

STATEWIDE
GEOTHERMAL RESOURCE ASSESSMENT

Circular C-103

UPDATE



State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development

Honolulu, Hawaii
December 1992



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Governor

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MANABU TAGOMORI, Manager-Chief Engineer

Honorable William W. Paty, Chairperson
Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Dear Mr. Paty,

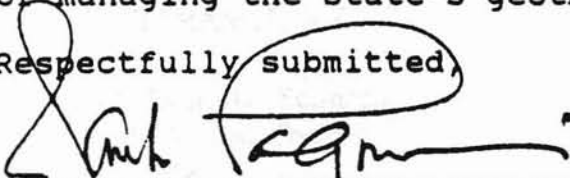
Transmitted herewith for your consideration is the Statewide Geothermal Resource Assessment report update prepared pursuant to requirements of Section 205-5.2, Hawaii Revised Statutes.


This report updates a statewide, county-by-county assessment of Hawaii's potential geothermal resource areas, based on currently available geotechnical information.


Presented are the Committee's updated recommendations for high temperature geothermal resource areas having the potential for electrical power generation. High temperature is defined to be greater than 125 degree celcius (250 degree fahrenheit) at depths less than 3 kilometers (9800 feet). These areas have been mapped and identified as potential geothermal resource areas. Also identified in the assessment process were low temperature (less than 125 degree celcius) geothermal resource areas. Further research may be directed in these areas to determine the availability of geothermal resources for future consideration in identifying potential geothermal resource areas.

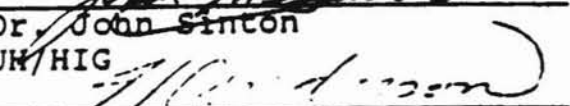
The Committee has completed its periodic assessment of geothermal resources in the State of Hawaii and will continue to be available to assist the Department of Land and Natural Resources in aspects of managing the State's geothermal resources.


Respectfully submitted,



Mr. Manabu Tagomori, Co-Chairman
DLNR/DOWALD

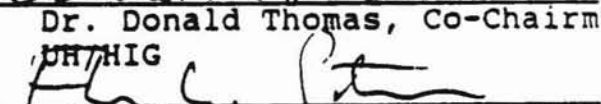

Dr. Harry J. Olson
UH/HNET

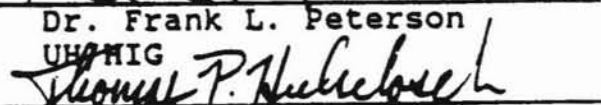

Dr. John Sinton
UH/HIG


Dr. James L. Anderson
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Mr. Dean Nakano
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Dr. Frank L. Peterson
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Mr. G. O. Kasperance
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Dr. Fred Duennebier
UH/HIG

ACKNOWLEDGEMENT

The Geothermal Technical Advisory Committee acknowledges the assistance of the individuals listed below who provided geotechnical information, participated in technical sessions, and assisted in field visits of sites by the Committee.

MURRAY GARDNER, GeothermEx, Inc.

RALPH PATTERSON, Ralph Patterson Associates

W.L. DOLIER, Ralph Patterson Associates

ART SEKI, Hawaiian Electric Company

RODNEY NAKANO, Hawaii County

STEVE MORRIS, Puna Geothermal Venture

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PREFACE

Act 296, Session Laws of Hawaii 1983, as amended by 151, SLH 1984, required that the Board of Land and Natural Resources examine various factors when designating subzone areas for the exploration, development, and production of geothermal resources. These factors include potential for production, prospects for utilization, geologic hazards, social and environmental impacts, land use compatibility, and economic benefits. In 1984 the Department of Land and Natural Resources prepared a series of reports which addressed each of the subzone designation factors. A report was prepared which assessed the potential for production of geothermal energy throughout the State of Hawaii.

Section 205-5.2 provides that this assessment be updated periodically. This report updates the Board of Land and Natural Resources Statewide Geothermal Resource Assessment Circular C-103 dated September 1984.

The Geothermal Technical Advisory Committee, formed jointly by the Department of Land and Natural Resources and the Department of Business, Economic Development and Tourism, has reviewed once again the areas previously selected within the State which have the greatest potential to produce geothermal energy. The Committee has made changes to update the 1984 report according to its review of information that has become available after the initial report was prepared. The participation of the Committee members, who have volunteered their time and effort is greatly appreciated.

This report was updated by the Department of Land and Natural Resources Division of Water and Land Development under the direction of Manabu Tagomori, Manager-Chief Engineer. The Appendices to this update are available upon request.

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SUMMARY

A Geothermal Technical Advisory Committee was formed to assist the Department of Land and Natural Resources in updating its assessment of geothermal resource potential within the State of Hawaii for application to electrical power generation. Participants were selected on the basis of their expertise in the fields of geology, geochemistry, geohydrology, geothermal exploration technology and the geology of the Hawaiian Islands.

Technical Advisory Committee members met in a series of meetings held on the islands of Oahu and Hawaii to update the previous assessment using the most recently available geotechnical data relevant to the assessment and identification of potential geothermal resource areas.

The statewide geothermal resource assessment update was made on a county-by-county basis and was based on a qualitative interpretation of more recent surveys, exploratory geothermal drilling data, and anomalous water well data.

The Geothermal Technical Advisory Committee reviewed the assessment criteria used in the earlier evaluation of geothermal resource potential. It was agreed that the earlier criteria were still appropriate for the current evaluation but that an additional factor, permeability of the potential reservoir, should be included in the evaluation to the extent data are available.

I. Revision of Assessment Criteria

A. Current Criteria

- a. > 125°C
- b. < 3 km depth
- c. ground elevation

B. Revision

- a. Temperature - none
- b. Depth - none
- c. Elevation - none
- d. Permeability - include to the extent that we have data

II. Revision of Geothermal Potential

<u>Area</u>	<u>Prior Assessment of Resource Potential</u>	<u>New Data</u>	<u>Proposed Assessment</u>
Kauai	< 5%	No	< 5%

<u>Area</u>	<u>Prior Assessment of Resource Potential</u>	<u>New Data</u>	<u>Proposed Assessment</u>
Oahu Waianae	< 5%	No	< 5%
Koolau	< 5%	No	< 5%
Molokai	< 5%	Blackhawk EM Study; Waterwell Data	Defer for further evaluation of new data
Lanai	< 5%	Drilling and Water quality data	< 15% revisit after more study
Maui			
Olowalu	< 15%	No	< 15%
Lahaina	< 5%	No	< 5%
Honolua	< 5%	No	< 5%
Haleakala			
S.W.R.Z.	25% or less	Linenert EM Study; Warm air vents on upper rift	25% or less
Haleakala			
N.W.R.Z.	< 5%	No	< 5%
Haleakala			
E.R.Z.	25% or less	No	25% or less
Hawaii			
Kawaihae	< 10%	Blackhawk Studies; Water well data	< 10%, revisit after more data available
Hualalai	35% or less	No	Defer for further evaluation
Mauna Loa			
S.W.R.Z.	35% or less	No	35% or less
Mauna Loa			
N.E.R.Z.	35% or less	No	35% or less
Kohala	< 5%	No	< 5%

<u>Area</u>	<u>Prior Assessment of Resource Potential</u>	<u>New Data</u>	<u>Proposed Assessment</u>
Mauna Kea N.W.R.Z.	< 20%	No	< 20%
Mauna Kea E.R.Z.	< 10%	No	< 10%
Kilauea S.W.R.Z.	> 90%	No	> 90%
Kilauea E.R.Z.	> 95%	New Drilling	> 95%

III. Revision of geothermal potential lines

A. Molokai

- a. no change pending further analysis

B. Lanai

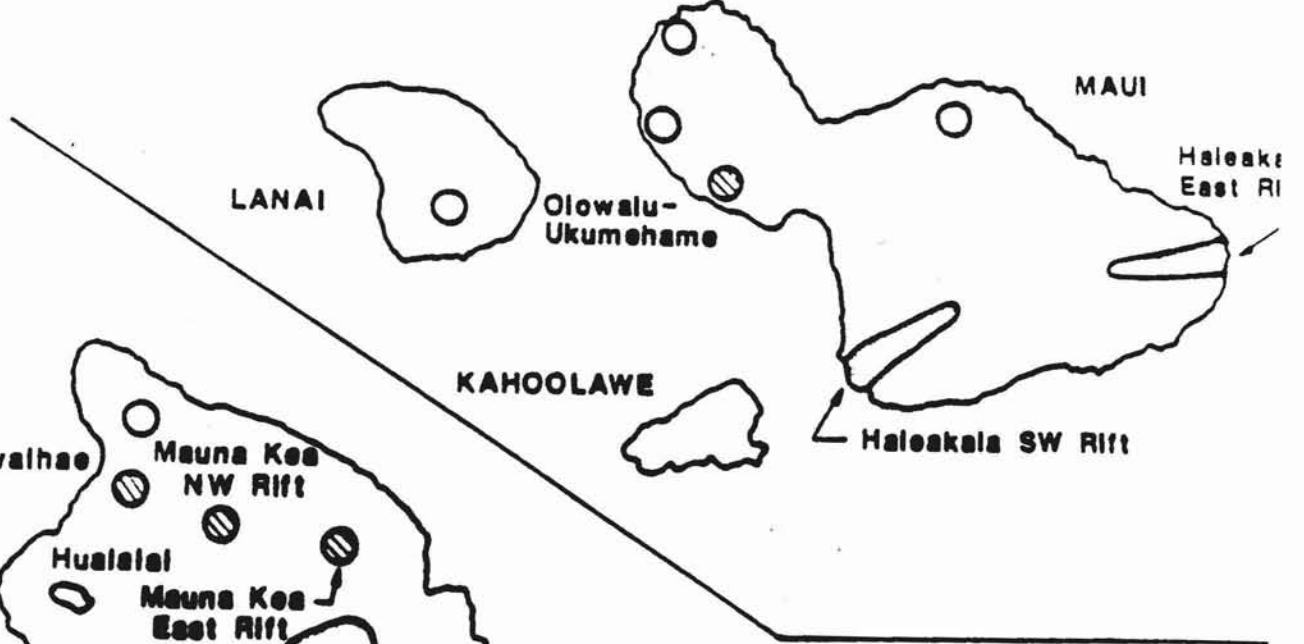
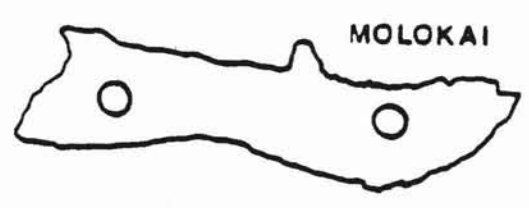
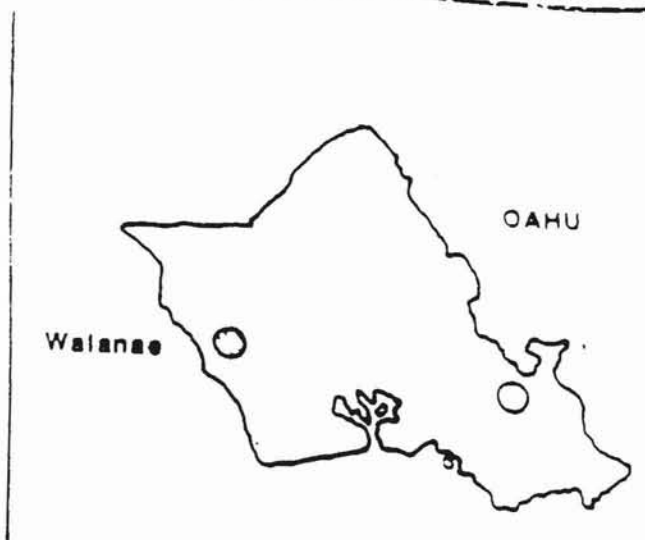
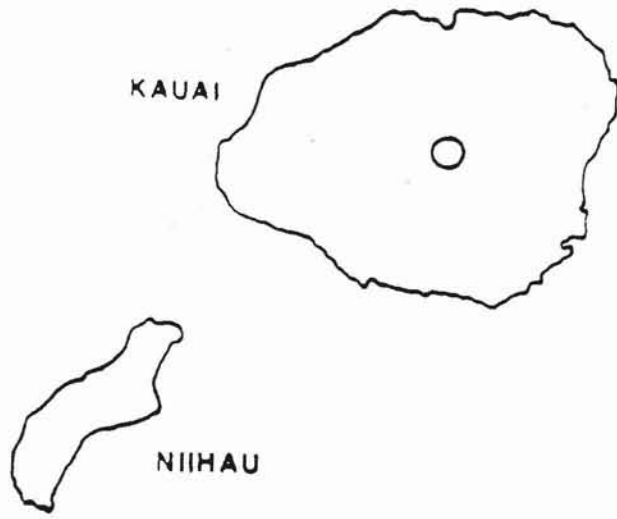
- a. potential geothermal resource within caldera boundary (< 15% probability)

C. Haleakala S.W.R.Z.

- a. no change pending further analysis

D. Kilauea E.R.Z.

- a. move 90% line north by 1 km
- b. leave 25% in current location



-  HIGH TEMPERATURE RESOURCE
-  LOW TEMPERATURE RESOURCE A
-  OTHER ASSESSMENT AREAS

STATEWIDE GEOTHERMAL RESOURCE ASSESSMENT

INTRODUCTION

The Board of Land and Natural Resources is charged with the responsibility of designating geothermal resource subzones in the State of Hawaii by Chapter 205, Hawaii Revised Statutes.

This Chapter provides that the statewide geothermal resource assessment be updated periodically in order to provide the best scientific basis for designation of geothermal resource subzones.

This update of the initial statewide geothermal assessment, prepared in 1984 as "Statewide Geothermal Resource Assessment Circular C-103" has been prepared by utilizing currently available information and recent interpretations of this data. Certain studies, interpretations, and exploratory well data were not available at the time of the initial study. These include studies by Blackhawk and Lienert, interpretations by the ENEL consulting team, interpretations of recent SOH data by GeothermEX, Inc. and Ralph Patterson Associates, certain anomalous data from recently drilled water wells, and data from exploratory and commercial geothermal wells drilled in the Kilauea East Rift Zone.

This update includes remapping of estimated percent probability of geothermal resources in the Kilauea East Rift Zone and inclusion of a new area of Lanai with geothermal resource potential.

GEOTHERMAL TECHNICAL ADVISORY COMMITTEE

The Department of Land and Natural Resources in cooperation with the Department of Business, Economic Development and Tourism has jointly selected a committee of technical experts who are closely associated with the field of geothermal research in the State of Hawaii. Some of the same individuals who voluntarily served on the initial Geothermal Resources Technical Committee have volunteered once again to serve on the Geothermal Technical Advisory Committee. The latter Committee has expanded its scope to include other functions beside assessing the resource and updating the 1984 Geothermal Resources Assessment. These added functions include identifying geographic and subject areas where further geothermal research is needed, reviewing current projects and activities, and proposing and evaluating geothermal research proposals, as well as serving as an advisory body in resource management, regulation and enforcement. The Technical Advisory Committee also fosters communication and cooperation between the commercial developers involved in geothermal exploration and their technical consultants, on the one hand, and public sector technicians, regulators and officials with geothermal/alternate energy responsibilities, on the other.

A list of the participating committee members and their area of technical expertise is described below:

Mr. Manabu Tagomori Area of expertise: Manager - Chief Engineer, Division of Water and Land Development, Department of Land and Natural Resources.

Dr. Donald Thomas Area of expertise: Geochemistry, Geology, Geohydrology, Geothermal Exploration Technology, and the Geology of the Hawaiian Islands.

Dr. Harry J. Olson Area of expertise: Geology, Geothermal and Mineral Exploration and Development; Hard Rock Drilling.

Dr. Frank L. Peterson Area of expertise: Hydrology, Insular Hydrogeology, Engineering Geology, Environmental Geology, Hawaiian Geology.

Dr. John Sinton Area of expertise: Igneous Petrology and Geochemistry; extensive experience studying Hawaiian volcanic rocks and ocean floor basalts.

Dr. James L. Anderson Area of expertise: Volcanology; Structural Geology; Igneous Petrology.

G.O. Lesperance Area of expertise: Civil engineer; involved with Hawaii's geothermal program since 1982; DBEDT Geothermal Project Office.

Dean Nakano Area of expertise: Geothermal Program Manager, Department of Business, Economic Development and Tourism.

Dr. Thomas P. Hulsebosch Area of expertise: Igneous and Metamorphic Petrology; Geochemistry; X-ray Fluorescence and electron microprobe analyses of geological materials.

Dr. Frederick Karl Duennebier Area of expertise: Geology, Seismology, and Geophysical Instrumentation; Exploration Geophysics and Refraction Seismology, Earthquake Seismology, Marine Tectonics, Ocean Drilling, Borehole Instrumentation, Instrumentation of Volcanoes and the Ocean Floor; seismicity of the moon and seismic study of mars.

A more detailed resume of each committee member can be found in Appendix C.

ASSESSMENT APPROACH AND CRITERIA

A series of committee meetings was scheduled between May and December 1991, with one of the Committee's goals to complete the update of the Statewide geothermal assessment by the end of 1991. The first meeting set the scope and schedule for the Committee. The second meeting concentrated on the SOH program. In the third meeting, the resource evaluation update process began with presentation of new data for various geographic areas and suggestions for further assessment models. The fourth meeting was held in Hilo, Hawaii, and was followed by a field trip to the Puna Geothermal Venture site at Kapoho. At the fifth meeting, Dr. Thomas presented his analysis of some of the recent information from water wells presented at the previous meeting.

At the next two meetings, the Committee concentrated on the task of resource reassessment. It was determined that the Committee's work would be presented in the form of an update to the initial Statewide Geothermal Resource Assessment Circular C-103 report. The initial assessment was reviewed by the Committee, and a draft update was prepared by Dr. Thomas. This update was reviewed, evaluated and approved by the Committee in subsequent meetings.

The following is a list of the Geothermal Technical Advisory Committee's meetings which concentrated on resource assessment:

<u>Date</u>	<u>Place</u>
April 12, 1991	Honolulu, Hawaii
May 17, 1991	Honolulu, Hawaii
June 21, 1991	Honolulu, Hawaii
August 2, 1991	Hilo, Hawaii
September 5, 1991	Honolulu, Hawaii
October 14, 1991	Honolulu, Hawaii
November 18, 1991	Honolulu, Hawaii
December 18, 1991	Honolulu, Hawaii

The new information upon which the Committee's update is based is included in the list of references, Appendix A. The following types of geological, geophysical and geochemical data were used in the initial assessment, and in the update: groundwater temperature data, geologic age, geochemistry, resistivity, infrared surveys, seismic monitoring, magnetics, gravity surveys, exploratory drilling, and self potential anomalies.

STATEWIDE RESOURCE ASSESSMENT

The Geothermal Technical Advisory Committee reviewed the previous statewide assessment and took into account all available new data, also on a statewide basis. Changes resulting from the examination of new data are as follows:

HAWAII COUNTY

The Geothermal Technical Advisory Committee decided to leave the assessment the same as in the initial assessment, except that on the basis of the Blackhawk studies at Kawaihae, and various water well data, the Committee decided to revisit that area for further study. In the Hualalai area, the Committee decided to defer its assessment for further evaluation.

Based on the fact that 15 wells have been developed in the Kilauea East Rift Zone, the Committee decided to increase the percentage of geothermal potential from 90% to 95% since there appears to be a proven resource in the area.

MAUI COUNTY

A study by B. Lienert has indicated the presence of resistivity anomalies along the lower SWRZ that can be interpreted to indicate temperatures of up to 59°C at the top of the basal lens in this area.

Also the Committee plans to revisit the Haleakala SWRZ because of the observation of warm air vents in the area.

On the Island of Lanai, the Committee increased the assessment from < 5% to < 15% based on drilling and water quality data, and planned to revisit the matter after further study. Three water wells on Lanai indicated elevated temperatures; two indicated elevated magnesium and chloride levels. The desire is to resample these wells for future assessment. (A complete listing of assessment of well data from recently drilled wells is included in Appendix B, Minutes of Geothermal Technical Advisory Committee Meetings.)

CITY AND COUNTY OF HONOLULU

There was no revisiting of the earlier assessment of areas on Oahu.

KAUAI COUNTY

There was no revisiting of the earlier assessment of Kauai County.

POTENTIAL GEOTHERMAL RESOURCE AREAS

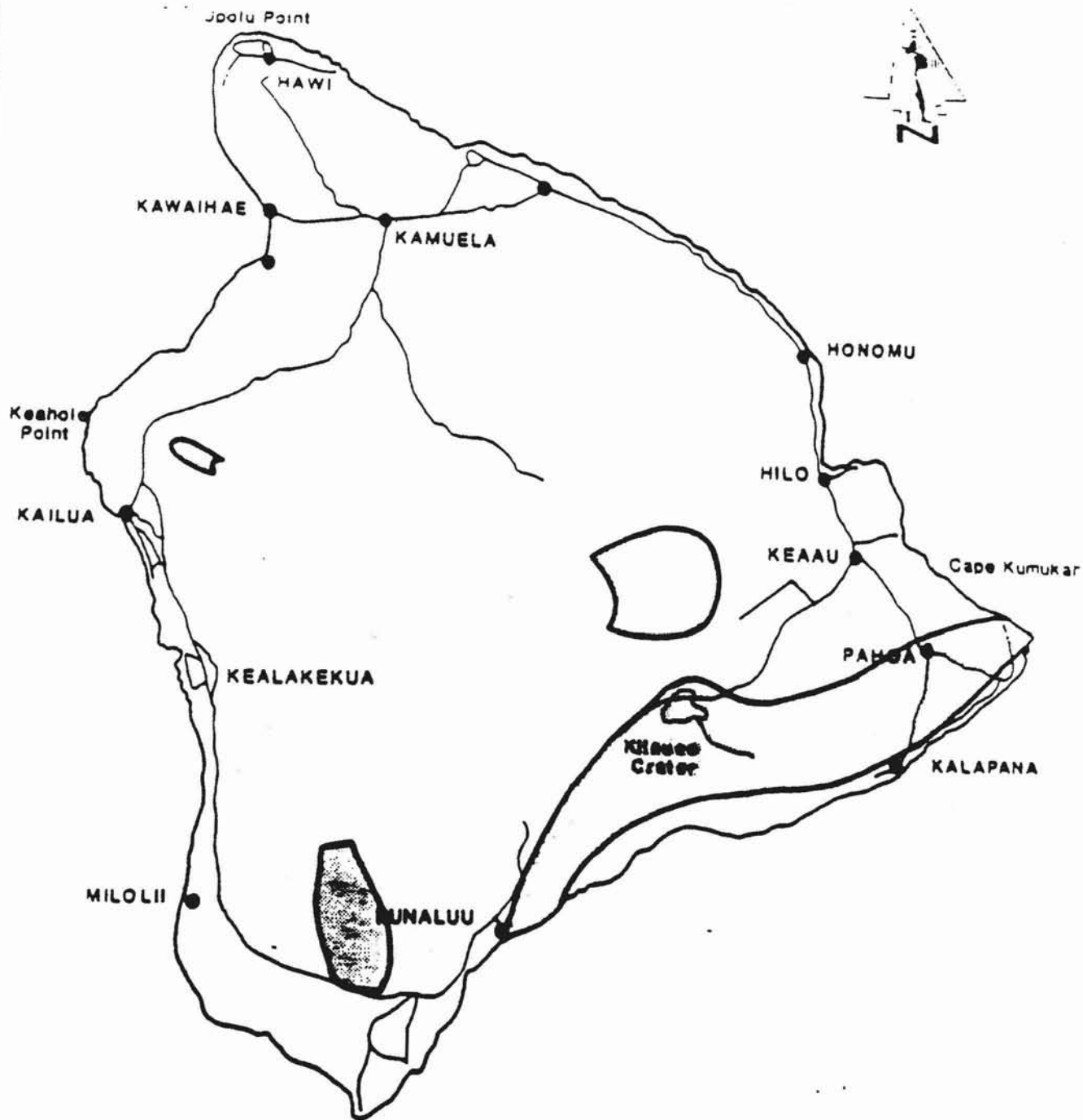
The Geothermal Technical Advisory Committee restated its conclusion that no single geothermal exploration technique except for exploratory drilling is capable of positively identifying a subsurface geothermal system. Accordingly, the Committee is supportive of future slim observation hole exploratory drilling, and participated extensively in discussions on optimal locations for future exploratory wells to maximize their effectiveness in providing information on locations of geothermal resources.

The former conclusion of the previous Geothermal Resource Technical Committee was retained by the Geothermal Technical Advisory Committee that for production of electrical energy, current technology would require the resource to have a temperature greater than 125°C at a depth of less than 3 km.

The additional feature of permeability has been added, however, to the criteria. It was determined that this information is important, but is not readily available.

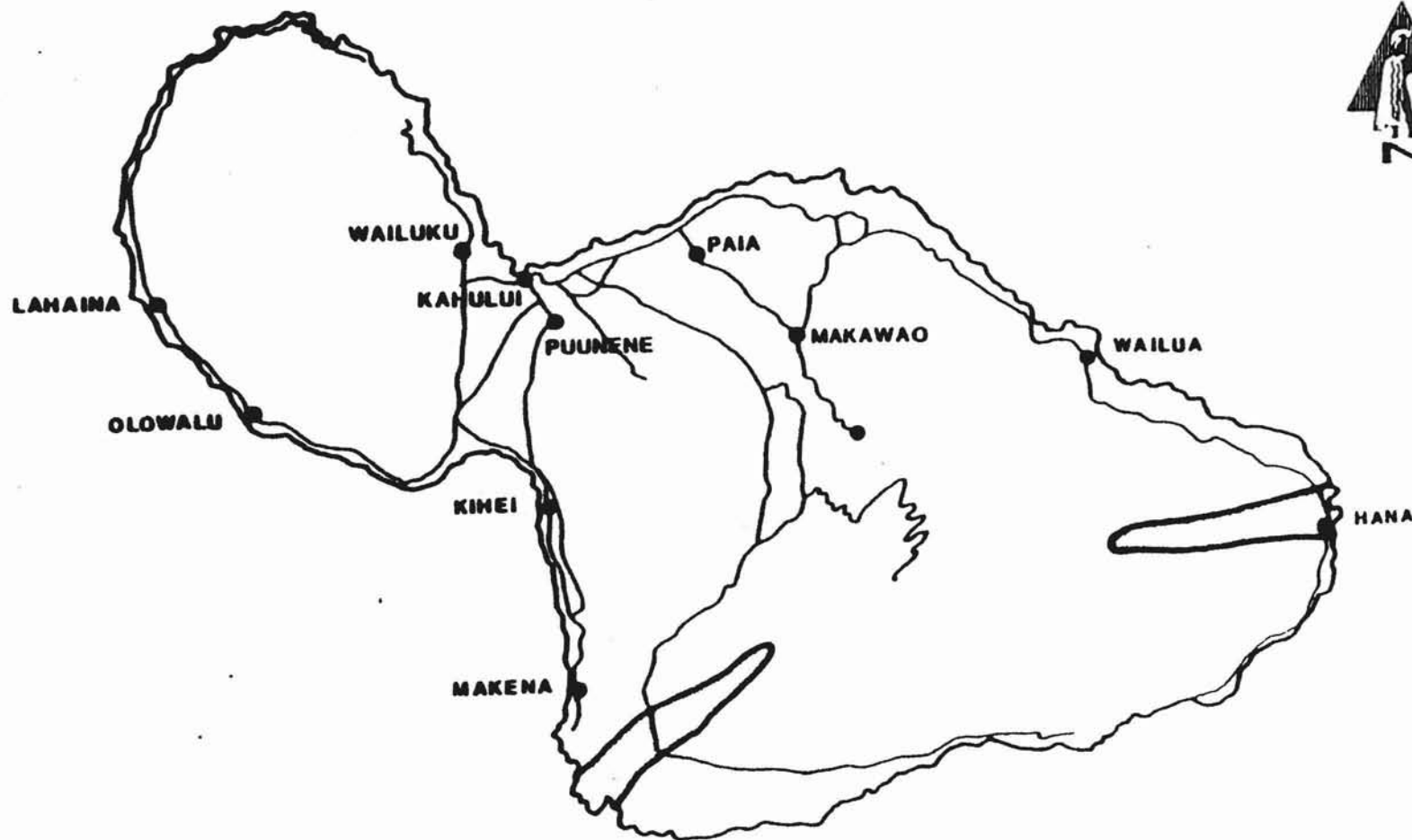
High temperature potential geothermal resource area mappings have not changed since the initial statewide geothermal resource assessment was made in 1984, and are reproduced as such in this update.

ISLAND OF HAWAII



**HIGH TEMPERATURE POTENTIAL
GEOTHERMAL RESOURCE AREAS**

ISLAND OF MAUI



GEOTHERMAL RESOURCE AREAS

OTHER GEOTHERMAL RESOURCE AREAS

Because low temperature applications of geothermal heat do not require specialized permits and are not confined to geothermal resource subzones, potential geothermal resource areas having temperatures below that necessary for electrical production have not been treated here.

CONCLUSIONS

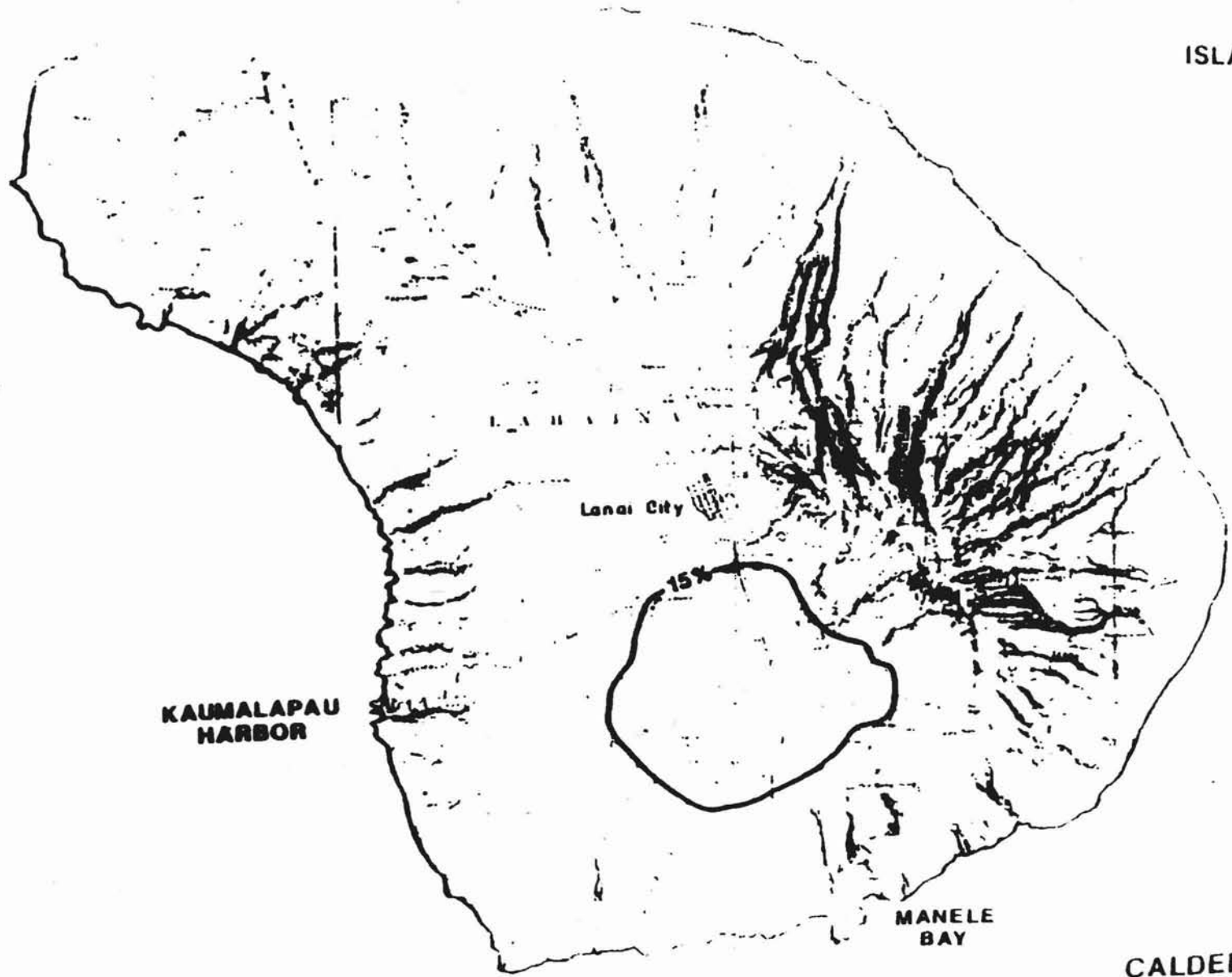
The results of the Geothermal Technical Advisory Committee's updated assessment is essentially to note that there is now a proven resource in the Kilauea E.R.Z., thereby increasing the potential from 90 to 95% probability for location of geothermal resources and to indicate a broader range to the North for the 90% potential in the Pahoa area; and to note that there are unusually high temperatures occurring in water well samples in the Palawai Basin area of southern Lanai Island, thereby increasing the potential from 5 to 15% for location of geothermal resources; and to note that a number of areas are worthy of revisiting for further study.

The Geothermal Technical Advisory Committee is now an on-going committee with a broad scope of tasks, including assessing on-going studies, proposing and planning future studies, advising government in developing a geothermal resources management plan, and coordinating relations between developers and government regulators and planners. As an on-going body, their research will result in re-assessing geothermal resource potential in the State of Hawaii on an on-going basis.

At this time, the results of the current assessment update do not indicate a need to propose changes in the four existing geothermal resource subzones in the State of Hawaii.

Maps showing the 15% potential area on Lanai, and showing the broader revised 90% potential band are attached.

ISLAND OF LANAI



KAUMALAPAU
HARBOR

Lanai City

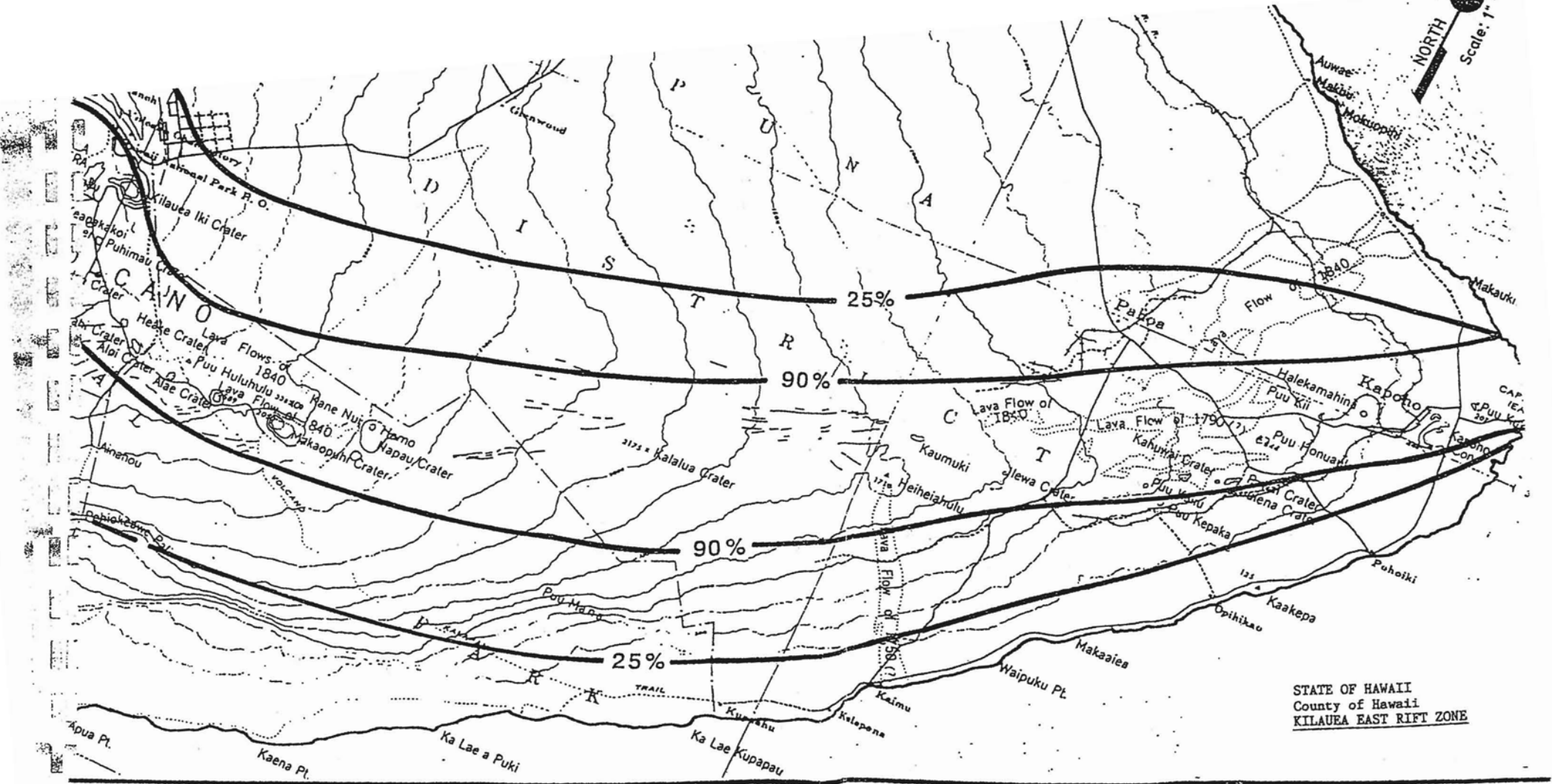
15%

MANELE
BAY

CALDERA BOUNDARY

5

NORTH
Scale: 1" = 1 mile



STATE OF HAWAII
County of Hawaii
KILAUEA EAST RIFT ZONE