermore, costs such as land and Land Agreements, Environmental Impact Statments, Power Purchase Agreements, and Maintenance Agreements are escalating the cost of the wind farm beyond what was anticipated. It is important that these costs be considered in future installation cost projections on similar projects.

For the site of Hawaii, the cost of the transportation of the equipment and all auxiliary hardware to the island, and then from the port of entry to the project sites is a very significant addition to the total installation cost; they are enhanced by the non-availability of large cranes and insufficient port facilities on the north shore of Oahu.

The installation of the WTGs is scheduled for the beginning of 1983 and commercial operation of the entire wind farm is expected beginning in 1985.

THE BIG ISLAND PROJECT

A 4 MW project is being developed for installation on the Island of Hawaii (Big Island). It is connected into the Hawaii Electric Light Company (HELCO) grid at the Kamea Range (Fig. 6).

A Land Agreement was made with the Parker Ranch, owner of the land in this area. The Power Purchase Agreement has been executed with HELCO specifying the amount and quality of power to be delivered to the HELCO system.

Two meteorological towers have been installed near the sites and meteorological data are presently being obtained. Concurrently, preliminary sites were established and geological and topographical work was performed to validate the viability of the established sites (Fig. 7).

The power will be collected from the generators at 4160 volts and then a single step-up transformer will increase the voltage to 34.5 kV, the voltage of the existing transmission line.

The present schedule calls for start of commercial operation at the end of 1982 with a total system cost of less than $12 million.

SOLANO COUNTY PROJECT

A 350 MW wind power project is being planned by Windfarms Ltd. near San Francisco, California.

Location

The project is located in the hills south of Vallejo in a parcel bounded by Interstate 80, 780, and 680 in the rolling hills of Solano County (Fig. 8).

Project Description

A Letter of Agreement has been signed with the Pacific Gas and Electric Company (PGandE) which outlines location, size, and power requirements of this wind power installation. The total installation will include approximately 100 machines of various designs.

The first 90 megawatts of this wind farm will be connected to an existing 115 kV line that transverses diagonally through the area.

The electrical interconnection line of this farm will be underground at 20 kV, similar to the Hawaiian project. Phase I power will be collected at two switchyards, stepped up, and then transmitted into the existing 115 kV lines (45 MW each).

A preliminary layout of phase I of this project is shown in Fig. 9.

Additional transmission line capacity will be required when the project exceeds 90 megawatts. This is projected for 1986. PGandE is planning the new transmission line in order to transport 260 megawatts out of this area into the PGandE grid and satisfy other local power requirements.

Preliminary WTG sites have been selected for phase I of this project (90 megawatts) and meteorological studies have started with preliminary surveys of the site areas by kite measurements.

Two temporary 10-meter towers have been erected and two 100-meter towers are projected to be installed as soon as permits and equipment are available.

Aside from the meteorological activities and preliminary site planning, the current thrust of this project is completing the Environmental Impact Statement, grading plans, and the layout and routing of roads and electrical power lines are being developed.

The Environmental Assessment is progressing with the assistance of Dan Coleman Associates. The first geological survey has been completed by Earth Sciences, Inc.

The present schedule projects the start of installation of the first portion of phase I by mid-1983 and will proceed on an installed power schedule shown in Fig. 10.

The Solano Project is the first large wind farm within the continental United States and will serve as an excellent example for integration of wind power into large continental grid systems.

DESIRABLE FEATURES OF FUTURE WIND TURBINE GENERATORS

The wind farm installations discussed in this paper indicate that wind power is entering a new phase. The technology developed and gathered by DOE, NASA, and private industry is being used to produce large and reliable wind power machines that fit the use for utility-type wind power production.

It is, therefore, appropriate to make a few remarks on desirable characteristics of these wind machines.

Low Equipment Cost

The tremendous cost of the currently available machines makes it mandatory to use them in connection with high average wind velocities and with utilities having high electricity production costs. Present tax credits are very helpful but it is absolutely necessary to reduce the cost of future machines to a level where the kilowatt hour can be produced below 5 cents, including all installation, service, and finance costs.

Optimum Machine Size

The considerable cost of site preparation, land costs, transportation, and other auxiliary costs require that the machines be sized as large as feasible and that the size optimization take into account a realistic assessment of these costs based on present requirements.

The recent trend which we have seen in the MOD-5 studies confirms this point and we hope that future developments will strengthen the economic viability of wind power systems for areas with lower wind velocities and for utilities where the avoided cost of electricity is not extremely high.

Low Erection Cost

The previous paragraph underlines the necessity of lowering erection costs of the WTGs and also the necessity of reducing erection time in order to minimize the cost of interest during construction. New cost effective methods have to be found especially for the erection of machine clusters such as those described in this paper.

Transportation Costs

The planning of our Hawaiian installation has shown that transportation has a significant impact on the overall cost of the project. The main problems here are overall dimension and overall weight.

The local non-availability of large cranes is a very important factor. Road clearances of over 14 feet can also be a detracting requirement. Therefore, the limitation of size and weight is an important design parameter which should be considered in order to make the transportation and installation more cost effective and less time consuming.

Reliability/Maintenance

From the standpoint of the user of a wind installation, the most unestablished items in his equation are the cost of maintenance and the outage time of the equipment for this maintenance. It is most important that the equipment be designed with a very high availability factor and, at the same time, a very low maintenance cost. That means that simplicity of design, a minimum of parts, and good accessibility for all maintenance should be high priority items.

A simple and cost effective maintenance program for a 30-year period has to be established.

Environmental Impact

In the past few years, Environmental Impact Statements have filled many months at the beginning of a power plant project. It is important that wind turbines are being designed in a way to have minimum impact on the environment. In particular, this includes the creation of noise and visual impact. Another large portion of this impact is the electromagnetic interference that affects TV as well as communication links.

Life

In the immediate future where privately-owned wind farms will be more predominant, the life of the machine will be a very important factor for financing the entire project. It will be a long time before life projections on machines can be based on experience. It is, therefore, especially important that the early machines are of a very long life expectancy and operate in a reliable and predictable fashion.

We are presently entering a new phase of wind turbine generator development that reaches beyond the technical feasibility stage of the first machines. It is now our responsibility to prove that wind farms can be built and operated as long life reliable power sources and that the sight of large wind power farms should be as common for future generations as the many thousands of power generating and water pumping machines existing in the early part of this century.

ORIGINAL PAGE IS
OF POOR QUALITY

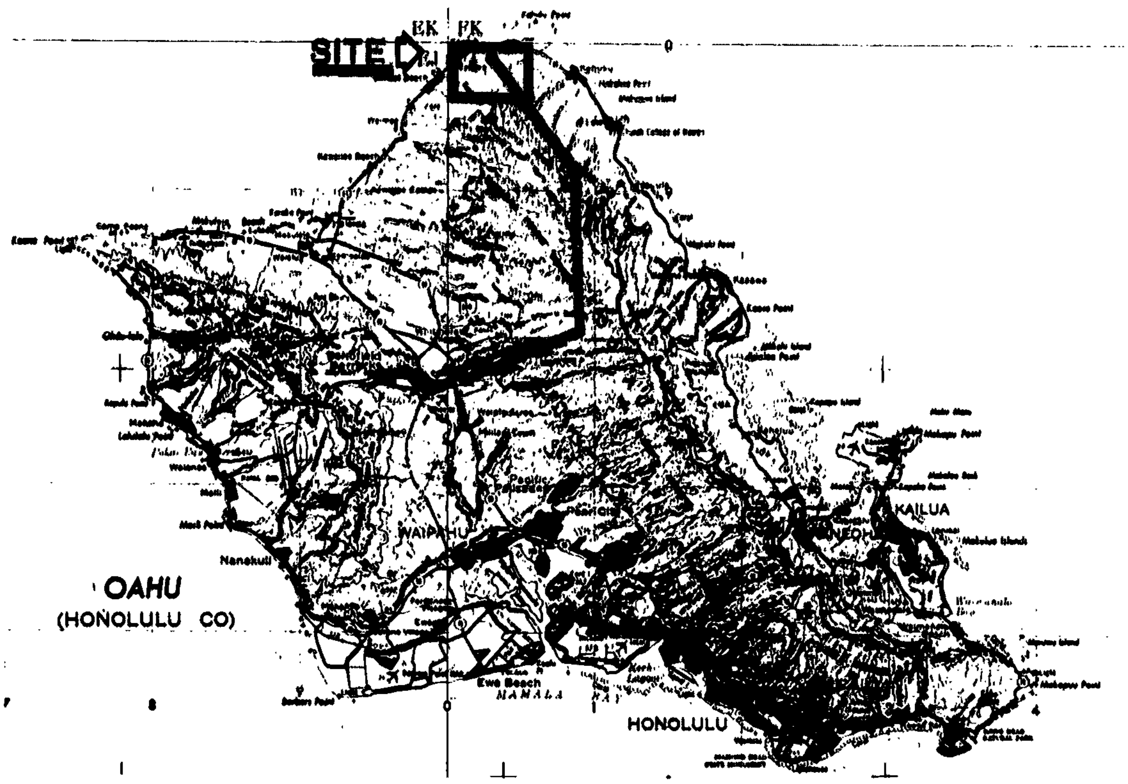

Fig. 1

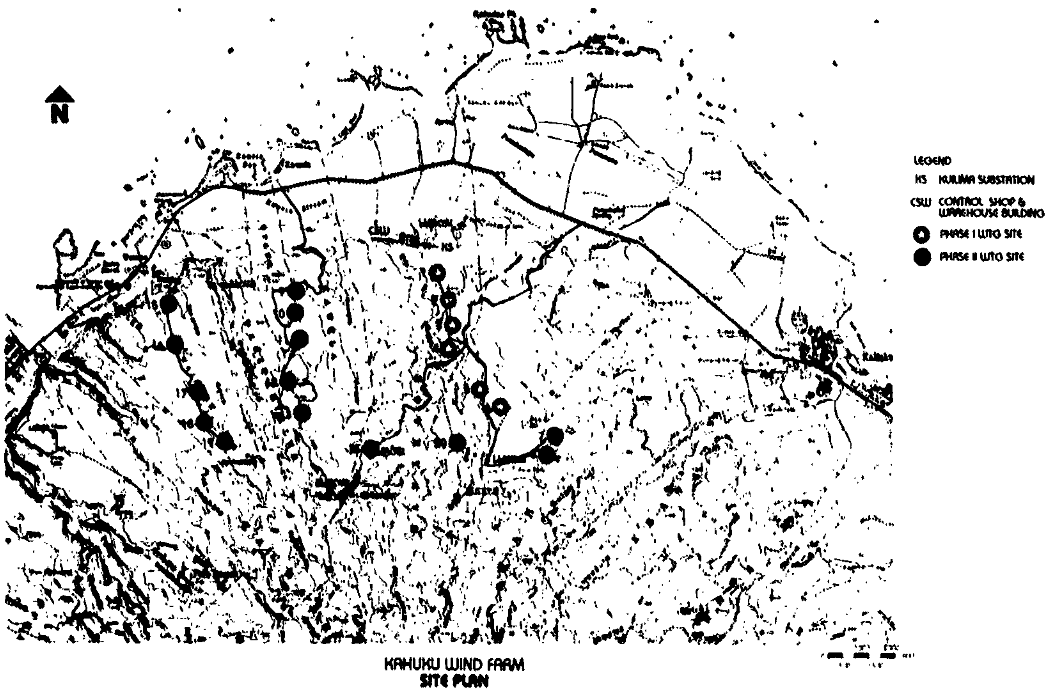

Fig. 2

KAHUKU POINT
WIND FARM SYSTEM CHARACTERISTICS

POWER	80 MW
YEARLY ENERGY OUTPUT	>300 x 10^6 KWhr/YEAR
WTG	20 HAMILTON STANDARD WTS-4
NAMEPLATE RATING	4 MW
ROTOR DIAMETER	80M
HUB HEIGHT	80M
RPM/ROTOR DIRECTION	30 RPM/DOWNWIND
TOTAL WEIGHT	407 TONS
TOWER WEIGHT	200 TONS
NACELLE & ROTOR	207 TONS

TRANSMISSION LINE

1ST PHASE INSTALLATION 6 WTGs
22.5 MW/46 KV TO EXISTING KUILIMA SUBSTATION
2ND PHASE INSTALLATION 14 WTGs
80 MW/138 KV TO WAHIAWA SUBSTATION (20 MI.)

LOCATION: DAVIS, OPAHA & WAILEE RIDGES

SUBSTATION & SWITCHYARD: AT KUILIMA SUBSTATION

Fig. 3

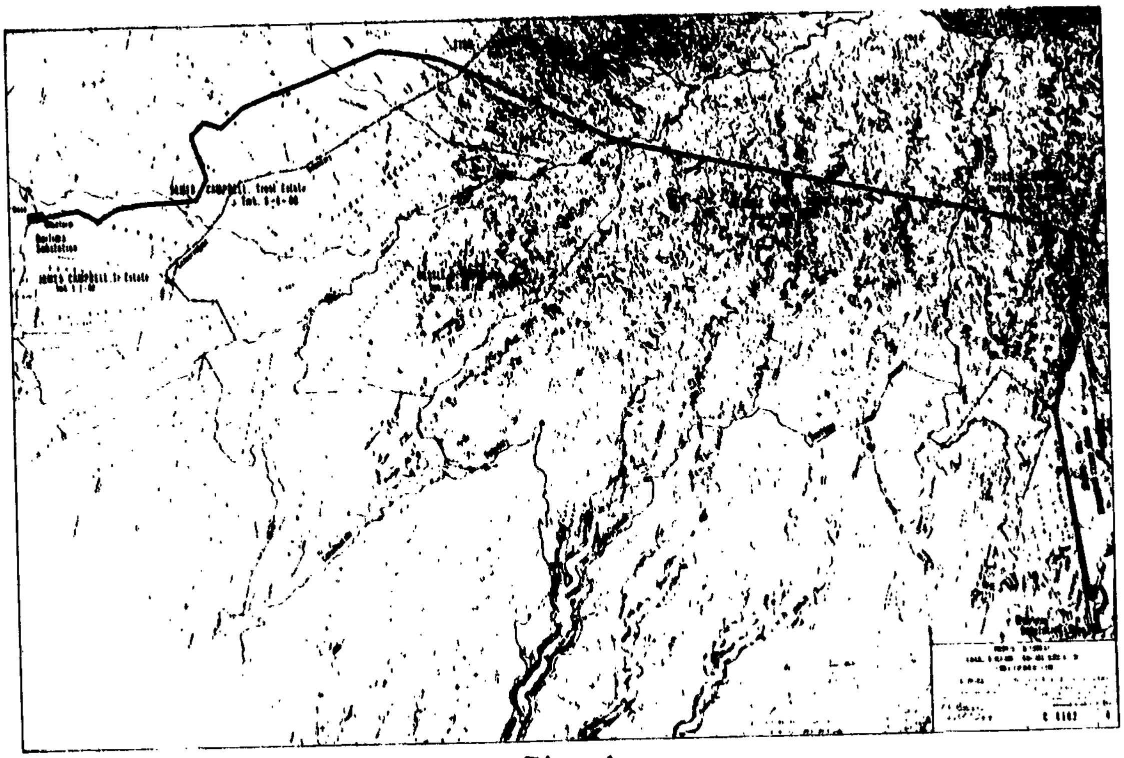

Fig. 4

REQUIRED PERMITS

CDUA	CONSERVATION DISTRICT USE
DLU	CONDITIONED USE/HEIGHT WAIVER SUBDIVISION FOR LEGAL
ZBA	ZONING VARIANCE
FAA	WTG AIRCRAFT HAZARD DETERMINATION TRANSMISSION-AIRCRAFT HAZARD DETERMINATION
DPW	GRADING PERMIT
BUILDING DEPT.	BUILDING PERMIT
FIRE MARSHALL	FIRE APPROVAL
DEPT. OF HEALTH	POLLUTION VARIANCE & NOISE PERMIT WASTE WATER PERMIT TO OPERATE
DOT	TRANSPORTATION PERMIT PERMIT TO WORK ON STATE HIGHWAY STREET USAGE PERMIT
DPED	CONSISTENCY DETERMINATION
COE	PERMIT FOR ACTIVITIES ON WATERWAYS
DLU	SPECIAL MGMT. AREA PERMIT

Fig. 5

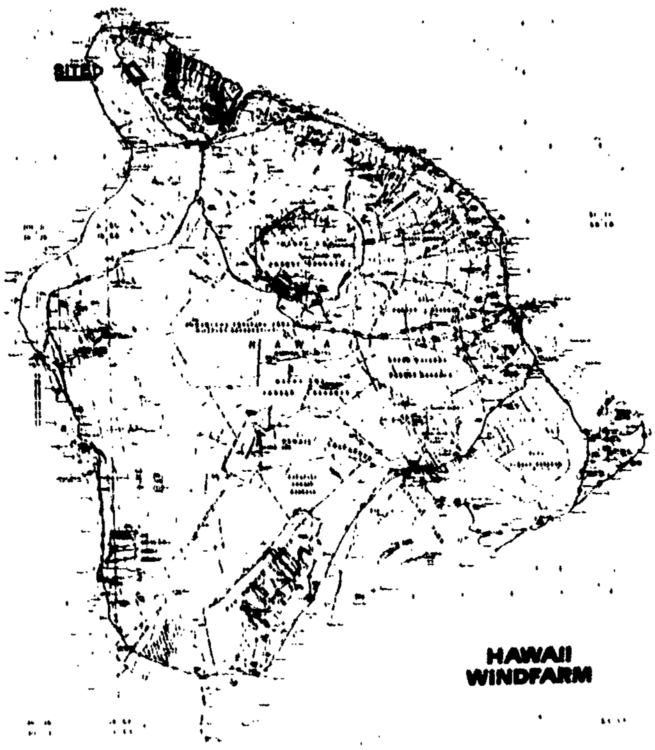

Fig. 6

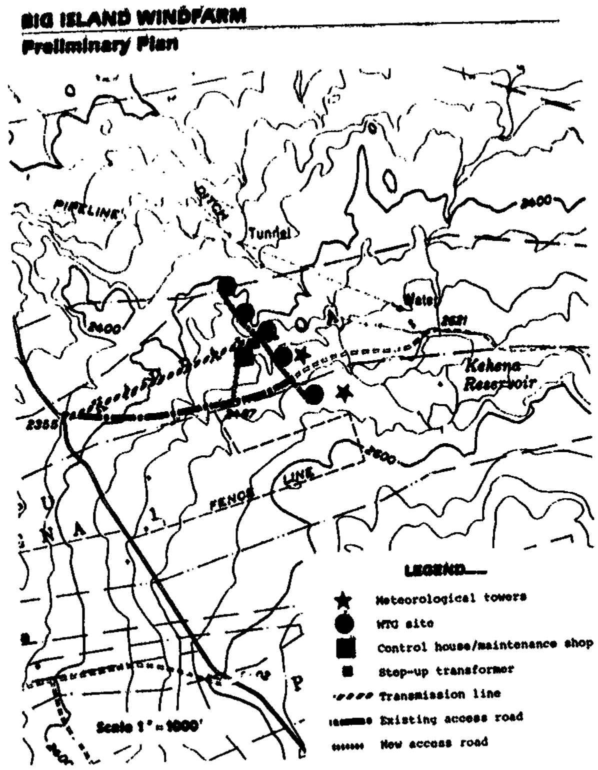
BIG ISLAND WINDFARM
Preliminary Plan
PIPELINE
Tunnel
Kehena Reservoir
FENCE LINE
LEGEND
Meteorological towers
WTG site
Control house/maintenance shop
Step-up transformer
Transmission line
Existing access road
New access road
Scale 1" = 1000'

Fig. 7

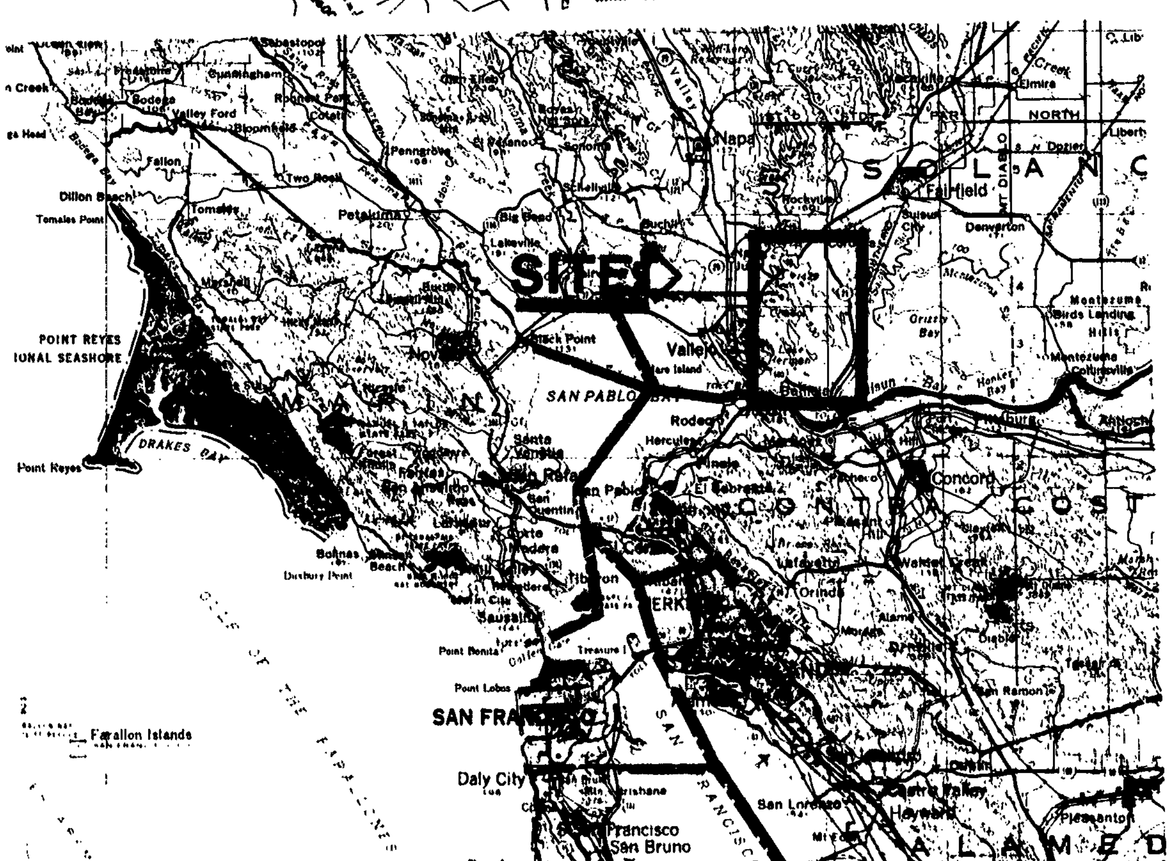
SITE
Napa
Fairfield
Petaluma
Vallejo
SAN PABLO BAY
POINT REYES
Point Reyes
DRAKES BAY
Concord
SAN FRANCISCO
Daly City
Pacifica
San Bruno
Farallon Islands

Fig. 8

ORIGINAL PAGE IS
OF POOR QUALITY

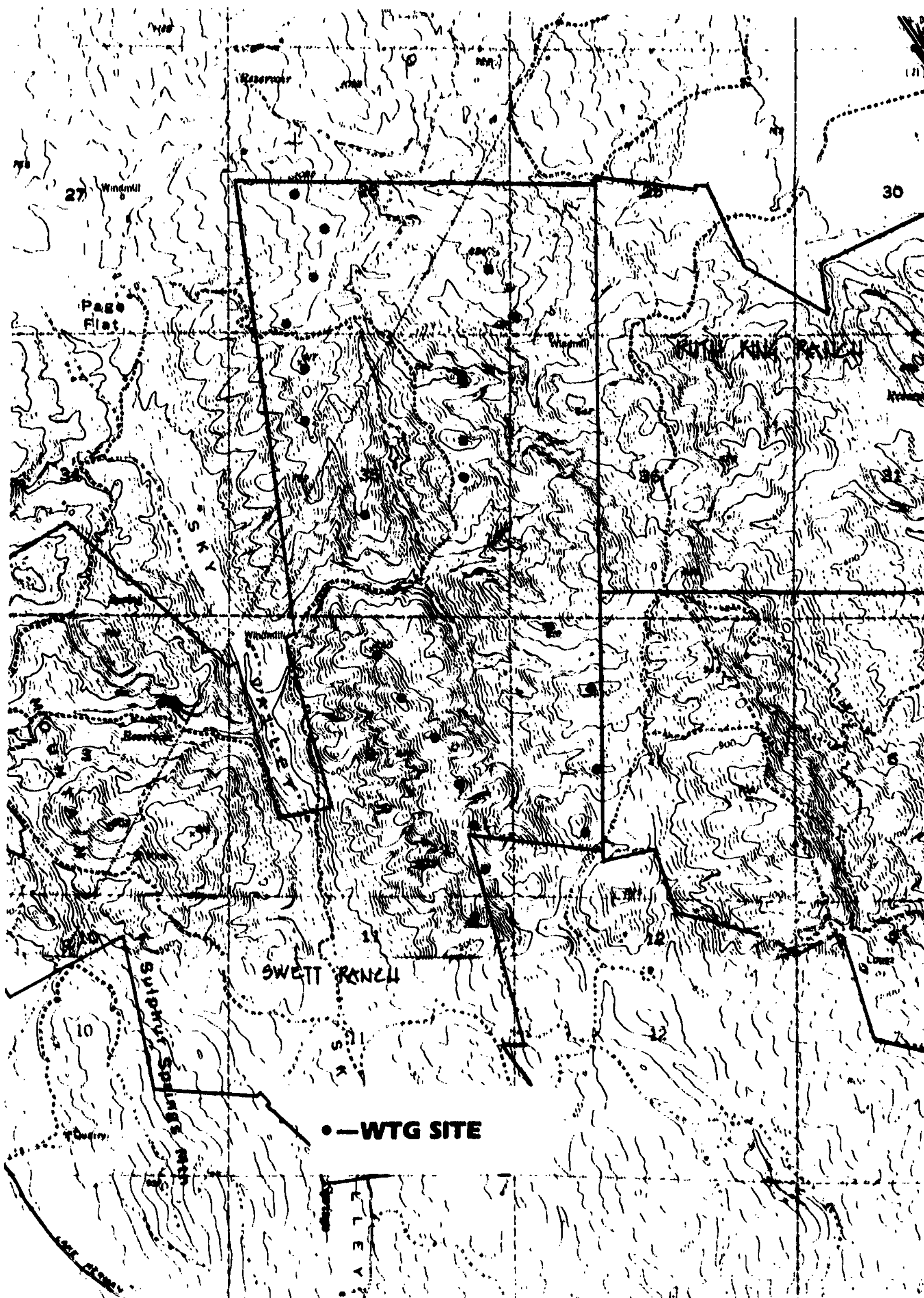

Fig. 9

SOLANO WINDFARM PROJECTED CAPACITY

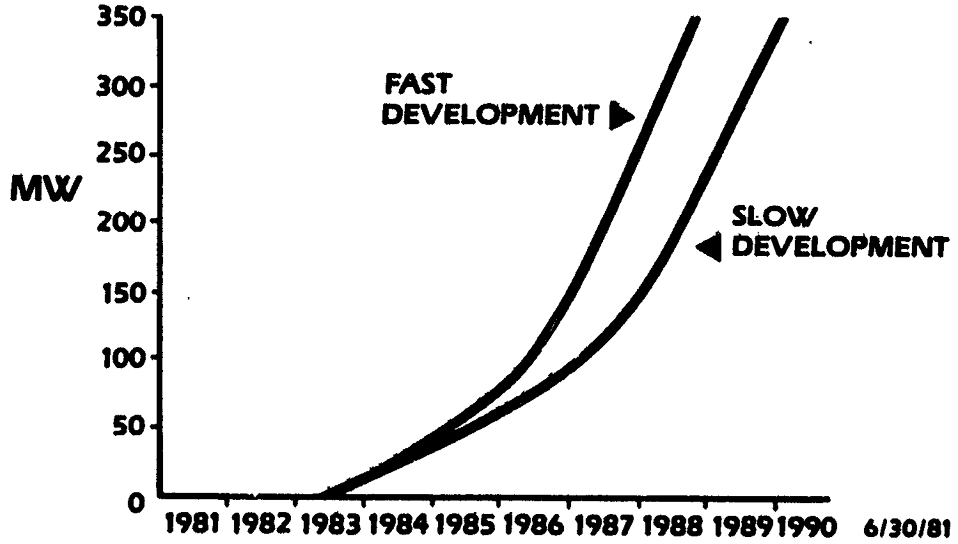

Fig. 10