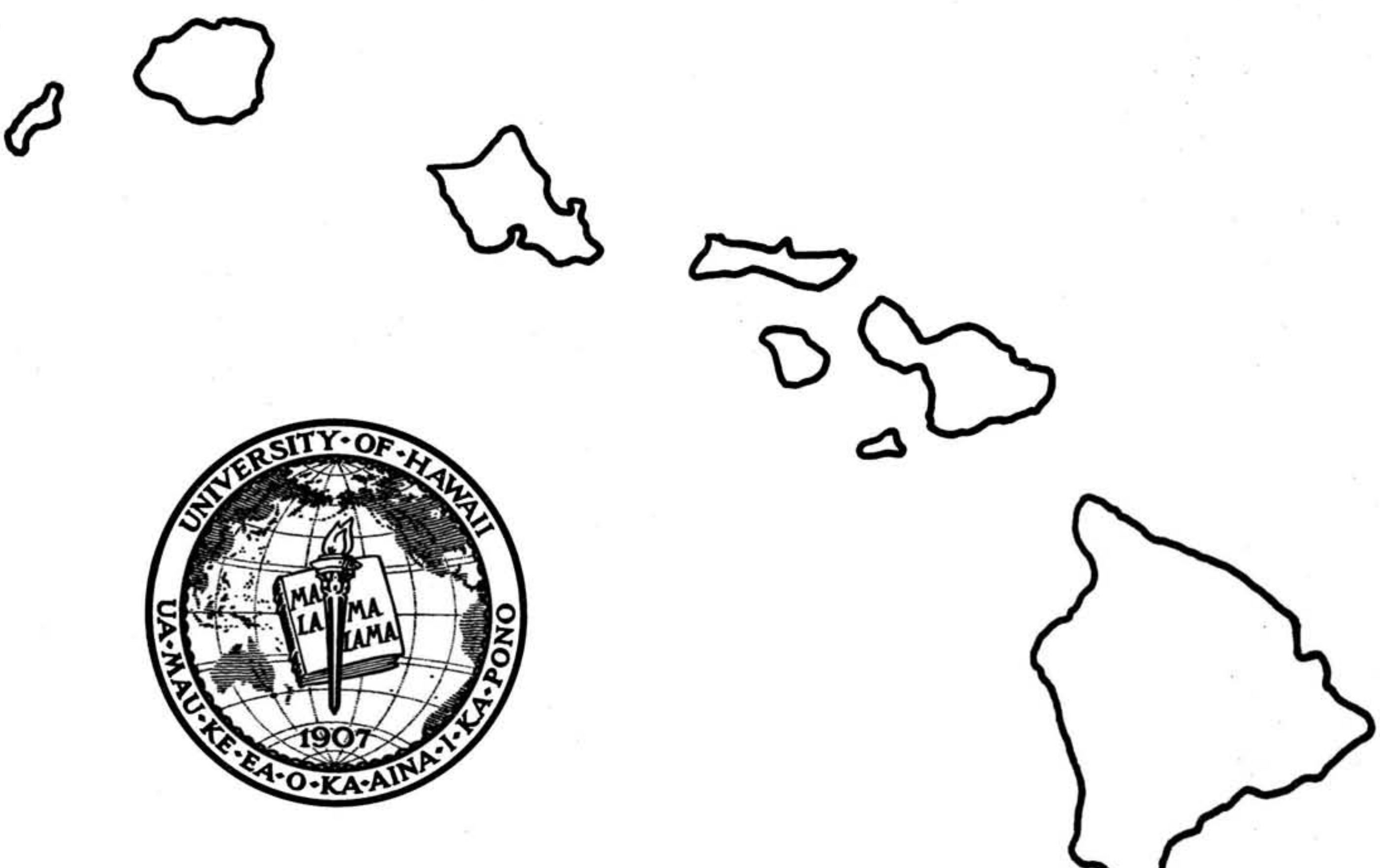
THE HAWAII GEOTHERMAL PROJECT

QUARTERLY PROGRESS REPORT NO. 3

December 1, 1973 Through February 28, 1974



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December 1, 1973 Through February 28, 1974

SUPPORT FOR PROJECT PROVIDED BY:

National Science Foundation
State of Hawaii
County of Hawaii

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University of Hawaii
Holmes Hall 240 - 2540 Dole Street
Honolulu, Hawaii 96822

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HAWAII GEOTHERMAL PROJECT

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OVERVIEW

Highlights of third quarter activity include the initial meeting of the National Liaison Board and consideration by the 1974 State Legislature of a number of bills and measures relating to geothermal energy.

Included in the report are summary statements by the three program managers on the progress made to date in each of the research tasks. These statements are identical to the summary reports to be included in the proposal to NSF for additional funding to complete Phase I. A more complete record of accomplishment in the Engineering and the Socioeconomic Programs is contained in the following publications:

1. Quarterly Progress Reports I, II, and III of the Engineering Program
2. Legal and Public Policy Setting for Geothermal Resource Development
3. Geothermal Power Economics - An 80-Page Annotated Bibliography

The National Liaison Board held its first meeting at Hilo, Hawaii on February 8-9, 1974, with eight of its nine members in attendance. The Board's role is to provide: (1) overall evaluation on progress of the HGP to date; (2) input to assist in subsequent program planning; and (3) interaction with the various geothermal projects represented by the Board members. Included at the end of this section is a brief summary of this initial meeting of the Board prepared by Carolyn Sharma, Administrative Assistant.

The discussions that took place among HGP personnel and National Liaison Board members were lively and productive. Their results are reflected in the strategy to request an eight-month extension and additional funding from NSF with which to complete Phase I -- the exploratory surveys. Successful continuation of Phase I through calendar year 1974 will provide the necessary information to begin planning for Phase II -- the research drilling program -- with actual drilling to commence in early 1975. Dr. Agatin T. Abbott, Chairman of the Department of Geology and Geophysics, will be director of the drilling program and has been added to what is now a seven-man Executive Committee for the HGP.

The budget to be requested from NSF for completing Phase I is summarized in Table I. The research tasks to be continued or initiated are listed in column one. The three new tasks are: 2.1 Preparation for Drilling; 2.6 Geochemical Surveys; and 4.1, 2 Environmental Safeguards.

The first column of figures in Table I represents the total budget required for the eight-month extension from May 1, 1974 through December 31, 1974, and which will complete Phase I. The second and third columns are the best estimates of the total amount of carry-over funds from: (1) National Science Foundation; and (2) the State and County of Hawaii, that will still be unencumbered as of May 1, 1974. The fourth column is the difference between the total budget and carry-over funds, so represents the total amount of new support requested from NSF ($340,000) for the program extension. The last column shows the total support for the 20-month Phase I research program.

An entirely separate, but related, issue was the preparation of a proposal to the NSF Energy Related Graduate Traineeship Program for eight graduate traineeships in geothermal energy, to be distributed among the departments of Economics, Geology & Geophysics, Civil, Electrical, & Mechanical Engineering.

LEGISLATIVE BILLS

There are a number of bills and measures relating to geothermal energy currently under consideration by the 1974 State Legislature. A copy of each of these bills and resolutions or written testimony by HGP personnel is appended at the end of this report.

Three of these measures have particular relevance to the HGP. House Bill No. 2197-74, Relating to Reservation and Disposition of Government Mineral Rights, was submitted by the State Department of Land and Natural Resources. It establishes in law the definition and ownership of geothermal resources, and identifies the regulatory agency which will provide for the administration and management of the resource. Dr. Kamins provided testimony on this bill before the appropriate legislative committees, based on the report his program had written on "Legal and Public Policy Setting for Geothermal Resource Development."

Included in the Supplemental Capital Improvements Project Budget submitted by the Governor is a $500,000 item for exploratory geothermal drilling. The attached testimony by Drs. Shupe, Woollard, and Abbott provides, in order:

(1) an historical overview of the HGP and where these drilling funds fit into the total program; (2) some geological background on the Big Island, as it relates to the exploratory drilling program; and (3) technical aspects of the research drilling. The $500,000 was requested as contingency support and is dependent upon matching federal funds. Efforts have been initiated for identifying funding for the total exploratory drilling program from federal sources, but this C.I.P. item would provide Dr. Abbott with some flexibility as drilling progresses.

Senate Bill No. 1646-74 establishes a Natural Energy Institute at the University of Hawaii, which would provide increased visibility and support for natural energy systems -- including geothermal. Dr. Shupe is leading the University testimony on this measure and has received assistance in preparation and support for the bill from Drs. Craven, Woollard, and Yuen.

All three of these measures were reviewed and endorsed by the Governor's Energy Policy Task Force (of which Drs. Craven and Shupe are members); so were introduced as part of the Administration's energy package. To date, their progress through the various legislative committees has gone smoothly.

IN MEMORIUM

The HGP, and many of us personally, lost a staunch friend in Atherton Richards, member of the Hawaii Advisory Committee, who died on February 17, 1974. His keen mind, vision, and enthusiasm for the potential of geothermal energy in Hawaii will be missed by us all.

John W. Shupe
Project Director

TABLE I

HAWAII GEOTHERMAL PROJECT

PHASE I EXTENSION

BUDGET DISTRIBUTION BY PROGRAM AND TASK

	Budget for 8-month Extension	Carry-over Funds NSF	Carry-over Funds State & County	New NSF Budget Request	Total Phase I Budget
MANAGEMENT					
1.0 Coordination	$23,300	$1,736	$9,644	$11,920	$63,785
GEOPHYSICS					
2.0 Support	48,165				
2.1 Preparation for Drilling	10,729				
2.2 Geoelectric	67,886				
2.3 Gravity and Magnetic	---				
2.4 Thermal	26,289				
2.5 Microseismic	36,292				
2.6 Geochemical	32,884				
SUBTOTAL	222,245	17,520	0	204,725	460,527
ENGINEERING					
3.0 Support	19,491				
3.1 Reservoir Engineering	47,260				
3.6 Power Plant Design	50,244				
SUBTOTAL	116,995	22,944	14,024	80,027	178,370
ENVIRONMENTAL-SOCIOECONOMIC					
4.0 Support	14,401				
4.1,2 Environment	12,675				
4.3,4,5 Legal and Planning	6,550				
4.6 Economics	18,061				
SUBTOTAL	51,687	0	8,600	43-087	89,077
TOTAL PROJECT	$414,227	$42,200	$32,268	$339,759	$791,759

SUMMARY OF THE INITIAL MEETING OF THE NATIONAL LIAISON BOARD OF THE HAWAII GEOTHERMAL PROJECT

The National Liaison Board of the Hawaii Geothermal Project (HGP) held its first annual meeting at the County Council Room in Hilo on February 8 and 9, 1974, with eight of the nine Board members present. A list of participants is appended. The Board's collective role, as leading proponents of geothermal energy, is: (1) to provide evaluation and input to assist in the technical planning of the project; and (2) to develop an interchange of ideas and information among the various geothermal programs which they represent, and with the HGP.

The meeting was called to order at 1:00 P.M. on Friday, February 8 by Dr. Shupe, who welcomed the gathering and established an informal format, which was followed throughout the agenda. The meeting continued until 6:00 P.M. on Friday and reconvened at 8:30 A.M. on Saturday, with adjournment at 12:00 noon.

The following presentations were made:

Mr. Coryell outlined the interest of NSF in the HGP and solicited the assistance of the Board in evaluating the objectives and progress of the HGP.

Dr. Shupe gave a brief overview of the project's organization, concept, and scope, pointing out the interaction of the Hawaii Advisory Committee and the National Liaison Board with the Geophysical, Engineering, and Environmental-Socioeconomic Programs.

Dr. Furumoto presented a progress report on the Geophysical Program, listing the status of the various surveys. Later in the meeting Dr. Keller discussed the result of the reconnaissance resistivity survey he had completed for the HGP, and Dr. Abbott gave a slide presentation on the infrared air-photo survey. Dr. Keller, in addition to reporting on the resistivity surveys, also provided a thorough discussion, illustrated with slides, of the results of the 4,137-foot hole that was drilled in Kilauea National Park, Hawaii earlier in 1973.

Dr. Yuen presented the results of the Engineering Program and distributed copies of Engineering Reports #1 and #2, pointing up progress to date. Dr. Cheng, with assistance from Dr. K. Lau, presented the preliminary results of a mathematical analysis on a simplified model of a coastal aquifer.

Dr. Kamins discussed tne pending legal bills currently on tap for presentation to the Hawaii State Legislature (draft copies and other supporting data so distributed) and was supported by Drs. Kornreich and Sheets. Also presented was a summary of the work that has been initiated on the economic study presently underway.

Ensuing discussions later led to further input by Dr. Abbott, who, after summarizing the infrared results, offered his viewpoints on drilling techniques and site possibilities. Mr. Coryell pointed out that, while NSF-RANN would not fund exploratory commercial wells, they would consider proposals for a scientific research drilling program.

Dr. White presented a brief analysis on a model of the area in which the deep hole was drilled by Dr. Keller, which represented his interpretation of the data obtained by Dr. Keller.

Lively discussion resulted from much of the information that was presented, with all members of the Board, the HGP personnel, and many of the audience taking an active role in posing probing questions, voicing opinions, providing interpretations on data, and offering suggestions on program direction. Although there was not complete unanimity on the interpretation of results to date, there did appear to be overall approval on the direction that the research program is taking, as well as general agreement that a multiple research drilling program is essential to the understanding and furtherance of the geothermal interest on the Big Island.

ATTENDEES AT THE MEETING OF THE NATIONAL LIAISON BOARD FEBRUARY 8-9, 1974

NATIONAL LIAISON BOARD

Mr. David N. Anderson, Geothermal Officer
State of California Resources Agency

Dr. Ritchie B. Coryell, Program Manager
National Science Foundation

Dr. George V. Keller, Professor
Colorado School of Mines

Dr. James T. Kuwada, Vice President
Rogers Engineering Company, Inc.

Dr. Henry J. Ramey, Jr., Professor
Stanford University (Petroleum Engineering)

Dr. Robert W. Rex, President
Republic Geothermal, Inc.

Dr. Donald H. Stewart, Researcher
Battelle Pacific Northwest Laboratories

Dr. Donald E. White, Geothermal Researcher
U. S. Department of the Interior

UNIVERSITY OF HAWAII - MANOA

Dr. Agatin T. Abbott
Professor, Geology & Geophysics
Hawaii Institute of Geophysics

Dr. Ping Cheng
Associate Professor, Mechanical Engineering
College of Engineering

Dr. James C. S. Chou
Professor, Mechanical Engineering
College of Engineering

Dr. Augustine S. Furumoto
Professor, Geophysics; Seismologist
Hawaii Institute of Geophysics

Dr. Robert M. Kamins
Professor of Economics
Department of Economics

Dr. Deane H. Kihara
Associate Professor, Mechanical Engineering
College of Engineering

Dr. Donald B. Kornreich
Attorney-At-Law
NASA-Ames/HGP Consultant

Dr. L. Stephen Lau
Professor, Civil Engineering
Director, Water Resources Research Center

Dr. Gordon A. Macdonald
Senior Professor, Geology & Geophysics
Hawaii Institute of Geophysics

Dr. Richard E. Peterson
Associate Professor, Business Economics
College of Business Administration

Dr. George M. Sheets
Attorney-At-Law
Legal and Regulatory Consultant

Dr. John W. Shupe
Dean
College of Engineering

Dr. Patrick K. Takahashi
Assistant Professor, Civil Engineering
College of Engineering

Dr. George P. Woollard
Director
Hawaii Institute of Geophysics

Dr. Paul C. Yuen
Associate Dean
College of Engineering

UNIVERSITY OF HAWAII - HILO CAMPUS

Dr. Bill H. Chen
Assistant Professor, Engineering

Dr. J. Bruce Finlayson
Assistant Professor, Chemistry

Dr. Kah Hie Lau
Assistant Professor, Engineering

Dr. Satya P. Sood
Professor, Chemistry

INVITED PARTICIPANTS

Dr. Eugene M. Grabbe, Director
Center for Science Policy &
Technology Assessment (DPED)

Mr. Francis R. Montgomery, Vice President
Engineering Division
Hawaiian Electric Company, Inc.

Dr. Donald W. Peterson, Scientist-in-Charge
U. S. Geological Survey
Hawaiian Volcano Observatory

Dr. Paul M. Miwa, Chancellor
Hilo Campus
University of Hawaii

There were approximately 20 additional observers in attendance, including a number of the participants of the Joint U.S.-Japan Seminar on volcano energy, as well as interested scientists and engineers from the U.S. Geological Survey, the Hilo Electric Light Company, and the technical community.

HAWAII GEOTHERMAL PROJECT

GEOPHYSICAL PROGRAM PROGRESS REPORT

Augustine S. Furumoto

Upon receipt of Grant GI 38319 from the National Science Foundation and matching grants from the State and County of Hawaii, the geophysical exploration program was initiated. Since the Institute of Geophysics did not have some of the equipment necessary for the proposed work, certain aspects of the proposal such as the IR study and the preliminary electrical investigation were contracted out to groups able to start work immediately, since a delay of at least six months could be expected in getting delivery on equipment. At about the same time, George Keller of the Colorado School of Mines was drilling an exploratory hole in the National Park area of Kilauea Volcano. The information from that drilling project as it progressed provided much useful information of value to the geophysical program.

Because of limitations of funding, only the following types of surveys were planned to be carried out during the first year:

1. Aerial infrared survey covering geologically favorable areas
2. Electrical resistivity surveys of the Puna rift area using the dipole method
3. Electromagnetic surveys of selected areas
4. Microseismic and microearthquake surveys

The aerial photo surveys were the responsibility of Agatin Abbott. The work was contracted to Towill Corporation. Results were available by September 1973.

The dipole electrical resistivity survey for reconnaissance purposes was contracted to George Keller of the Colorado School of Mines. The results were in by August 1973.

The electromagnetic surveys were under the supervision of Douglas Klein. As all of the equipment had to be built, the field work started late and is still underway at the time of writing of this proposal.

The microearthquake surveys, under the supervision of A. S. Furumoto, got off to a late start because of over eight months delay in getting delivery on equipment. Because of this, the schedule outlined in the original proposal was impossible to maintain. The original proposal planned for surveillance of microearthquakes first, then ground noise surveys. But as instruments for the microearthquake system were not delivered by the manufacturers until February 1974, the ground noise survey was done first, without the benefit of data from the expected microearthquake survey.

Although every economy was made in carrying out the initial phase of surface investigations, including skimping on per diem and borrowing equipment, in January 1974 it became clear that all the proposed cannot be completed with the remaining funds. A decision was therefore made to postpone a major portion of the seismic surveys and redistribute the funds so that the other surveys could be brought to fruition with maximized results. As for the seismic surveys, a reconnaissance ground survey was carried out and the instrument system for microearthquake surveillance was carefully calibrated and field tested on Oahu.

In the following section, short descriptions of the accomplishments of each task are given. For more details, the reader must await the publication of progress reports.

1. Photogeologic Survey

Task 2.1
Progress Report 1973
Investigator: A. T. Abbott

Imagery from Infrared Scanning of the East and Southwest Rift Zones of Kilauea and the Lower Portion of the Southwest Rift Zone of Mauna Loa, Island of Hawaii

INTRODUCTION

From July 31 through August 4, 1973 night time flights for obtaining infrared imagery along the east and southwest rift zones of Kilauea and the southwest rift zone of Mauna Loa were undertaken on the island of Hawaii. Flights were also made on Hualalai and Kohala volcanoes, but because of inconclusive results are not included in this report. Ground control stations had been established during daylight hours several days prior to starting the flight program. Students stationed at the ground central points guided the aircraft on predetermined flight paths by the use of directional lights which were visible to the plane's navigator. Results of the infrared scanning program are considered to be very successful. Events leading up to the final imagery on 8 x 10 color prints will be discussed below.

The sum of $23,900 was designated by the NSF to be expended on aerial photogeologic work on the Hawaii Geothermal Project. Infrared scanning was the only aerial technique employed in this phase.

A firm specializing in infrared surveys, Daedalus Enterprises of Ann Arbor, Michigan was selected as best equipped and experienced in Hawaiian conditions to accomplish the infrared imagery survey. Towill Engineering Corporation of

Honolulu provided the aircraft, pilot and navigator and submitted a report with maps and black and white aerial photographic mosaics. These firms earlier the same year had flown paths for Dr. George Keller of the Colorado School of Mines, who was engaged in locating a deep drill hole near the summit of Kilauea.

FLIGHT PATHS AND DESCRIPTIONS

(1) East Rift Zone of Kilauea

Two long parallel flight paths were flown along the East rift zone from points outside the boundary of Hawaii Volcanoes National Park to Cape Kumakahi. Shorter paths crossing the two long parallel lines were flown at the intersection of the rift zone with the main highway between Pahoa and Kalapana. Approximately 35 line miles of usable record was obtained. From this the following strips were selected for reproduction in infrared false color imagery:

Three miles of flight paths high on the rift zone at an average ground elevation of 2100 feet provide excellent examples of rift lineation and temperature aureoles. The DIGICOLOR prints showed a temperature range of 14°C to 20°C. Numerous sites along the rift showed spots of white color indicating the temperature exceeded the highest range on that temperature set. This is not surprising in view of the fact that wisps of steam are issuing from some of the vents probably as a result of meteoric water coming in contact with residual heat of lavas from the 1966 eruption in this area. Downslope from the steam vents, a fairly extensive area shows a slightly higher surface temperature than its surroundings, by an average of 1°C.

The area for the second set of DIGICOLOR prints in the Kilauea east rift zone was selected from a flight path of approximately two miles in length across the area of intersection of the rift zone and the Pahoa-Kalapana highway at a ground elevation of approximately 1000 feet. The temperature range of this path is 16°C - 25°C or 1.5°C per color. Again numerous sites showing white along the rift zone indicate local hot spots and an aureole of decreasing temperatures are distributed outward from the rift. Fine examples of surface temperature zones are demonstrated in this imagery.

(2) Southwest Rift Zone of Kilauea

A flight path 12 miles long was followed from the point of intersection of the western boundary of Hawaiian Volcanoes National Park and the main highway between Kilauea summit to Pahala to a point on the sea coast approximately 4 miles east of Punaluu.

The altitude maintained was about 3000 feet above ground level. Throughout most of the strip a thermal anomaly was evident along the Great Crack. The temperature range on the flight path was 18°C - 22°C. Of unusual interest on this path is a thermal anomaly in a target-like pattern near the southern end of the Great Crack approximately 1 1/4 miles from the coast line at an elevation of 300 feet above sea level. The target-like pattern is 1200 feet wide, 1600 feet long. The roughly circular pattern of thermal anomaly lies 600 feet northwest of a splinter extension of the Great Crack. The highest temperature within the target area reaches the red color or 22°C in two small spots, and within the Great Crack extension, small local spots reach white, or off scale.

The anomaly appears to be associated with the lower slopes along the south side of Puu Kolekole, a prehistoric cinder cone, and with the extension of the Great Crack.

This surface thermal anomaly as registered by infrared scanning imagery should receive careful attention as a potential area for further geophysical investigation and possibly research drilling.

(3) The Southwest Rift Zone of Mauna Loa

A flight path with the total length of approximately 22 miles followed the southwest rift of Mauna Loa from an elevation of approximately 7000 feet above sea level to the tip of South Point. Only the lowest five mile section of this path to the tip of South Point showed any significant thermal anomalies. This portion has been reproduced in DIGICOLOR and prints developed.

The temperature range on one subset is 16°C - 22°C. Thermal anomalies appear along the cliff face of the Kahuku fault as clusters along the base of the cliff and as linear features possibly indicating bedding planes in the lava flows. Numerous spots along the cliff register red and a few local areas show white, or off scale.

The cause of these anomalies is not known at the present time. The Kahuku fault scarp, which reaches 400 feet in height in this area, faces west. Consideration must be given to the possibility that the anomalies result from residual late afternoon solar heat. The imagery was taken at 0030 hours in order to reduce the effect of residual heat. The physical distribution of the warmer areas does not appear to show a pattern that might be caused by residual heating, none the less this factor must be kept in mind.

Another, more intriguing possibility lies in the concept that heat may be rising from depth along the plane of the Kahuku fault and issuing at the base of the cliff and along bedding planes of the lava flows. The Kahuku fault is a major structural feature of Mauna Loa shield volcano. It extends ten miles inland from the coast and has been followed out to sea for a distance of over 15 miles. Depth recordings made on board the R/V Valdivia in 1973 while steaming past the extension of the fault 4 miles off shore registered a vertical displacement along the fault plane of 1900 meters.

Further geophysical and geological work should be concentrated in the section of the lower portions of the Kahuku fault. This may have promise as an area in which to locate an array of research drill holes.

Also of interest along the South Point shoreline as registered by the infrared imagery is the temperature distribution in the sea water. Directly offshore a large patch of water shows as a white area indicating that its temperature is greater than 22°C. It is not recognized at this time whether this is a bay of warm surface water brought in by ocean currents or wind or whether the warming is caused by some other process.

2. Electrical Resistivity Surveys

Task 2.3

Progress Report 1973

Investigator: George Keller
Report by: A. S. Furumoto

The electrical resistivity surveys by George Keller were done in June and July 1973 and a report entitled "An Electrical Resistivity Survey of the Puna and Kau Districts, Hawaii County, Hawaii" was submitted by him. The method he used is known as the dipole mapping method. In short, using existing well casings as dipole sources, he caused a large amount of current to flow into the ground, then with a pair of probes the area round the dipole source was surveyed to measure variations in voltage and current. With that, resistivity of the ground between the dipole source and probes is determined. The survey in effect gives an integrated picture of resistivity with respect to depth. Hence the method is a good reconnaissance tool.

The results of the survey came up with two promising areas indicating subsurface low resistivity. Both of these areas lie along the Northeast Rift zone of Kilauea. In Figure 1 the circled area roughly outlines the low resistivity anomaly.

3. Electromagnetic Survey

Task 2.4
Progress Report 1973
Investigator: Douglas Klein

1. The electromagnetic survey group of the Hawaii Geothermal Project can report the following accomplishments:

a. Completion of a loop-loop magnetic induction survey in the northeast Puna area.

b. Development of a deep-sounding wire-loop magnetic induction system.

c. Reconnaissance of four areas on Hawaii Island (excluding Puna) which have promising geothermal aspects.

d. Emplacement of 12 electrode pairs for future deep geoelectric sounding on Hawaii Island.

2. The two-loop induction survey in the Puna area was a follow up to the dipole-dipole galbanic survey of G. V. Keller and associates. The results of Keller's survey which warranted further exploration was the possible existence of shallow geothermal regions in the areas outlined by the dashed lines in Fig. 1. High temperature well waters in these areas add support to such a possibility. The two-loop soundings, whose locations are indicated in Fig. 1, were established with the object of locating the extent of the regions of high conductivity, thus potentially hot water, in the upper 100 meters of the crust. The results were negative in this regard. Local conductivity anomalies at stations 18-1, 19-1, 20-1 and station 6-1, and 3-1, 3-2 could be due to heating effects along the East Rift zone or due to increased porosity associated with Rift fissures. However,

the existence of shallow high temperature areas of large horizontal extent are not in evidence. It is recommended that detailed "deep" geoelectric surveys be carried out in the anomalous areas mentioned above, under the hypothesis that these regions are shallow indicators of a wider spread geothermal region at depth.

3. In view of the need for deeper penetrating equipment a concentrated effort went into the construction of a power source for a time-domain wire-loop induction method. This power source will provide approximately a 20 amp current-step square wave at 1000 VDC. The system is essentially complete except for field tests. The system is solid state and built to withstand rugged field conditions. The expected depth of penetration of this system is about two kilometers.

4. In anticipation of future operations, four areas on Hawaii were examined in detail for survey sites. These areas, indicated on Fig. 2 (Task 2.2, Geoelectric, of the proposal) were chosen with regard to the rift zone location, age of most recent volcanic activity, available drill hole temperature data and the results from the infrared scanning study.

5. Since the effective use of the wire-loop induction technique requires low resistance electrical earth-grounds, 12 electrode pairs were emplaced for the future surveys. Seven of these were emplaced by Sandia Corporation using a technique of air-dropping specially designed inert-missles. The reason for early emplacement of electrodes is that the contact resistance can be expected to decrease with age due to natural processes causing closer compaction of earth about the electrodes. Although more electrodes will probably be required, at least future surveys can begin with the several good source field sites now established.

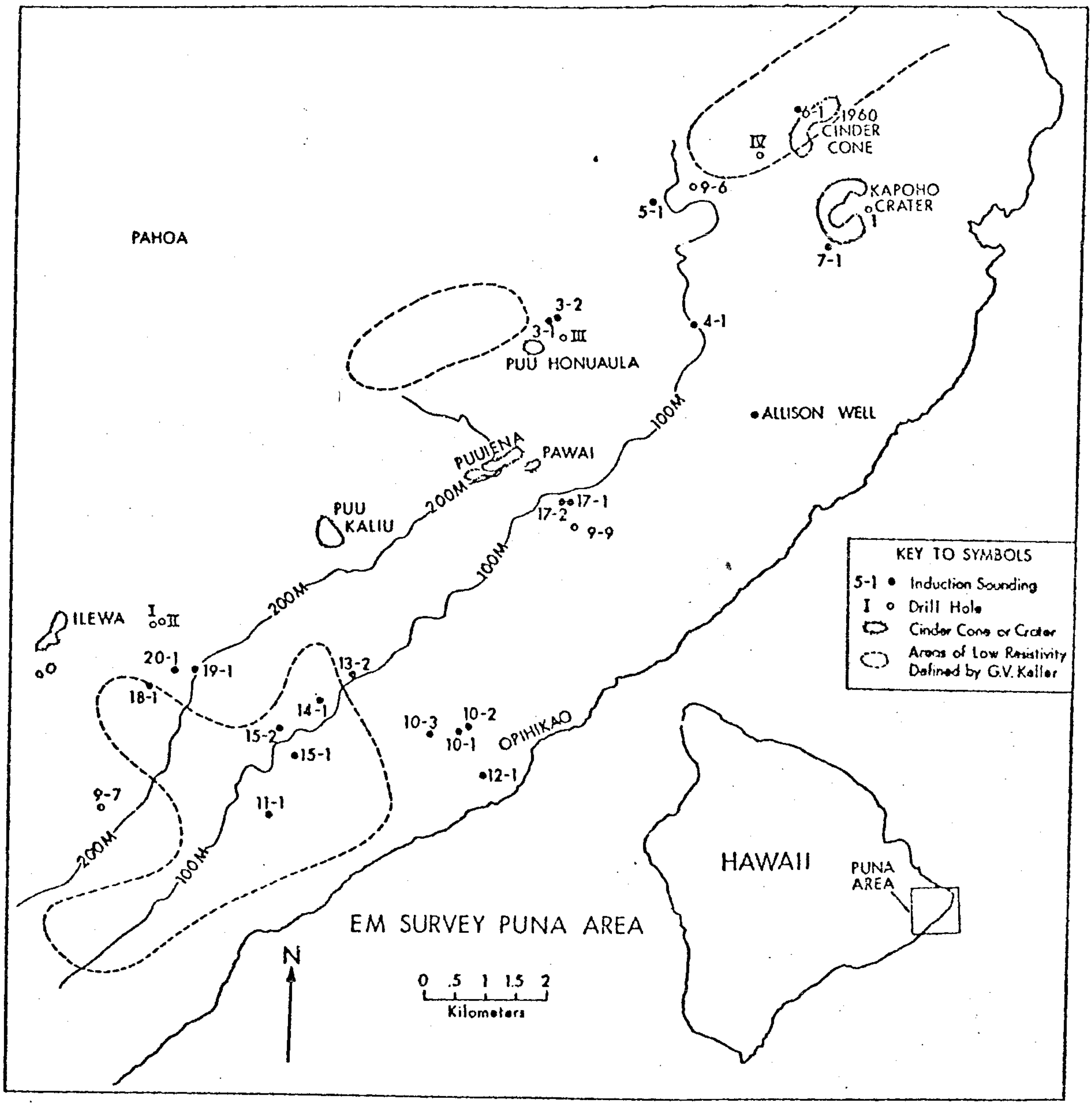

Figure 1

Map of two-loop Magnetic Induction Survey Area

4. Microearthquake and Microseismic surveys

Task 2.5

Progress Report 1973

Investigator: A.S. Furumoto

Although it was planned to carry out microearthquake surveys during the first year, it was decided to postpone these surveys until the second year. The main reason for this decision was the delay in getting delivery on equipment and that funds were being used up at a higher rate than anticipated in running the other surveys. In the final analysis it was judged better to obtain excellent results from three types of surveys than obtaining marginal data from four types of surveys.

However, the equipment for the microearthquake surveillance program purchased is now assembled and undergoing tests. The seismic surveillance system consists of a central recording station and six satellite stations. At a satellite station seismic signals picked up by geophones are amplified, frequency modulated, and then telemetered by radio to the central recording station. Data is recorded on tape at the central station.

For the microseismic or ground noise survey, a simple system was devised. The instrument package consists of two geophones, an amplifier bank, and a TEAC R-70 cassette tape recorder which can record in FM mode or in direct analog form. The package is small enough to be housed in the backseat of a compact car.

With the above instrument package, the eastern section of Puna district was surveyed on a preliminary basis for ground noise. At the present writing (February 1974) part of the field data has been subjected to power spectra analysis. It seems that there is a peak in ground noise around 1 herz.

HAWAII GEOTHERMAL PROJECT

ENGINEERING PROGRAM PROGRESS REPORT

Paul C. Yuen

The principal objectives of the Engineering Program are (1) applied research in problem areas related to the extraction of energy from geothermal resources, and (2) planning and design of environmentally-acceptable geothermal power plants. Research during the past period has been in the areas of (1) studies complementary to and in support of the Geophysics Program, and (2) studies of the economical and technological feasibility of different methods of converting heat energy in a geothermal reservoir to electrical energy. Results of the research effort have been reported in the three quarterly progress reports published to date, and the following technical memorandum and reports:

1. Warm Water Wells on the Island of Hawaii, Technical Memorandum No. 1, January 1, 1974.
2. Modelling of Hawaiian Geothermal Resources, Technical Report No. 1, November 1, 1973.
3. Steady State Free Convection in an Unconfined Geothermal Reservoir, Technical Report No. 2, March 15, 1974.
4. Geothermal Reservoir Engineering: State-of-the-Art, Technical Report No. 3, March 15, 1974.

I. Summary of Past Research

A. Task 3.1 Well Test Analysis

Personnel on this task spent the greater part of the initial funding period conducting comparative surveys and becoming acquainted with the field of geothermal reservoir engineering. Early in the development of research alternatives the Well Test Analysis (Task 3.1) and Ghyben-Herzberg Lens Dynamics (Task 3.2) teams began working together with responsibilities split into three areas: (1) computer modelling, (2) physical modelling, and (3) well test measurement/analysis. The computer modelling group is reporting under

Task 3.2. Task 3.1 includes physical modelling and well test measurement/analysis.

A preliminary system design was completed for the physical model. The model will focus initially on the reservoir, which will later be interfaced with the Ghyben-Herzberg model. The Rayleigh number (N_{Ra}) was determined to be the dimensionless number of greatest significance. A parametric study in the range of $30 < N_{Ra} < 1000$ will be attempted. The object will be to obtain streamline, temperature, and pressure patterns as permeability, pressure and temperature are modified. The possibility of self-sealing will be investigated, and simulation of the ultimate geothermal field will follow.

An international survey on the state of geothermal reservoir engineering was initiated and a final analysis will be forthcoming. A short course on petroleum well test analysis revealed that an intensive self-education program, supplemented with on-the-job experience was essential for later capability in well test analysis. Arrangements to obtain these are being completed.

Two surveys are in the early stages of completion: (1) petroleum/gas well test measurement/analysis techniques, and (2) geothermal well test measurement/analysis techniques. A comparative cost analysis of downhole and well-head instrumentation is also in progress.

B. Task 3.2 Ghyben-Herzberg Lens Dynamics

1. Steady State Free Convection in an Unconfined Geothermal Reservoir

The theoretical study of steady-state free convection in a coastal, unconfined, rectangular aquifer with non-isothermal geothermal heating from below has been completed. A parametric study was conducted to investigate the effects of various parameters on the movement of seawater, the upwelling of water, and the pressure and temperature distributions in a geothermal reservoir. It has been found that to a first-order approximation: (1) the pressure in the unconfined geothermal reservoir is almost hydrostatic; (2) the flow rate of seawater depends only on the horizontal temperature gradient of the reservoir; (3) although there is some decrease in temperature distribution in the lower portion of the aquifer in a small region near the ocean as a result of inflow of cold water, the water also acts as a heat-carrier in the rest of the aquifer; (4) the convection of heat is more efficient vertically than horizontally; (5) the size of the geothermal source has an important effect on the temperature distribution in the reservoir; (6) the location of the heat source has some effect on the temperature distribution in the region near the ocean, but its effect on the temperature for the rest of the aquifer is small; (7) the discharge number has a strong effect on the temperature distribution of the aquifer; and (8) there is a noticeable upwelling of the water table at the location directly above the heat source, the amount of upwelling depending on the vertical temperature gradient of the porous medium and the prescribed temperature of the impermeable surface. The upwelling of the water table as a result of geothermal heating is predicted analytically for the first time. The details of the analysis are described in Technical Report No. 2. A manuscript based on the report is now under preparation, and will be submitted for publication in the JOURNAL OF GEOPHYSICAL RESEARCH.

2. The Effects of Pumping and Re-injection in a Geothermal Reservoir

The mathematical formulation of this problem was presented in Quarterly Report No. 2. Numerical solution of the problem is difficult due to the presence of delta functions in the governing equations. To gain some experience in dealing with singular functions in partial differential equations, work has already begun on the numerical solution of the simpler problem of pumping and re-injection under isothermal conditions. A novel numerical scheme is now being tested for this simple case. Preliminary results indicate that the method is promising. A technical report covering this phase of work will be completed by June, 1974. We will extend this numerical method for the more difficult problem of pumping and re-injection under non-isothermal conditions.

3. Finite Element Formulation of Free Convection in a Geothermal Reservoir

Work is progressing on the finite element solution of the problem of free convection in a porous medium with a free surface, including an irregular geometry for the reservoir. In the past six months, a literature survey has been completed and the problem is now being formulated mathematically. It is expected that this work will be completed by December, 1974.

C. Task 3.6.1 Heat Exchanger and Binary-Fluid Cycle Design

1. Heat Exchanger Design

A general computer program for a vertical counterflow heat exchanger which can be applied over a range of conditions was completed with the input values of (1) tube size, spacing, and arrangement, (2) tube-side and shell-side inlet temperatures, pressure and fouling factors, and (3) shell side flow velocity and exit state of fluid. The computer program will calculate (1) number and length of tubes required, (2) pressure drop, and (3) fluid and heat transfer parameters on both shell side and tube side.

This program was run for a specific case of isobutane as the working fluid, a brine inlet temperature of 350°F, and pinch point temperature difference of 20°F. It was found that the tube lengths required for a 10 MW plant were rather large (of the order of 175 feet), but that there existed a set of operating conditions for which the required tube length was a minimum.

2. Binary-Fluid Cycle Design

A computer program which allows the evaluation of the performance of various working fluids as input parameters are varied, has been written, and prooftested. These parameters include: (1) brine temperature, (2) condenser temperature, (3) turbine inlet temperature and pressure, (4) component efficiencies, and (5) thermodynamic properties of working fluid.

Output parameters computed were: (1) cycle efficiencies, (2) required flow rates of working fluid and brine, and (3) state of working fluid at each station.

Runs were made for isobutane and Refrigerant-11 at various turbine inlet temperatures and pressures. For the cases tested, it was found that at higher pressures a smaller brine flow rate is required. As turbine inlet temperature is varied, with pressure held constant, the brine flow rate required goes through a minimum for isobutane, but is relatively constant for Refrigerant-11.

D. Task 3.6.2 Optimal Geothermal Plant Design

There is increasing interest in the utilization of heat from hot brine at 350° to 500°F by using a fluid, such as Freon or isobutane, as the working fluid in a closed cycle. This study has shown that a regenerative isobutane cycle can significantly reduce the heat rejection from the plant and lower the cost of power produced. The discharge temperature of brine of the regenerative cycle is much higher than that of the basic cycle; thus, the waste heat can be used for producing fresh water with a multiple-effect evaporator. A sample calculation indicated that nearly one-half of the hot brine from a well could be converted into fresh water. For geothermal reservoirs located in areas where the supply of fresh water is inadequate, the combination of a regenerative isobutane power plant with a multiple-effect evaporator for desalting water could be a feasible solution in some cases.

The design of a power plant is dictated by economic justification in a competitive society. Economic designs can be achieved only by careful analysis of all the possible solutions for a given situation. Such analyses are usually started from heat balances of various plant schemes to establish the respective heat rates and equipment sizes. Heat balances have been made to evaluate the effects of superheating saturated geothermal steam, additional heating by auxiliary fuel, and cooling with deep ocean water. For the plants using mixed-pressure turbines driven by steam flashed out from hot brines at one or more levels, a numerical method has been worked out to optimize the flashing pressures of multistage plants with consideration of different degrees of flashing efficiency and heat losses.

The parameters which affect the production from a liquid-dominated aquifer are pressure and temperature of reservoir, depth of well, drawdown pressure, wellhead pressure, diameter of well, and surface friction. The interrelationship among these parameters has been studied. The results will be helpful to the interpretation of well testing data and to the selection of the operating pressure for a self-flowing well. Problems of pumping hot brine from a well have also been considered. It appears there is no proven equipment to force the hot brine out from a very deep well at present.

HAWAII GEOTHERMAL PROJECT

SOCIOECONOMIC PROGRAM PROGRESS REPORT

Robert M. Kamins

A 42-page report on Legal and Public Policy Setting for Geothermal Resource Development in Hawaii was completed and presented to appropriate committees of the Hawaii State Legislature, which is considering bills to establish a legal regime for geothermal energy in this state. The report summarizes the current status of federal and state law bearing on this new resource, and discusses the water law cases in Hawaii which may be pertinent. It concludes that without a clarification of the legal nature and ownership of geothermal resources here, rapid development would be inhibited by the resulting uncertainty, and thus proposes that the Legislature make a determination. (A determination either way -- that the resource belongs to the owner of the overlying land, or that it is a resource retained by the state in granting title to the overlying land -- is likely to be challenged in the courts, if a valuable geothermal "deposit" is discovered, but a legislative determination would speed the process and likely influence its outcome.)

The report also examines the possible economic outcomes for geothermal development on the Island of Hawaii -- either a relatively small field which could supply a substitute for oil in powering the island's electric supply system, or a larger field which may (i) attract industry to the Big Island, or (ii) support a hydrogen economy on Oahu and throughout the state. In the latter event, considerable investment by the State of Hawaii would be required to supply the necessary infrastructure, along with direct industrial plant construction by private enterprise.

Also completed this past quarter was an 80-page annotated bibliography on Geothermal Power Economics, covering 192 items. Addenda to the bibliography are being prepared and will be distributed from time to time as we add to our files and understanding of this growing literature.

Utilizing this bibliography, we have begun to compile a detailed inventory of geothermal field operations around the world, noting particularly data on exploration, development, production, costs and returns. With this data we plan to set some of the parameters for modelling economic impact projections for geothermal development on the Island and within the State of Hawaii. To the same purpose, we are gathering best estimates of the costs of alternative energy sources in this setting -- oil, nuclear power, and solar energy.

David N. Anderson prepared an initial draft of proposed Geothermal regulations for Hawaii in the event that the Legislature passes an administration bill placing geothermal resources under the jurisdiction of the Hawaii Department of Land and Natural Resources, which seems the logical administrative agency. The draft draws upon the considerable experience of the State of California, adopted to the rather different circumstances of Hawaii. If the pending bill is enacted into law, we will be available to work with the Department of Land and Natural Resources in refining the draft to become the operating rules and regulations of this state for geothermal development.

APPENDIX

(To be made one and twelve copies)

THE SENATE

SEVENTH.......... LEGISLATURE, 19 74

STATE OF HAWAII

S.C.R. NO. 1

SENATE CONCURRENT RESOLUTION

REQUESTING THE PRESIDENT OF THE UNITED STATES TO RELEASE FEDERAL FUNDS FOR USE IN CONDUCTING GEOTHERMAL RESEARCH.

WHEREAS, the current energy crisis is disrupting commerce and industry throughout the United States, and is seriously affecting the comfort and well-being of our citizens; and

WHEREAS, prolonged shortages of energy resources could seriously endanger the public health, safety and welfare; and

WHEREAS, the United States is heavily dependent upon the nations of the Middle East and other countries for the basic resources to generate our energy requirements; and

WHEREAS, such dependence has made it extremely difficult for the United States to adequately provide for the energy requirements of our citizens; and

WHEREAS, the energy crisis clearly demonstates the necessity for the United States to seek diversity and develop alternate sources of energy susceptible to more direct control; and

WHEREAS, exploratory research is likely to reveal heretofore untapped geothermal resources below the surface of the earth representing new, potential resources to fuel our energy requirements; and

WHEREAS, research in geothermal resource probably will entail tremendous financial costs which can only be undertaken by the federal government; now, therefore

BE IT RESOLVED by the Senate of the Seventh Legislature of the State of Hawaii, Regular Session of 1974, the House of Representatives concurring, that the President of the United States be and is hereby respectfully requested to release and make available federal funds for use in conducting geothermal research; and

BE IT FURTHER RESOLVED that duly authenticated copies of this Concurrent Resolution be transmitted to the President of the United States Senate, the Speaker of the United States House of Representatives, and to each member of the Congressional delegation from the State of Hawaii.

OFFERED BY:

1/22/74

(To be made one and twelve copies)
THE SENATE
SEVENTH........ LEGISLATURE, 1974
STATE OF HAWAII

S.B. NO. 1392-74

A BILL FOR AN ACT

MAKING AN APPROPRIATION FOR GEOTHERMAL ENERGY RESEARCH.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF HAWAII:

SECTION 1. There is appropriated out of the general revenues of the State of Hawaii, the sum of $______________, or so much thereof as may be necessary for the costs of conducting geothermal energy research in the State of Hawaii.

SECTION 2. The sum appropriated shall be expended by the State Department of Land and Natural Resources for the purpose of this Act.

SECTION 3. This Act shall take effect upon its approval.

INTRODUCED BY:

1/21/74

H. B. NO. 2376

Also SB 1646-74

A BILL FOR AN ACT

ESTABLISHING THE HAWAII NATURAL ENERGY INSTITUTE AND MAKING AN APPROPRIATION FOR PLANNING THE STRUCTURE AND OPERATION THEREOF.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF HAWAII:

SECTION 1. The current energy crisis is caused by a global energy shortage which will worsen through the remainder of this decade and may continue to the end of this century. The State of Hawaii, with its total dependence for energy on imported fossil fuel, is particularly vulnerable to dislocations in the global energy market. This is an anomalous situation, as there are few places in the world so generously endowed with natural energy: geothermal, solar radiation, ocean temperature differential, wind, waves, and currents--all potential non-polluting power sources. The purpose of this Act is to establish the Hawaii Natural Energy Institute that will coordinate and undertake the development of non-polluting natural energy sources for Hawaii; and, to make an appropriation for planning the structure and subsequent operation of the Institute. Although the ultimate structure of the Institute will not be determined until after a year of planning and development, its immediate establishment as provided herein will provide the needed visibility, focus and encouragement for energy related activities directed toward converting Hawaii's natural resources into viable energy systems. These alternative energy systems will:

(1) Diminish Hawaii's total dependence on imported fossil fuels,

(2) Meet the State's increasing energy demands with little or no environmental degradation, and

(3) Contribute to the technology base for finding solutions to the national and global energy shortgage.

SECTION 2. The Hawaii Natural Energy Institute is hereby established as a research unit at the University of Hawaii-Manoa. The President of the University of Hawaii will appoint from appropriate University staff an Energy Planning Committee and designate its chairman. This Committee will serve as a steering committee and the Chairman shall be the Acting Director of the Institute during the initial year both for carrying out the operations and functions of the Institute and for planning the ultimate organizational structure. Nationally recognized energy planners may be consulted on specific goals and general organizational structure of the Energy Institute. The President will also appoint a broadly based Policy Advisory Committee to provide interaction between interested segments of the community and the Energy Planning Committee. A report containing recommendations for the structure and subsequent operation of the Energy Institute will be prepared by the Energy Planning Committee for presentation to the Legislature twenty (20) days before the beginning of the 1975 Session.

SECTION 3. There is appropriated out of the general revenues of the State the sum of fifty-five thousand dollars, or so much thereof as may be necessary, to be expended by the University of Hawaii for planning the structure and subsequent operation of the Hawaii Natural Energy Institute, and for the hiring of necessary staff and consultants during the next fiscal year.

SECTION 4. This Act shall take effect July 1, 1974.

INTRODUCED BY:

By Request

FEB 6 1974

TESTIMONY TO THE HOUSE FINANCE COMMITTEE
ON THE $500,000 C.I.P. ITEM FOR EXPLORATORY GEOTHERMAL DRILLING
APPEARING IN THE SUPPLEMENTARY C.I.P. BUDGET

John W. Shupe, Dean of Engineering, University of Hawaii

The Hawaii Geothermal Project was established to coordinate geothermal interests throughout the University of Hawaii and to obtain funding to support a research program which, if successful, could result in the development of geothermal power for Hawaii.

The 1972 State Legislature allocated $200,000 from the C.I.P. budget as planning funds for geothermal related research, with $100,000 of the total allocation to be administered through the County of Hawaii. Release of these funds was contingent upon matching federal support. The Hawaii Geothermal Project received a $252,000 grant from the National Science Foundation (NSF) on May 7, 1973 to initiate Phase I of the project. The $200,000 from the State and County was released shortly after that, and the project got under way during the summer of 1973.

Research activity was organized into three separate programs, with a co-principal investigator for each program. Overall coordination is provided by Drs. George P. Woollard, John P. Craven, and John W. Shupe, principal investigator. Input and evaluation at the local and national levels comes from the Hawaii Advisory Committee and the National Liaison Board (copies of membership attached).

The initial $452,000 budget, which will be essentially expended by June 1, 1974, has supported the following research activity:

<u>Geophysical Program</u> - Dr. Augustine S. Furumoto, Co-P.I.

Geophysical exploratory surveys to define the most favorable areas for geothermal investigations, including: (a) Airborne infrared sensing to determine areas of high heat flow to the surface; (b) Electrical resistivity and electromagnetic surveys to help locate any apparent geothermal anomalies; and (c) Microseismic studies to obtain additional information on potential areas of thermal activity.

<u>Engineering Program</u> - Dr. Paul C. Yuen, Co-P.I.

Initial engineering research activity includes: (a) Analytical models of possible subsurface conditions resulting from geothermal anomalies; (b) Studies of the effects of geothermal development on the Ghyben-Herzberg fresh water lens; and (c) Investigation of energy recovery from hot brine.

Environmental-Socioeconomic Program - Dr. Robert M. Kamins, Co-P.I.

> Background research and reports have been developed on the following socioeconomic issues relating to the introduction of geothermal power to Hawaii: (a) Legal and regulatory aspects of the ownership and administration of geothermal resources; and (b) Economic and planning studies on the impact of geothermal power on the State and County of Hawaii.

The major emphasis in the early phases of this study is on the Geophysical Program, since the issue of if and where geothermal resources exist is crucial to the Project. However, parallel engineering studies were initiated to assist in interpretation of geophysical results, and legal studies were begun to help clarify the ownership and regulatory aspects, since these points must be resolved before any investment capital will go to the development of geothermal power in Hawaii.

The likelihood for continuing operational support from NSF through 1974 looks good. This should permit completion of Phase I and lead to planning for Phase II -- the exploratory drilling program. Dr. Agatin T. Abbott, Chairman of the Department of Geology and Geophysics, who has had extensive experience in exploratory drilling, will be in charge of the drilling program.

It should be emphasized that Phase II will not be a commercial drilling program, but will be a research program to obtain additional information which will lead to better understanding of the geothermal regime of the Big Island. There is still no guarantee that a conventional geothermal fluid (steam or hot water), which can be readily converted to electric power, exists in Hawaii. This exploratory drilling program is the necessary next step in resolving this issue.

Efforts have been initiated to identify funding for the total exploratory drilling budget from NSF. The $500,000 requested through the C.I.P. budget as matching support would: (1) supplement NSF funding, if it should prove to be inadequate to meeting the total planning and drilling programs; and (2) provide the drilling director, Dr. Abbott, with some flexibility in establishing the most effective program as drilling proceeds.

With the potential importance of geothermal energy to Hawaii, it is essential to determine: (1) if conventional geothermal resources exist that can be readily converted to electricity; or (2) whether it will be necessary to move directly to a long-range research effort to develop other techniques for converting geothermal energy -- in the form of hot rock and/or molten magma -- to useful power.

Energy Hearing called by Senate President David McClung

Testimony on the $500,000 Item in the State CIP Budget to be Used as A Contingency Reserve in Support of Exploratory Drilling in Connection with the Hawaii Geothermal Project

George P. Woollard
Director, Hawaii Institute of Geophysics
University of Hawaii

Introduction

As the background on the Hawaii Geothermal Project initiated in 1973 under a grant from the National Science Foundation with supplemental funding from the State and County of Hawaii has been presented by Dean John Shupe of the College of Engineering at the University, I will not discuss this program nor its objectives, but confine my remarks to the practical geological problems involved and why it is prudent to have contingency funds available for this project in the event they are needed.

Factors that have to be Taken into Consideration

Although geothermal energy as expressed by volcanism is obviously present on the island of Hawaii, the primary sources lie in the Hawaii Volcanos National Park area which is legally out of bounds for commercial exploitation. Of equal importance is the fact that results from a 4137-foot deep scientific drill hole in the National Park located within a quarter mile of Kilauea crater showed no evidence of reaching elevated temperatures exceeding that of boiling water above a depth of about 5000 feet. This result plus that from earlier shallow (2000 foot) drill hole tests in the Puna region and general geological knowledge indicated: (1) finding a source of exploitable geothermal energy would not be a simple matter; (2) the need for a carefully conducted series of integrated studies to define the location of possible "hot spots"; and (3) the desirability of finding sites at as low as surface elevation as possible if there is to be commercial exploitation. From a knowledge of the geology of the islands, it was also recognized that there was a need to find, if possible, an area where the highly porous and permeable volcanic rocks have been sealed off around and over any "hot spot" so that the heat is not rapidly conducted away by downward circulating surface water and tidal action of sea water underlying the Ghyben-Harzberg lens of fresh water underlying the island.

To get a handle on this aspect of the problem would require geothermal, geochemical and tidal studies in wells and also coastal offshore studies of changes in temperature and salinity to define where there is, and is not, warmed fresh water outflow along the coast and into the sea from the island.

The above all represent parts of the initial stage of the investigation that is now in progress to define the most favorable areas for the second phase which will involve exploratory slim hole drilling in each area to get direct evidence on the significance of the geophysical and other investigations carried out.

It is in connection with this drilling phase, which is actually an advanced stage of the exploration program, and preliminary to any development drilling, that the contingency funds are requested. The exploratory drilling is the critical phase of the exploration program since it will provide direct rather than indirect evidence on: (1) the presence or absence of an underlying geothermal source in an area; (2) data as to whether the pukas in the rock over and around the source area have been sealed by steam and hot water taking minerals into solution from the rocks near the source and redepositing them in the primary gas vesicles and other openings in the surrounding rocks; (3) the actual thermal gradient and heat related to the source; and (4) data on the chemical properties of any steam or hot water present that are important from the standpoint of corrosive action and the design of an energy recovery system.

As now visualized, each area that looks promising on the basis of the initial program of integrated geophysical and other studies would be investigated in the exploratory drilling phase by drilling a limited number of shallow (possibly 2000 foot) holes to ascertain the areal pattern of changes in temperature, chemistry and sealing (if any) of the rock pukas, with one deep (6000 foot) hole in what appears to be the center of the most likely area for there being an underlying geothermal source. This last is essential for an adequate test since the positive indications being sought for a geothermal source may well not be unequivocally established in drilling to only 2000 feet. As the cost of drilling alone could exceed $1,000,000 per area investigated, and as it now appears there may be several such areas, it appears to be prudent and in the State's interests to have a contingency reserve to cover unforeseen costs that might develop in carrying out this critical phase of the investigation. In other words, there is no plan to spend additional State funds except on a contingency basis and as warranted by results obtained. An alternative use would be in the unlikely event it develops that NSF will require a State contribution in the form of matching funds. This last is not regarded as probable, and certainly will not be made a part of the proposal submitted to NSF, but there is always the possibility where a large request is involved that funding may be contingent on there being a State contribution to the program's costs.

One thing that I do wish to emphasize is that there is no guarantee that economical geothermal power can be developed on the Big Island, but without an investigation in depth, including exploratory drilling, we will never know whether it is feasible, of limited feasibility, or a pipe dream. With an expanding population, changing economy and a national focus on developing new energy sources with federal money to back such research, we feel it is in the State's interest at this time to establish whether geothermal power is a resource having value to the State or not.

3/9/74

Testimony of Dr. Agatin T. Abbott
Professor of Geology, University of Hawaii
on
the Supplemental CIP Budget
for Geothermal Energy Exploration in Hawaii

For nearly two years various kinds of research has been underway and are continuing on the island of Hawaii to determine the most favorable areas for the production of commercial quantities of geothermal energy. These various methods include electrical resistivity of the rocks at various depths, electromagnetic surveys, seismic surveys, airborne infrared scanning imagery of surface temperatures, geochemical work and thermal surveys of water wells. All of these methods of attack are important and useful to the degree to which they can be interpreted into real conditions that exist far beneath the surface.

Unfortunately each type of geophysical exploratory system has its limitations. The research gives us a set of data but the reading of that data is subject to an impressive set of possible misinterpretations. This is not to say that the geophysical and geological programs are not useful. They are tremendously useful and should be continued, but they cannot provide the final and definitive answers. The only tool that will tell us whether there is sufficient heat and water at depth to generate geothermal power is the drill. There is just no other way to find out -- once and for all.

I should pause to point out here that once we have drilled a deep hole or two and have actually measured the properties of the rock at various depths, these figures can then be applied to and compared with the geophysical data which will greatly increase the effectiveness of the geophysical program in future interpretations.

The National Science Foundation is anxious to consider a proposal for funding the drilling of exploratory holes on the island of Hawaii. This was clearly indicated at a meeting in February 1974 in Hilo with the Program Coordinator of the Geothermal Projects for NSF, Mr. Ritchie Coryell.

The National Advisory Board for the Hawaii Geothermal Project was also in favor of drilling as I had proposed in a letter in November of 1973. The Board recommended at the Hilo meeting that I serve as Principal Investigator of the Exploratory Drilling Program in connection with the National Science Foundation proposal. My testimony here puts forward some of the plans for drilling as I envision them at the present time.

Location of the Exploratory Holes

Up to this time the most favorable areas for locating exploratory drill holes, based on geophysical results of various kinds are:
1) along the lower section of the east rift of Kilauea, probably on the seaward side of the rift zone.
2) Along the lower portions of the southwest rift of Kilauea 1 to 2 miles inland from the coastline.
3) Along the lower portion of the southwest rift of Mauna Loa in the vicinity of South Point.
It should be made clear that these locations may change or other areas indicated as favorable as additional data comes in from the field.

Depth of the Holes

In my opinion there is little to be gained by the drilling of shallow holes (less than 1,000 feet) in any of the above mentioned areas. I believe that our target area, if indeed there is one, lies at depths of at least 5,000 to 6,000 feet or perhaps more and it is to this depth that we must explore. The National Advisory Board recommends that we can gather a good deal of information with 2,000 foot holes. This may be true and it is my plan to drill some 2,000 foot holes as a means of accumulating information to better understand the subsurface conditions to locate the deeper holes.

I think its reasonable to say that if the temperature gradient and water conditions are increasingly encouraging as we approach a 2,000 foot depth, I will plan to continue drilling deeper.

Number of Holes

The number of holes is limited by several factors, principally money, and time. As a very general estimate of the number of exploratory holes I would say that in each of the three favorable areas mentioned above we should plan on four 2,000 foot holes to gather information on subsurface conditions. In each of the three areas based on information obtained in the 2,000 foot holes I would propose one hole to 6,000 feet or more. This array brings the total in this phase to 12 2,000 foot holes and three 6,000 foot holes for a total drilling distance of 42,000 feet.

Cost of the Holes

The drilling program will of course be put out for bids and there is no way at this time to speculate on how the bids will run. Only very tentative costs can be estimated. The costs vary with the depth and diameter of the hole and with how contingencies for delays and difficulties are handled.

From several sources however a figure of $50 per foot for an approximate 6 inch diameter hole is within reason. If we complete the drilling program as outlined here the total cost of drilling would be approximately $2,100,000. These figures represent only the drilling. There would be other costs of measurement of temperatures and other scientific tests as the drilling proceeds.

STATE CONTINGENCY FUND

In speaking directly on the problem of the Supplemental CIP Budget, it should be emphasized that the Drilling Program would prefer to fund the project on Federal funds alone because of the high risk and doubtful outcome of this venture. We are by no means assured of success no matter how many holes we drill or how deep they go. Conditions may just not exist for the production of geothermal energy on a commercial scale. For this reason the State funds are subject to very careful scrutiny and subject to rather harsh criticism if the project fails to produce a favorable result.

We would welcome State funding in the amount of $500,000 with the understanding that it is to be used only as a contingency fund in case the Federal funds fell short of accomplishing what we feel would be a fair test to determine whether or not there is a chance for geothermal energy development on Hawaii.

H. B. NO. 2197-74

A BILL FOR AN ACT

RELATING TO RESERVATION AND DISPOSITION OF GOVERNMENT MINERAL RIGHTS

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF HAWAII:

SECTION 1. Findings and determination. The Legislature of the State of Hawaii finds and declares that the geothermal resources of the State provide an energy potential which may be utilized to supply power economically with minimal adverse environmental effects. It is the intent of the Legislature to establish in law the definition and ownership of the geothermal resources, to encourage their development, and to provide for their administration and management in the public interest.

SECTION 2. Section 182-1, Hawaii Revised Statutes, is amended to read:

"Sec. 182-1 Definitions. In this chapter, if not inconsistent with the context:

(1) 'Minerals' means any or all of the oil, gas, coal, phosphate, sodium, sulphur, iron, titanium, gold, silver,

bauxite, bauxitic clay, diaspore, boehmite, laterite, gibbsite, alumina, all ores of aluminum and, without limitation thereon, all other mineral substances and ore deposits whether solid, gaseous, or liquid, including all geothermal resources, in, on, or under any land, fast or submerged; but does not include sand, rock, gravel, and other materials suitable for use and used in road construction.

(2) 'Board' means the board of land and natural resources.

(3) 'Reserved lands' means those lands owned or leased by any person in which the State or its predecessors in interest has reserved to itself expressly or by implication the minerals or right to mine minerals, or both.

(4) 'State lands' includes all public and other lands owned or in possession, use and control of the then Territory of Hawaii or the State of Hawaii, or any of its agencies and this chapter shall apply thereto.

(5) 'Occupier' means any person entitled to the possession of land under a certificate of occupation, a nine hundred and ninety nine year homestead lease, a right of purchase lease, a cash freehold agreement, or under a deed, grant, or patent, and any person entitled to possession under a general lease, and also means and includes the assignee of any one of the above.

(6) 'Force majeure' means any fire, explosion, flood, volcanic activity, seismic or tidal wave, mobilization, war (whether declared or undeclared), act of any belligerent or any such war, riot, rebellion, the elements, power shortages, strike, lock-out, difference of workmen, any cause which prevents the econmic mining of the lease, or any other cause beyond the reasonable control of the party affected, whether or not of the nature or character hereinabove specifically enumerated.

(7) 'Mining operations' means the process of excavation, extraction, and removal of minerals, and the development of any and all geothermal resources, from the ground, design engineering, other engineering, erection of transportation facilities and port facilities, erection of necessary plants, other necessary operations or development approved by the board preceding or connected with the actual extraction of minerals and the development of geothermal resources.

(8) 'Mining lease' means a lease of the right to conduct mining operations, including geothermal resource development, on state lands and on lands sold or leased by the State or its predecessors in interest with a reservation of mineral rights to the state."

SECTION 3. Statutory material to be repealed is bracketed.

New material is underscored. IN printing this Act, the revisor of statutes need not include the brackets, the bracketed material or the underscoring.

SECTION 4. This Act shall take effect upon its approval.

INTRODUCED BY:

JAN 28 1974