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STATE OF HAWAII
NATURAL ENERGY LABORATORY OF HAWAII

DEVELOPMENT PLAN FOR THE HAWAII OCEAN SCIENCE & TECHNOLOGY PARK AND EXPANSION OF THE NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
MODIFICATION OF PROPOSED ACTION
TO PERMIT ALTERNATIVE METHODS OF SEAWATER RETURN-FLOW DISPOSAL AT THE NATURAL ENERGY LABORATORY OF HAWAII

November 1986
Draft

Office of Environmental Quality Control
235 S. Beretania #702
Honolulu HI 96813
586-4185

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AT THE NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

Prepared for the

STATE OF HAWAII
NATURAL ENERGY LABORATORY OF HAWAII

Jack P. Huizingh
Executive Director

Prepared By

MCM PLANNING

Honolulu, Hawaii

November 1986

Draft

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
NOVEMBER 1986

PROJECT:	DEVELOPMENT PLAN FOR THE HAWAII OCEAN SCIENCE & TECHNOLOGY PARK AND EXPANSION OF THE NATURAL ENERGY LABORATORY OF HAWAII: MODIFICATION OF PROPOSED ACTION TO PERMIT ALTERNATIVE METHODS OF SEAWATER RETURN FLOW DISPOSAL AT THE NATURAL ENERGY LABORATORY OF HAWAII
LOCATION:	KEAHOLE POINT, NORTH KONA ISLAND OF HAWAII STATE OF HAWAII
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Summary

Description of the Action

The Natural Energy Laboratory of Hawaii (NELH) was established by the Hawaii State Legislature in 1974 to manage and operate a research facility on approximately 322 acres of state-owned land at Keahole Point on the island of Hawaii (TMK 7-3-43:42) for research, development and demonstration of natural energy resources. The Keahole site was selected for NELH because of the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual solar insulation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. The unique characteristics of the site make it an excellent environment for conducting ocean related research such as Ocean Energy Thermal Conversion (OTEC).

An environmental impact statement for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii (HTDC FEIS) was accepted by the Governor in September 1985. Among the actions assessed in the statement was the disposal of 42,000 gpm of seawater return flows from ocean thermal energy conversion (OTEC) and mariculture operations at NELH by means of trench, well, canal and mixed-water discharge pipe. At the time the HTDC FEIS was accepted, the State of Hawaii planned to install a cold water pipe and pump system for HOST Park and the U.S. Department of Energy (DOE) was planning to fund a cold and warm water system for OTEC research. Subsequently, the DOE learned that it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. Rather than installing separate seawater pipe systems, DOE and the state entered into a cooperative cost-sharing agreement to provide the required ocean water for both projects with one seawater system.

OTEC is a power generating system that uses the temperature difference between warm surface water in the tropical ocean and the cooler water at depth to run a heat engine. Research on two types of operating cycles, closed (CC) and open (OC), is presently being conducted at NELH. The Solar Energy Research Institute (SERI), a DOE working group, is developing a research experiment to establish the feasibility of producing significant amounts of net power from an OC OTEC system. The demonstration plant experiment proposed for NELH is sized at 165 kW of gross power and is anticipated to be in operation in 1991, after approximately four years of scoping experiments and testing at the site.

Expansion facilities to support this research program will be constructed by the State of Hawaii with the financial support of the U.S. DOE. These new expanded facilities are planned to include: (1) an ocean water supply system (pipes and pumps) capable of delivering 16,100 gpm of mixed warm and cold seawater; (2) a water system test facility for developmental research for open-cycle OTEC; and (3) an expanded facility for experiments with OTEC-related mariculture.

The 165 kW demonstration plant, when operational, will discharge approximately 16,100 gpm of seawater. The seawater will be mixed in a ratio of 1 part cold to 1.5 parts warm. Because the mixed-water discharge pipe that was originally proposed as the means to dispose of the projected seawater return flows will not be funded at the present time, alternative, less costly methods of disposal were evaluated.

The alternative disposal facility recommended for OTEC discharges is a shallow trench located within the NELH compound. The recommended trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at its closest point. This facility would initially serve as a research trench for discharge quantities in the range of 3,000 to 5,000 gpm. During the 3 to 4 year scoping and testing period, an intensive water quality monitoring program would be undertaken in conjunction with the trench disposal in order to determine the actual impacts associated with the discharge flow. In the event that

CORRECTION

THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY

SEE FRAME(S) IMMEDIATELY FOLLOWING

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unacceptable impacts occur, alternative disposal facilities can be constructed and the water diverted to the new system.

Research at NELH has proven the value of the pure cold ocean water for the production of mariculture products such as abalone and microalgae. Legislation passed in May 1984 amended the NELH enabling legislation to allow on-site commercialization of successful research and development projects. Based on the experience of the past three to four years, it appears that significant potential exists for commercialization of several species of aquatic plants and animals at NELH. These include: microalgae, macroalgae, marine mollusks, crustaceans and finfish.

At full development of NELH it is projected that an additional 25,900 gpm of seawater return flows from mariculture operations will be generated. The consitutents of the discharge water will depend on the culture organism and its intended use. The overall warm and cold seawater mix is assumed to be 4:1.

The disposal facility recommended for return seawater from mariculture operations is a trench located makai of the NELH access road, approximately 750 feet from the shoreline. In order to facilitate NELH mariculture operations, the trench could be constructed anywhere southeast of this area as long as it is located adjacent to the access road. Because it is anticipated that there will be a gradual increase in volumes of water used, the proposed monitoring program can provide early detection of any adverse impacts so that alternative disposal methods can be instituted if they occur.

Significant Impacts

- The disruption and displacement of the existing brackish water lens for some distance inland and along the coast. In the long term, trees with deep root systems that reach groundwater level may not be able to survive the change in salinity caused by the ocean water

plume. This can be mitigated by planting trees with a greater tolerance to salinity.

- The anchialine ponds on the project site will slowly lose their brackish character. Because the species of endemic shrimp present in one of the ponds has been observed to tolerate greater salinities than those anticipated from NELH discharges, and their diverse diet would allow ready adaptation if other components of the ecosystem would change, it does not appear that the impacts of disposal will have a serious impact on the essential character of the ponds.

- OC OTEC discharges containing reduced concentrations of oxygen may tend to depress metabolic activity of the coastal community, but trench disposal will considerably diffuse entry of these waters to the sea and rapid mixing at entry would tend to minimize this impact. Reoxygenation by aeration is a suggested mitigating measure for this potential impact.

- Potential sublethal impacts from discharging seawater at temperatures cooler than the ambient water temperature of the receiving waters could include reduced metabolic rates, especially of corals. Trench disposal will afford some warming and will greatly diffuse the flux and allow for high initial dilution in the receiving waters. It does not appear that the magnitude of the potential temperature depression would cause mortalities in the benthic community, but monitoring of community metabolism is required to provide quantitative estimates of impact.

- Nutrient concentrations in OTEC discharges will be elevated over those of receiving waters. The offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would be expected to greatly increase macroalgal biomass because grazing is inhibited in the surge zone. The adverse impact would primarily be aesthetic. Nutrient

enrichment of the offshore waters could be beneficial to the local fishing industry.

- In OC OTEC research where lysing occurs, the usability of nutrients in the discharge is expected to increase. In addition, dissolved oxygen is expected to decrease. An increase in organic material could result in increased rates of biofouling in closed-cycle heat exchangers and low dissolved oxygen levels could adversely affect heat exchanger corrosion rates. A monitoring program is required to provide quantitative estimates of this impact if it should occur.

- Disposal of mariculture discharges into a shallow trench may result in some stimulation of the algal turf along the shore due to restricted opportunities for grazing by herbivorous fishes. Visual impact could be significant to some observers. Because of the absence of a "near-shore coastal regime" in the Keahole area, this impact is anticipated to be localized in the general vicinity of discharge facility.

- Certain chemical additives used in mariculture operations, unknown at the present time, could potentially impact the marine environment. The nature of all new chemicals should be reported and investigated prior to its introduction into the discharge system as it may significantly impact the resident epifauna.

Proposed Mitigation Measures

- Monitoring: Potential degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. A proposed water quality monitoring program has been designed to provide insights to an understanding of these impacts. Present plans for NELH include a gradual increase in volumes of water to be used. This will allow the monitoring program to provide early detection

of any impacts. In addition, the potential impacts are reversible. That is, if discharges are halted, the affected ecosystems could be expected to revert to baseline conditions.

The water-quality monitoring activities at NELH will enhance knowledge of coastal and ocean processes and facilitate the development of standards for mariculture and other ocean-related research and development activities throughout the state. This item is top priority because preservation of the integrity of the cold and warm ocean water resources is fundamental for the continued growth and success of the proposed projects. If the water is degraded, the projects will no longer have the unique resource necessary to attract the energy and mariculture activities important to their success.

o Reoxygenation: Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use in OC OTEC research. Reoxygenation through aeration is recommended to mitigate impacts on the environment from discharging oxygen-poor water. According to some scientists contacted by Oceanit Laboratories, reaeration could be easily accomplished by a fountain or any other turbulent motion in the air. However, it would be environmentally and economically beneficial to reinject the removed gases into the water prior to discharge. Research at U.H. indicates that this is very possible. Reinjection studies will be part of the research effort at NELH.

In any event, monitoring will be an important consideration of any research done on this problem as the degree of environmental impact of discharging oxygen-poor water is unknown. The proposed monitoring program should provide early detection of any adverse impacts so that alternative disposal methods can be instituted. Any adverse impacts on the environment are reversible and the ultimate mitigating measure would be to cease discharging oxygen poor water in a manner that affects the nearshore environment.

Alternatives Considered

Alternative disposal methods considered include: direct disposal via canal with ponding area; disposal into shallow trenches; and disposal into deep lined injection wells.

Theoretically, discharge into a canal with ponding area appears to be an environmentally acceptable method of disposing of OC OTEC return flows. However, before the same type of ponding area that is currently in use can be used for larger discharge volumes, additional investigations would be required to determine the physical characteristics that cause the existing pond to act as a "reactor vessel" that adds oxygen, removes nutrients and increases the discharge water temperature to approximately that of the ambient seawater. For this reason, and the fact that the land area for a ponding area might be prohibitively large in relation to the area available to NELH and that without additional studies NPDES permit requirements would be difficult to meet, discharge of 16,100 gpm of OC OTEC waters via canal was determined to be unfeasible at the present time.

Of the alternative methods and locations for disposal of the OTEC water analyzed, the most environmentally benign is deep injection. As proposed, the deep injection wells would provide the greatest residence time, about three months, and would create seepage through the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation of the algal turf at the shoreline it would come at substantial additional cost.

A cost comparison between trenches and deep injection wells indicates that, in general, deep injection wells are approximately 15 times more costly to construct and operate than disposal by trench within NELH. Without empirical data from monitoring a trench system, the theoretical minimal improvement in avoiding impacts to the environment by disposing via injection wells does not appear to warrant the additional cost.

Disposal of OTEC water via a mixed-water discharge pipe was assessed in the HTDC FEIS. This option is still available should the intensive monitoring program prove that unacceptable environmental impacts occur as a result of using other less-costly methods of disposal.

In terms of this SEIS, no project would mean no further funding by the U.S. DOE for both the proposed ocean water supply system and future research programs for OC OTEC at NELH until such a time as funds became available and a mixed-water discharge pipe could be designed and constructed. U.S. DOE OC OTEC research at NELH could be delayed for several years.

No project would also mean that research opportunities to monitor low-cost disposal methods would be lost. This could be significant in that a potential opportunity to transfer cost-effective, reliable disposal technology to undeveloped countries would be lost. In addition, the State of Hawaii is actively seeking high-tech mariculture enterprises to diversify the economy of the State. A cost-effective disposal technique might make the difference between success and failure for these "state-of-the-art" fledgling businesses.

Unresolved Issues

- Various approaches to reoxygenation of degassed OC OTEC waters are being discussed. The process is in the research stage. The specific process for this mitigating measure is unresolved and will be the subject of research. Monitoring of effects of degassed discharged water on nearby marine communities will serve to minimize the potential of adverse impacts until this is accomplished.

- A proposed water quality monitoring plan has been presented in this SEIS. Public input from the SEIS review process and further discussions with NELH, National Marine Fisheries Service, Fish and

Wildlife Service and the State Department of Health will be required before a specific plan is finalized and funded.

Compatibility With Land Use Plans

- o State Land Use Law: The NELH site is in the Urban District, therefore there is no conflict.

- o Hawaii Coastal Zone Management Objectives and Policies: Coastal Zone Consistency Certification is being addressed through the U.S. Army Corps of Engineers permitting process.

- o Conservation District Policies and Regulations: A Conservation District Use Permit (CDUP) for use of approximately 2940 acres of ocean waters and submerged lands for ocean research, alternative energy and mariculture research, and commercial mariculture and energy activities and facilities, including construction of up to 15 additional warm and cold water intake pipelines, was approved by the Board of Land and Natural Resources on July 23, 1986. Conditions on this permit require monitoring of anchialine ponds -- as described in this SEIS -- and approval of an acceptable seawater disposal system for OC OTEC water.

- o Hawaii Water Quality Standards and Permits: Coastal water quality is protected by the federal Clean Water Act (33 USC 1251 et. seq.) and the State Environmental Quality Act (Chapter 342, HRS), administered by the Hawaii State Department of Health. The two applicable regulations are Water Quality Standards and Water Pollution Control, Chapters 54 and 55 of Title 11, Administrative Rules.

  The waters off Keahole are classified as AA in the Water Quality Standards. The objective of this class is to keep these waters in their natural pristine state as nearly as possible with an absolute

minimum of pollution. Uses to be protected in this classification include oceanographic research.

Discharge into a trench is not covered by any specific environmental regulation. However, Section 33 of Chapter 342 contains a general prohibition against the discharge of any pollutant into state waters, which by definition include ground water. Although a specific permit would not be required, the proposed trench disposal system would need review by and approval of the Department of Health before it is implemented.

- Hawaii County General Plan: In conformance.

- Hawaii County Special Management Area: The County of Hawaii Planning Department will be requested to review the recommended disposal method and facility for conformance to the existing SMA permit for NELH.

The Hawaii State Plan: Objectives and policies (Part I) and priority guidelines (Part II) in relation to the economy, energy, etc., as described in the HTDC FEIS.

Environmental Policy: Chapter 344, HRS - State Environmental Policy Act - Conforms

Air Quality: Federal Clean Air Act, as amended (42 U.S.C. 1857h-7 et seq. and State Environmental Quality Act (Chapter 342 HRS) - No effect expected

Fish and Wildlife Habitat: Fish and Wildlife Coordination Act (16 U.S.C. Sec.661 et seq.) - Coordination is being accomplished through U.S. Army Corps of Engineers permit process.

Historic and Cultural Properties: National Historic Preservation Act of 1966, as amended (16 U.S.C. 1251 et seq.) -No historic sites will be disturbed by construction of disposal facilities.

Necessary Reviews and/or Approvals

The following list of necessary reviews and/or approvals does not include compliance activities to be undertaken by the U.S. DOE.

Federal

Clean Water Act (33 USC 1251 et. seq.)
-Administered by the State. See Department of Health

Federal Aviation Agency (FAA)
-Notice of construction within 20,000 feet of airport runways (14 CFR 77)

U.S. Coast Guard
-If required, license to construct facilities on Coast Guard land.

State of Hawaii

Department of Agriculture
-Mariculture operations culturing exotic species: Permit to import non-indigenous species.

Department of Health
-Trench Disposal: Review and approval for compliance with Section 33, State Environmental Quality Act (Chapter 342, HRS)
-Disposal Via Canal: Existing National Pollution Discharge Elimination System (NPDES) Permit must be modified if discharge exceeds 1500 gpm.
-Underground Injection Wells (UIC): Permit required even though proposed site is in an exempted aquifer area.
-Mariculture operations involving shellfish: Shellfish Sanitation Certificate.
-Individual domestic wastewater disposal systems: Permit required.

Department of Land and Natural Resources
-Satisfaction of and request to remove condition #8 -- approval of an acceptable seawater disposal system for 16,100 gpm of OTEC water -- from CDUA HA-1862.
-Historic Sites review.
-Approval of plans for construction within the Conservation District.
-Approval of all NELH tenants' subleases.

Hawaii County

Special Management Area (SMA) Use Permit
-Amend existing SMA #77 if required.
Subdivision Application and Approval.

Plan Approval and Various Construction Permits.

PART I: INTRODUCTION

A. NATURAL ENERGY LABORATORY OF HAWAII

The Natural Energy Laboratory of Hawaii (NELH) was established by the Hawaii State Legislature in 1974 by Act 213 to manage and operate an outdoor research facility on approximately 322 acres of state-owned land at Keahole Point on the island of Hawaii for research, development and demonstration of natural energy resources (Figure I-1). Legislation passed in May 1984 amended the NELH enabling legislation (Ch. 227, HRS) to allow on-site commercialization of successful research and development projects. NELH is governed by a managing board consisting of seven ex-officio voting members. NELH is placed within the Department of Planning and Economic Development (DPED) for administrative purposes.

The Keahole site was selected for the NELH facility because of the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual solar insolation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. The unique characteristics of the site make it an excellent environment for conducting ocean related research such as Ocean Energy Thermal Conversion (OTEC) and aquaculture.

OTEC is a power generating system that uses the temperature difference between warm surface water in the tropical ocean and the cooler water at depth to run a heat engine. Research on two types of operating cycles, closed and open, is presently being conducted at NELH. In closed-cycle (CC) OTEC, a low-boiling point working fluid (ammonia or Freon) flows through a series of components in a closed loop. The main components are two heat exchangers, a turbo generator and a feed pump. The working fluid is vaporized by heat from the warm seawater and passed through a turbo generator to generate electricity.

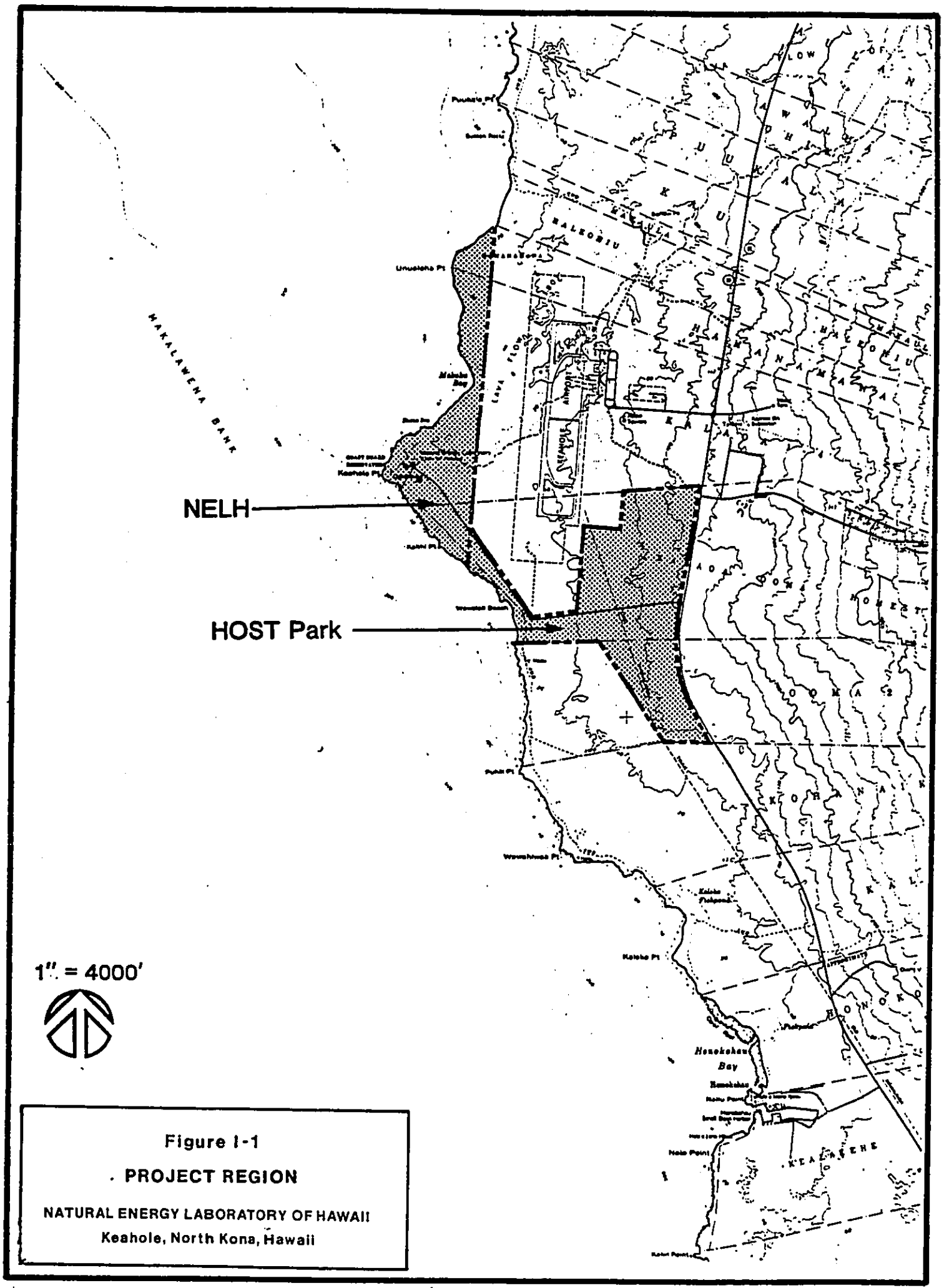


Figure I-1

PROJECT REGION

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

To complete the cycle, the fluid is then condensed by the cold seawater which has been transported to the surface via a cold water pipe.

In open-cycle (OC) OTEC, warm surface water is used as the the working fluid. Prior to evaporation the water is degassed, removing dissolved oxygen, nitrogen, carbon dioxide, and trace gases from the water. Steam is produced after a partial vacuum is created over the warm seawater. The steam, after passing through a turbine, is condensed using cold ocean water.

The U.S. Department of Energy (DOE) is planning to expand its funding (through the Solar Energy Research Institute (SERI)) of OC OTEC tests at NELH. Expansion facilities to support this research program will be constructed by the State of Hawaii with the financial support of the DOE. These new expanded facilities are also planned to include: (1) a water system test facility for developmental research for open-cycle OTEC; and (2) an expanded facility for experiments with OTEC-related mariculture.

An operating open-cycle demonstration plant will be built at NELH upon completion of approximately 2 to 3 years of research and testing by SERI. It is currently planned that this plant, which will provide a gross output of approximately 165 kW, will utilize 16,100 gpm of mixed warm and cold seawater (NELH, 1985).

The availability of high quality deep cold seawater used for OTEC experiments has also made possible many types of aquaculture with commercial potential. The deep cold water, which is continuously pumped ashore at NELH, has proven attractive for aquaculture operations because of its abundance of nutrients, low level of pathogens, and desirable temperature range for high value temperate species. As a result of the success of Hawaiian Abalone Farms (HAF) and the Cyanotech Corporation, which have demonstrated the suitability of the deep cold water for abalone culture and the commercial

production of algae for use as food supplements, fertilizers and pharmaceuticals, aquaculture activities have become as great an interest to potential researchers and developers as the energy-related projects of the facility.

B. RELATIONSHIP TO THE HAWAII OCEAN SCIENCE AND TECHNOLOGY PARK

To demonstrate Hawaii's commitment to the development of high technology enterprises, the 1983 Hawaii State Legislature created the High Technology Development Corporation (HTDC). HTDC is empowered to develop and administer industrial parks for high technology use and issue special purpose industrial revenue bonds to finance their construction. In the early 1980s, the NELH Board and staff recognized the need for providing additional sites when successful projects at the laboratory would expand into commercial operations. As a result one of the corporation's first development projects will be the Hawaii Ocean Science and Technology (HOST) Park, scheduled to begin construction in November 1986, on 547 acres of state-owned lands located adjacent to NELH (Figure I-1). A major reason for developing this particular site for ocean-related "high tech" activities is its proximity to NELH.

The State of Hawaii (through HTDC) is the developer and owner of the property, and will offer 35-year leases to qualified tenants. The entire area is master-planned for industrial use. A major objective in marketing HOST Park is to target industries that can utilize the unique resources of the Keahole Point area that NELH has demonstrated to be valuable for ocean-related high technology development. The types of companies that were identified as being prospective occupants of the park are high intensity aquaculture, alternate energy, marine biotechnology, pharmaceutical development, oceanography and tropical agriculture.

Developing HOST Park on property adjacent to NELH is intended to facilitate the transition from demonstration to full scale commercial operations. NELH will act as as an "incubator" for projects as they grow from the research stage to large scale commercial production. Together, the NELH and the HOST Park will be offered as an attractive and complementary package to high technology corporations which may be interested in establishing their operations in Hawaii.

C. PURPOSE AND NEED FOR PROPOSED MODIFICATIONS

An environmental impact statement for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii (HTDC FEIS) was accepted by the Governor in September 1985. Among the actions assessed in the statement was the disposal of 42,000 gpm of seawater return flows from OTEC and mariculture operations at NELH at full development and the disposal of 100,000 gpm from fully developed commercial operations at the proposed HOST Park. NELH discharge would be disposed of on-site by trench, well, canal and mixed-water discharge pipe, and HOST Park seawater return flows would be disposed of in trenches on the park site.

At the time the HTDC FEIS was accepted, the State of Hawaii planned to install a cold water pipe and pump system for HOST Park and the DOE was planning to fund a cold and warm water system for OTEC research. Subsequently, the DOE learned that it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. Rather than installing separate seawater pipe systems, DOE and the state entered into a cooperative cost-sharing agreement to provide the required ocean water for both projects with one seawater system. This combined system will include both cold and warm water intake pipelines and a pump station to service DOE, OTEC, NELH and HOST Park activities.

The mixed-water discharge pipe that was originally proposed as the means to dispose of the projected seawater that will be used in forthcoming OTEC experiments proved to be too expensive and cannot be funded at the present time. Alternative, less costly methods of disposal for a projected 16,100 gpm of mixed warm and cold OTEC seawater flows were then investigated. These included direct disposal via canal, trenches, deep lined injection wells and/or a combination thereof.

Because of NELH's concern for the preservation of the pristine quality of the intake waters, detailed assessments of the effects of OTEC discharge on nearshore and offshore water quality, including an evaluation of impacts on the biological environment, were prepared. Cumulative impacts of OTEC seawater return flows plus other on-site discharges, such as mariculture, were also evaluated prior to recommending method(s) to be used to dispose of OTEC water in lieu of the mixed-water discharge pipe.

D. ENVIRONMENTAL COMPLIANCE

In accordance with Section 11-200-27 of the Environmental Impact Statement Rules, a request for determination regarding the proposed modification to the methods of seawater return flow disposal at NELH (as disclosed in the HTDC FEIS) was submitted to the State of Hawaii, Office of Environmental Quality Control (OEQC). After review of the Request for Determination and the subject FEIS, OEQC determined, pursuant to the responsibility delegated to the accepting authority as stated in Section 11-200-27, Environmental Impact Statement Rules, that a supplemental statement was required because the alternative disposal systems for OTEC seawater flows may have different impacts than those described in the accepted FEIS.

This draft supplemental environmental impact statement has been prepared to comply with Chapter 343, Hawaii Revised Statutes and with

Section 11-200-27 of the Hawaii State Environmental Impact Statement Rules regarding supplemental statements. The accepted HTDC FEIS is incorporated into this document by reference. The information contained herein is also intended to provide the basis for, but not substitute for, any environmental compliance activities required by the Federal government.

PART II: PROJECT DESCRIPTION

A. ENERGY PROGRAMS AND PROJECTS

(See Appendix A for a more detailed description of energy programs and projects.)

1.0 Ocean Energy Technology

The U.S. DOE has identified the development of ocean energy technology as one of its long-range missions. Much of the current research at NELH has been associated with OTEC operating systems and related research. Development of the pumping facilities necessary for a CC OTEC experiment involved much research into corrosion of equipment and cables in seawater, bio-fouling counter-measures, heat transfer, and water quality analysis.

The following areas have been identified for future ocean energy technology research (DOE, 1985): (a) research and analysis on thermodynamics; (b) experimental verification and testing; (c) materials and structural research; and (d) oceanographic, environmental and geotechnical research.

2.0 OC OTEC

OC OTEC power is generated by a large low pressure turbine driven by water vapor produced from the evaporation of warm surface seawater. The evaporated seawater, working fluid, is later condensed by cold deep seawater. To increase the efficiency of the evaporator, dissolved gasses, primarily oxygen and nitrogen, should be removed from the warm seawater before it reaches the evaporator.

OC OTEC research focuses more on degassing than materials selection. OC OTEC research studies currently being conducted at NELH

concern heat and mass transfer and gas sorption kinetics which are experimenting with processes for degassifying warm and cold seawater. The degassification process changes the available form of organic carbon and other nutrients due to the low pressure environment via lysing of plankton and other microorganisms. If condenser tubes are used, fresh water can be produced; otherwise, the condensate is discharged with the cold seawater.

The DOE is planning to initiate scoping tests on various OC OTEC components using a newly designed Heat and Mass Transfer Scoping Test Apparatus (HMSTA) which was designed by the Argonne National Laboratory. These tests are programmed to commence in early 1987. In general, the experiments will focus on development of optimal removal techniques for degassing both warm and cold water. The apparatus will be varied from 0 degassing to 100% degassing in order to determine the limits of the process. At the present time it is predicted that 50 to 60% of the gasses will come out, primarily oxygen. As an additional experiment, reaeration techniques will be tested (Penney, 1986). Other future OC experiments anticipated for NELH include tests of direct contact and conventional heat exchangers; studies of non-condensible gases including basic sorption kinetic studies and their effects on heat transfer; and, tests on turbine materials and dynamics and mist lift cycles. (NELH, 1985).

It is anticipated that mixed seawater flows required to carry out the initial OC OTEC scoping experiments and testing will range from 3,000 to 5,000 gpm. The duration of each experiment is expected to range from a few hours to a few days.

3.0 165 kW Open-Cycle Demonstration Plant

The Solar Heat Research Division of the Solar Energy Research Institute (SERI), a Department of Energy core group, is also developing a research experiment to establish the feasibility of producing significant amounts of net power from an OC OTEC system

(Figure II-1). The experiment is sized at 165 kW of gross power and is adequate to evaluate turbine performance and system process interactions at a scale that can be projected to a commercial market entry system of 5 to 15 mW of electrical power (SERI, 1985). Figure II-2 presents a schematic illustration of large scale OTEC experimental equipment anticipated to be installed at NELH.

It is anticipated that initial testing will require up to 5,000 gpm of combined warm and cold seawater and will continue for approximately 3 to 4 years. The 165 kW OC demonstration, projected to be operating in 1991, will require 16,100 gpm mixed ocean water. Testing of the 165 kW plant is expected to run 24-hours a day for approximately 8 months to one year (Lewis, 1986)

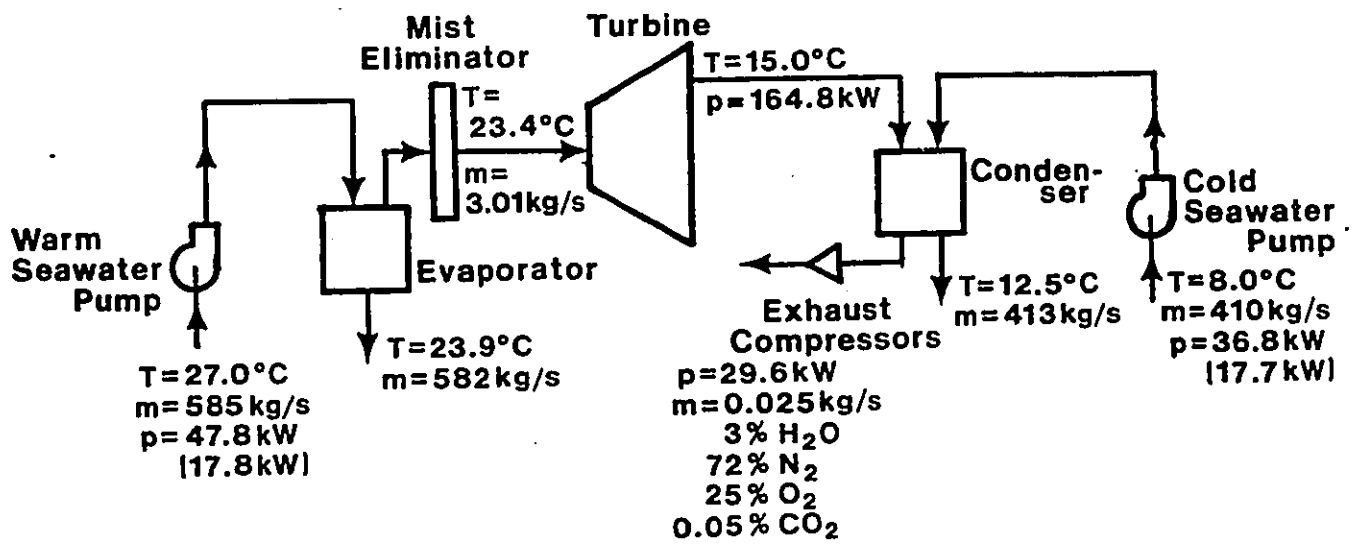
4.0 Seawater Return Flows from Planned Open-Cycle Experiments

When the OC OTEC 165 kW demonstration plant is in operation, approximately 16,100 gpm of mixed seawater is anticipated to be discharged. The seawater will be mixed in a ratio of (cold:warm) of 1:1.5. At the discharge point the temperature would be approximately 19°C; some additional warming will occur before the water reaches the ocean. These ratios and temperatures will vary during the initial 3,000 to 5,000 gpm experiments.

5.0 Recommended Method of Seawater Return Flow Disposal

5.1 Discharge Into a Trench Within the NELH Compound

The disposal facility recommended for OTEC discharges is a shallow trench located within the NELH compound (Figure II-3). The recommended trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at its closest point. The specific location of the trench within the NELH compound should be determined after a more detailed site analysis is undertaken.



Net Power = 164.8 − 47.8 − 29.6 − 38.6 = 46.8 kW
(164.8 − 17.8 − 29.6 − 17.7 = 99.7 kW)

Current design dictates a 3.75 m additional seawater head loss since the tank level is lower than barometric. Pumping power requirements for barometric level vacuum chambers are shown in parentheses.

Source: SERI, 1985

Figure II−1
OC OTEC.
EXPERIMENTAL FLOW DIAGRAM
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

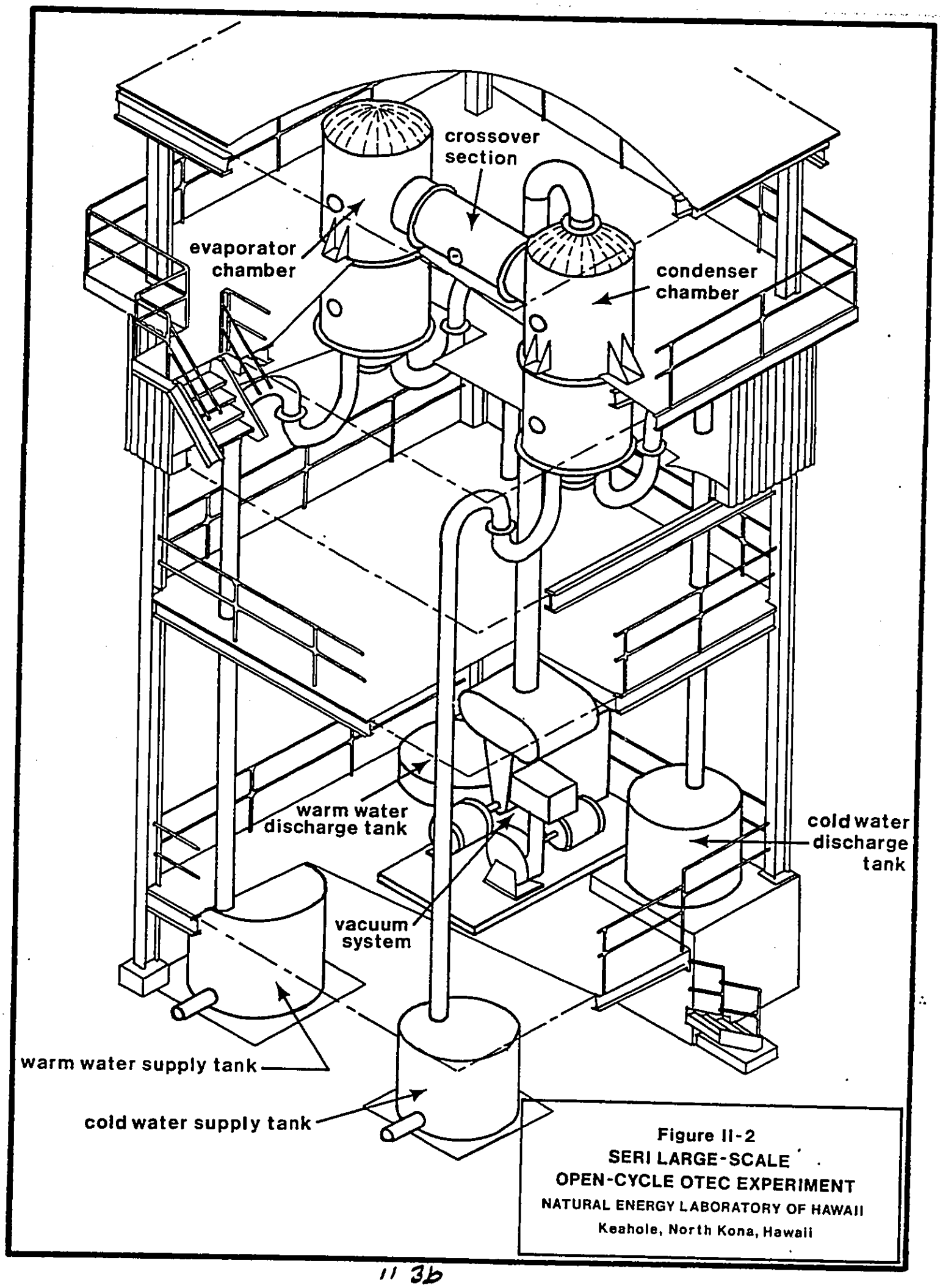


Figure II-2
SERI LARGE-SCALE
OPEN-CYCLE OTEC EXPERIMENT
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

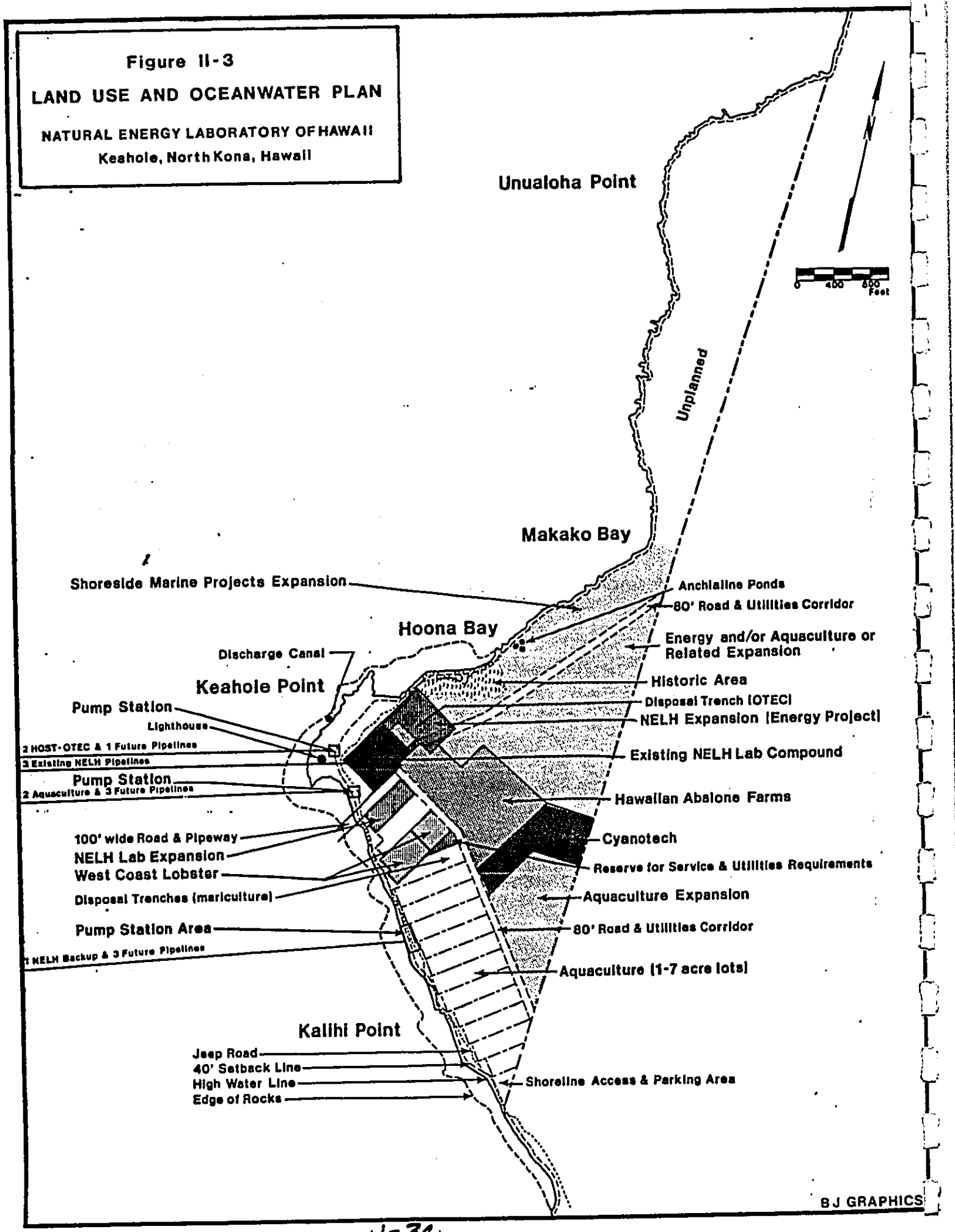


Figure II-3
LAND USE AND OCEANWATER PLAN
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii
Unualoha Point
Unplanned
0 400 800 Feet
Makako Bay
Shoreside Marine Projects Expansion
Anchialine Ponds
80' Road & Utilities Corridor
Hoona Bay
Energy and/or Aquaculture or Related Expansion
Discharge Canal
Keahole Point
Historic Area
Disposal Trench (OTEC)
Pump Station
NELH Expansion (Energy Project)
Lighthouse
2 HOST-OTEC & 1 Future Pipelines
3 Existing NELH Pipelines
Existing NELH Lab Compound
Pump Station
2 Aquaculture & 3 Future Pipelines
Hawaiian Abalone Farms
100' wide Road & Pipeway
Cyanotech
NELH Lab Expansion
West Coast Lobster
Reserve for Service & Utilities Requirements
Disposal Trenches (mariculture)
Aquaculture Expansion
Pump Station Area
80' Road & Utilities Corridor
1 NELH Backup & 3 Future Pipelines
Aquaculture (1-7 acre lots)
Kalihi Point
Jeep Road
40' Setback Line
High Water Line
Shoreline Access & Parking Area
Edge of Rocks
BJ GRAPHICS

A trench with the capacity to dispose of 16,100 gpm of OTEC water can be either 5-foot-wide by 5-foot-deep by 193-foot-long or 10-foot-wide by 10-foot-deep by 79-foot-long. In order to allow for non-homogeneity of the hydrogeologic characteristics of the disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage, the actual excavation should probably be twice the trench length. The exact dimensions of the trench should be determined during the design of the facility. If the full trench is not required for testing of the ocean water supply system, a smaller trench might be tested and monitored with lesser initial flows and the trench size could be modified based on this experience. A cross-section of a proposed disposal trench utilizing a perforated pipe and boulder or crushed lava backfill is presented in Figure II-4.

5.2 Monitoring

An important consideration for any on-land disposal method is monitoring. Because there are unknowns associated with OC OTEC discharge water and its impact on the environment, it is strongly recommended that a water quality monitoring program be instituted immediately and continued throughout the 3,000 to 5,000 gpm scoping tests of the OC OTEC process. The data collected in this program can be continually evaluated during this three to four year time period and alternative disposal facilities, such as deep injection wells, can be constructed if adverse impacts occur. Because the identified potential impacts are generally reversible (Part IV), the risk to the environment and future OTEC research under these conditions would be minimal.

Monitoring should take place at the disposal site, at the warm water intake and offshore. Because trench disposal could also affect the brackish water lens, the anchialine ponds north

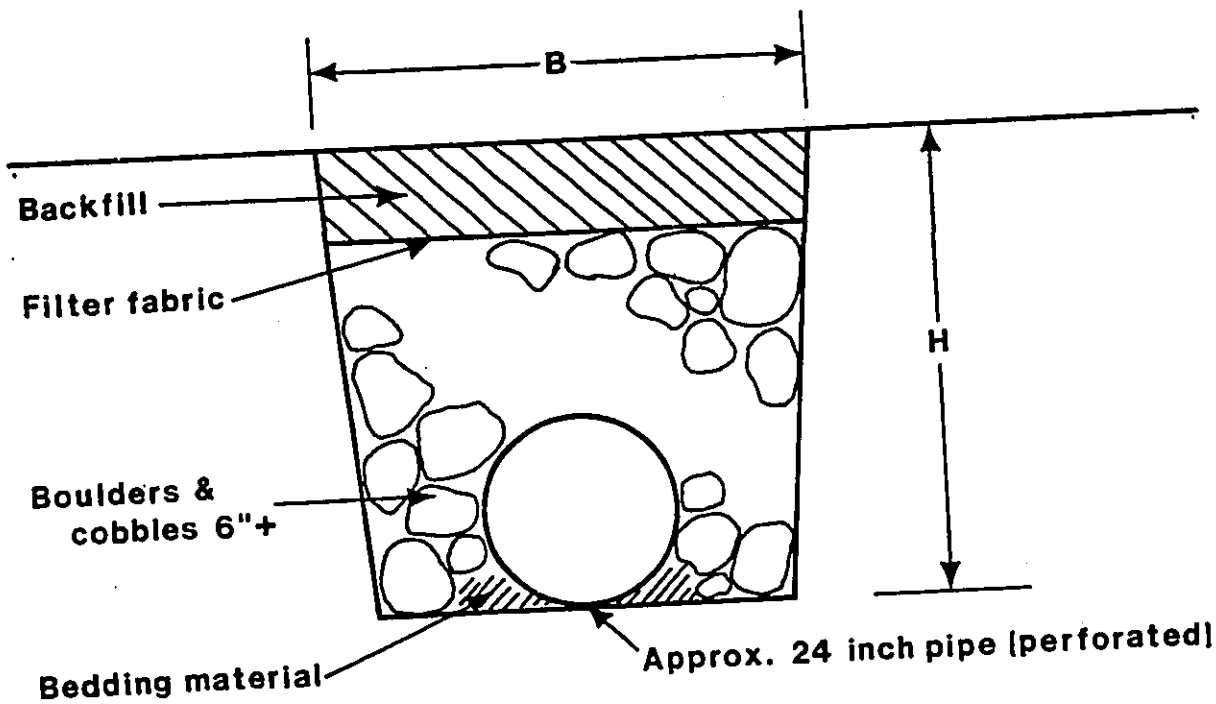


Figure II-4
DISPOSAL TRENCH CROSS SECTION
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

of NELH should also be monitored. A suggested water quality monitoring program is presented in Appendix B of this SEIS.

Operations of the trench should also be monitored to collect operation and maintenance data. The ultimate size of the trench might also be determined by research and experience with lesser flows associated with the preceding phases of the experimental process. Testing and monitoring accomplished in the earlier phases might indicate that smaller trenches are acceptable. This could be another test objective of the phased OTEC expansion program at NELH.

B. MARICULTURE PROJECTS

1.0 Future Mariculture Projects

The availability of high quality deep cold seawater makes possible many types of aquaculture with considerable commercial potential. Based on the experience of the past three to four years, it appears that significant potential exists for commercialization of several species of aquatic plants and animals, utilizing the properties of low temperature, high nutrient content and lack of pathogens that are found in the deep cold water. Appendix B (GK & Associates) describes the characteristics of the various mariculture projects suitable for NELH and for the adjacent HOST Park. The species described below, and possibly others, could be grown as intermediate products for consumption by other cultured species; as agricultural feed supplments; for human consumption; for water treatment purposes; for marketable seed stock; or for by-products such as beta-carotene or agar. Briefly, they are:

- Microalgae, such as Chaetoceros, Dunaliella, Tetraselmis, Spirulina, and Phaeodactylum;

- **Macroalgae**, such as Gelidium, Gracilaria, Laminaria, and Nori seaweed (Porphyra tenera);

- **Marine Mollusks**, abalone (Haliotis sp.), oysters (Crassostrea, Ostrea), clams (Tapes, Mercinaria, Tridacna), and opihi (Celana sp.);

- **Crustaceans**, such as shrimp (Penaeus) lobster (Homarus, Panulirus) and brine shrimp (Artemia);

- **Finfish**, such as coho salmon, steelhead trout, rainbow trout, mullet, tilapia, carp and mahimahi.

2.0 Seawater Return Flows from Projected Mariculture Operations

At full development of NELH it is projected that an additional 25,900 gpm of seawater return flows from mariculture operations will be generated. The constituents of the discharge water will depend on the culture organism and its intended use. The overall warm and cold seawater mix is assumed to be 4:1.

3.0 Seawater Return Flow Disposal (25,900 gpm)

3.1 Discharge Into a Trench Makai of NELH Access Road (Figure II-3)

The disposal facility recommended for return seawater from mariculture operations is a trench located makai of the NELH access road. A potential location for this facility (adjacent to the NELH compound, parallel to and approximately 750 feet from the shoreline) is evaluated in Part IV of this SEIS. In order to facilitate NELH mariculture operations, however, the trench could be constructed anywhere southeast of this area as long as it is located adjacent to the access road. Because distance to the shoreline from the access road increases towards the HOST Park site, relocation of the trench to this alternative area would result in a decrease in concentration of

the discharge at the shoreline and less potential for biostimulation of the algal turf.

Disposal trench dimensions for the quantity projected at full development of NELH (25,900 gpm) are approximately 5-foot-wide by 5-foot-deep by 362-foot-long. If necessary the length of the trench can be shortened by digging a deeper trench. As with the trench recommended for OTEC discharges, the exact dimensions of the trench should be determined during the design of the facility. Monitoring and maintenance considerations described for OTEC water disposal are also applicable to mariculture discharges. The mariculture trench would be similar to the cross-section presented earlier in Figure II-4.

3.2 Other Methods of Mariculture Discharge Disposal

Based on the analyses of the efficiency of algal mats for treatment of OTEC and mariculture discharges prior to disposal (GK & Associates, Appendix B), it appears that low volumes of mariculture discharge (less than 1,000 gpm) could be disposed of via canal and pond systems without significant environmental impact. These systems would require approval of the Department of Health.

C. NELH DEVELOPMENT PLAN

The proposed NELH Land Use and Ocean Water Plan is presented in Figure II-3. Figure II-5 illustrates proposed improvements and expansion of the NELH laboratory compound (called the Seacoast Test Facility (STF) by the U.S. DOE).

1.0 STF Upgrades

As discussed in the HTDC FEIS, DOE and the State are currently in the planning and design phases of upgrading the energy research and

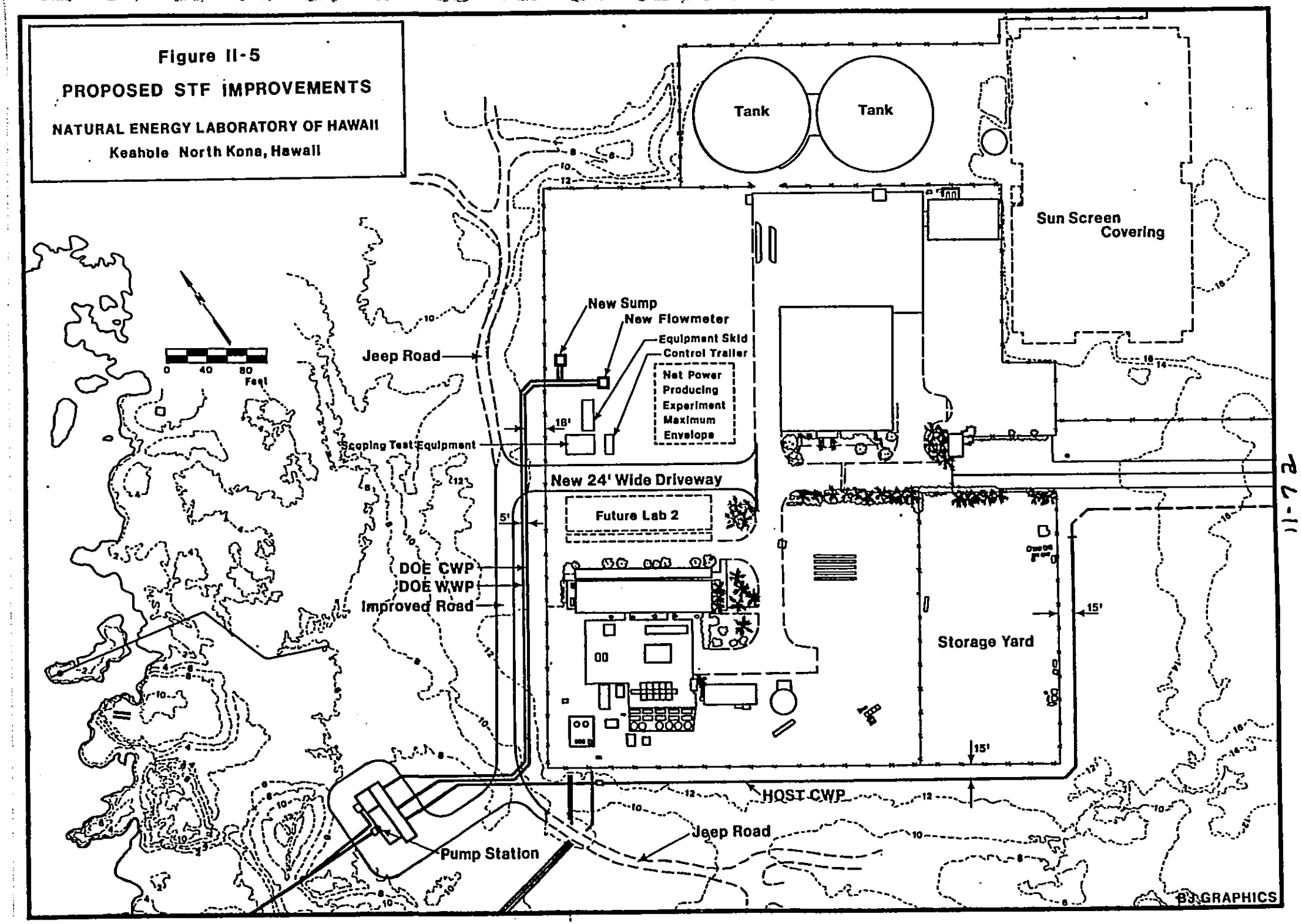


Figure II-5
PROPOSED STF IMPROVEMENTS
NATURAL ENERGY LABORATORY OF HAWAII
Keahole North Kona, Hawaii
Tank
Tank
Sun Screen Covering
New Sump
New Flowmeter
Equipment Skid
Control Trailer
Net Power Producing Experiment Maximum Envelope
Jeep Road
Scoping Test Equipment
New 24' Wide Driveway
Future Lab 2
DOE CWP
DOE WWP
Improved Road
Storage Yard
HOST CWP
Jeep Road
Pump Station
0 40 80 Feet
B3 GRAPHICS

testing capabilities of the STF. The purpose of the expanded test facility is to support experimental research on critical elements of advanced OTEC cycles as described in Section A. The facility is also being designed to support environmental, oceanographic and ocean engineering experiments to aid the development of diverse ocean energy supply operations. These upgrades will include:

- An experimental test facility to be located within the present laboratory property, occupying a space of approximately 1 acre;

- An improved road and new 24-foot wide driveway on the ocean side of the laboratory property;

- Four holding tanks (to maintain the appropriate pressures needed for the open-cycle experiment);

- A control building to house electrical power controls and a pumping station;

- Two ocean water intake pipes (1 warm and 1 cold), capable of delivering 9,500 gpm of warm surface seawater and 13,000 gpm of deep cold seawater. 6,500 gpm of cold seawater will be diverted to the adjacent HOST Park for use in commercial aquaculture and other ocean-related industries (Figure II-6);

- An ocean water pump station;

- Ocean water distribution lines from the pump station to the facility;

- A seawater return flow disposal facility for OTEC water; and

- New electrical power and control lines installed in underground ducts to the pumping station and within the NELH facility.

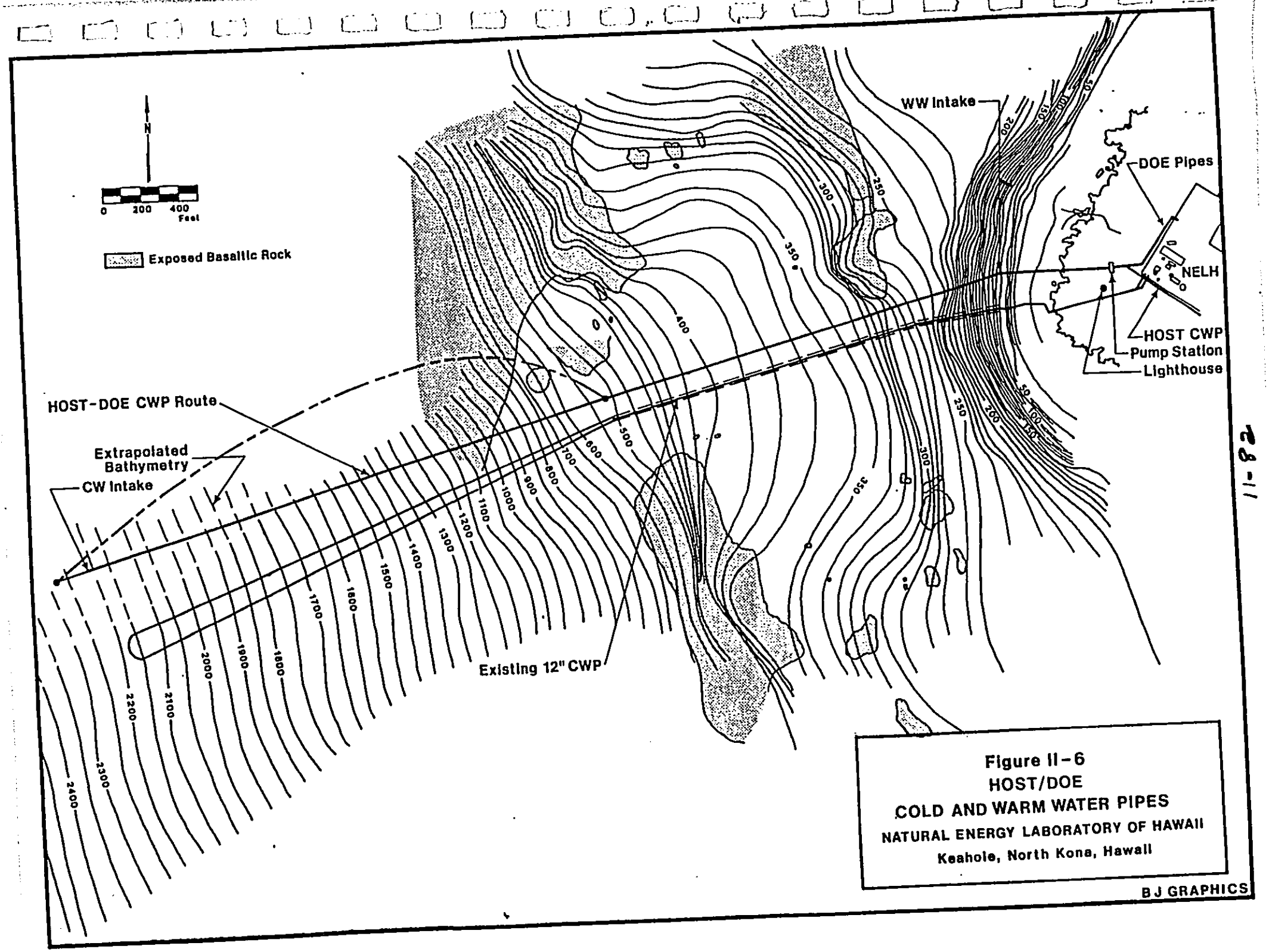


Figure II-6
HOST/DOE
COLD AND WARM WATER PIPES
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

2.0 Future NELH Laboratory Compound Expansion

The proposed land use and ocean water plan (Figure II-3) allocates an additional three acres north of the existing compound fence for future energy project expansion. The laboratory will also expand three acres to the south of the existing compound. The storage area will be moved to this new location so that more space is available near the laboratory building for intial research and development of mariculture projects.

3.0 R & D Aquaculture Expansion

In general, mariculture companies initially conduct research and development activities to determine appropriate mixes, temperatures and other water conditions for their products within the laboratory compound, moving outside the compound fence after the testing phases are completed. Approximately 60 acres, south of the laboratory fence and makai of the NELH access road, will eventually be subdivided into one to seven acre lots for use or lease by R & D firms.

4.0 Mariculture Commercial Demonstration Modules

Two major commercial demonstration projects are currently in operation on the NELH property: Hawaiian Abalone Farms (HAF), 21.3 acres and Cyanotech, 15 acres. An additional 18 acres (plus an optional 42) has been allocated for future use as commercial modules. These areas will be subdivided into 5 to 10 acre lots for lease to qualified entreprenuers.

5.0 Seawater Disposal Facilities

These facilities are anticipated to include disposal trenches, injection wells, algal ponds for pretreatment, and/or possibly some direct discharge canals.

6.0 Other Uses

When required for facility expansion, a new road will be constructed to the northern portions of the site. At that time, utility lines will be buried along the road.

7.0 Shoreside Marine Projects Expansion

Approximately 21 acres has been allocated for future shoreside marine projects such as solar ponds, wave energy conversion, and marine biomass energy.

8.0 Public Shoreline Access

An area of approximately one acre at the southern boundary of NELH (Figure II-3) is planned for future development as a public parking area to accommodate approximately 15 to 20 vehicles. Funding will also be requested for public restroom facilities at the time the parking area is constructed.

An additional small parking area for approximately 5 to 10 vehicles will be located at the northern terminus of the jeep trail, near Hoona Bay. This parking area, which will be used by fishermen who utilize the nearby shoreline for both day and night fishing, will not be graded or surfaced but will merely be delineated by poles or barrels and identified by a sign.

PART III: DESCRIPTION OF THE EXISTING ENVIRONMENT

A. LOCATION AND LAND USE

1.0 The Region

NELH is situated at Keahole Point, the westernmost portion of the island of Hawaii, within the North Kona District of the County of Hawaii (Figure III-1). According to the 1980 Census, North Kona had a resident population of 13,748 people (DPED,1983). The major urban center on the leeward side of the island, Kailua-Kona, is located in the District. The basic industries in North Kona are tourism, agriculture, and construction. The North Kona Coast is the County's major visitor destination area.

2.0 Land Use Designations

The NELH facility is located immediately makai of the Keahole Airport building restriction line; the property is situated within portions of the ahupua'a (land divisions) of Kalaoa 1-4, and 'O'oma 1, in Tax Map Key 7-3-43:42 (Figure III-2). It is within the State Land Use Urban District as reflected on State Land Use District Map H-2 (Keahole). The County of Hawaii General Plan Land Use Pattern Allocation Guide (LUPAG) Map designates the property as "Industrial" and it is zoned General Industrial (MG-3a). The property lies within the County of Hawaii's Special Management Area (SMA) and existing activities at NELH are currently permitted under SMA Permit #77. A Conservation District Use Permit (HA-1862) was recently approved by the BLNR authorizing NELH use of 2900 acres of offshore and submerged lands as an ocean use corridor.

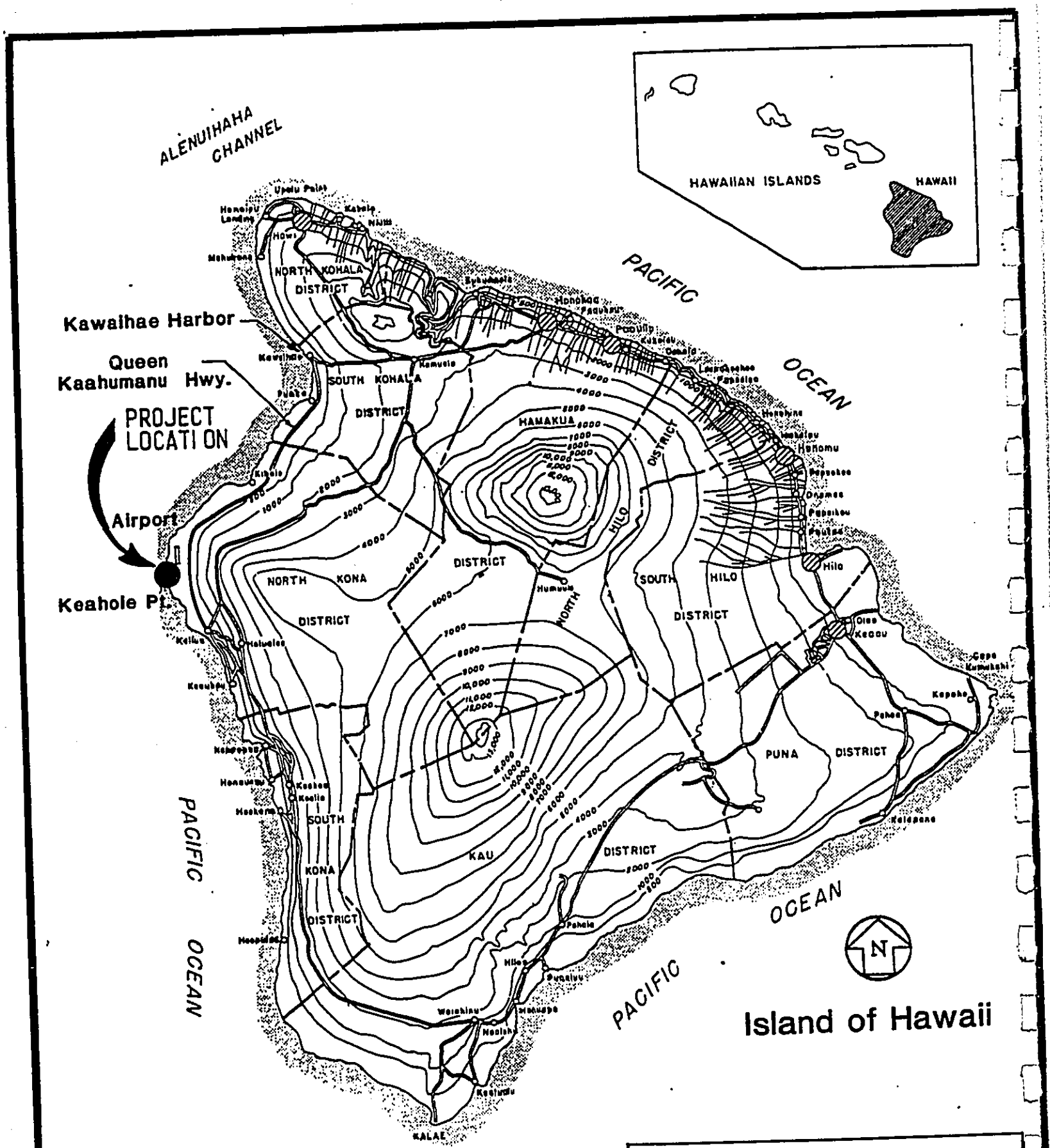


Figure III-1
PROJECT LOCATION
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

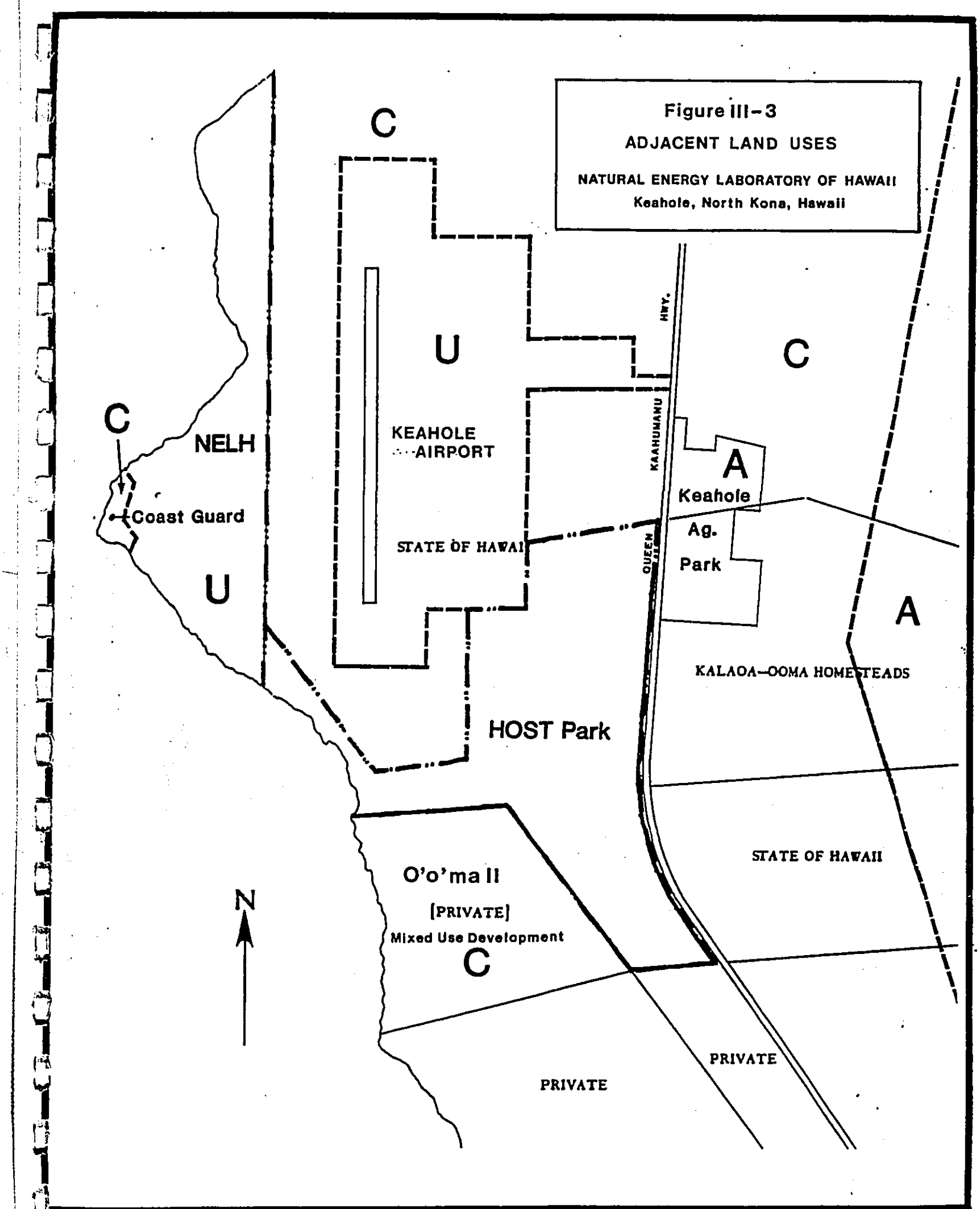


Figure III-3
ADJACENT LAND USES
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii
C
U
C
NELH
Coast Guard
U
KEAHOLE AIRPORT
STATE OF HAWAII
HWY.
KAAHUMANU
QUEEN
C
A
Keahole
Ag.
Park
A
KALAOA–OOMA HOMESTEADS
HOST Park
STATE OF HAWAII
O'o'ma II
[PRIVATE]
Mixed Use Development
C
N
PRIVATE
PRIVATE

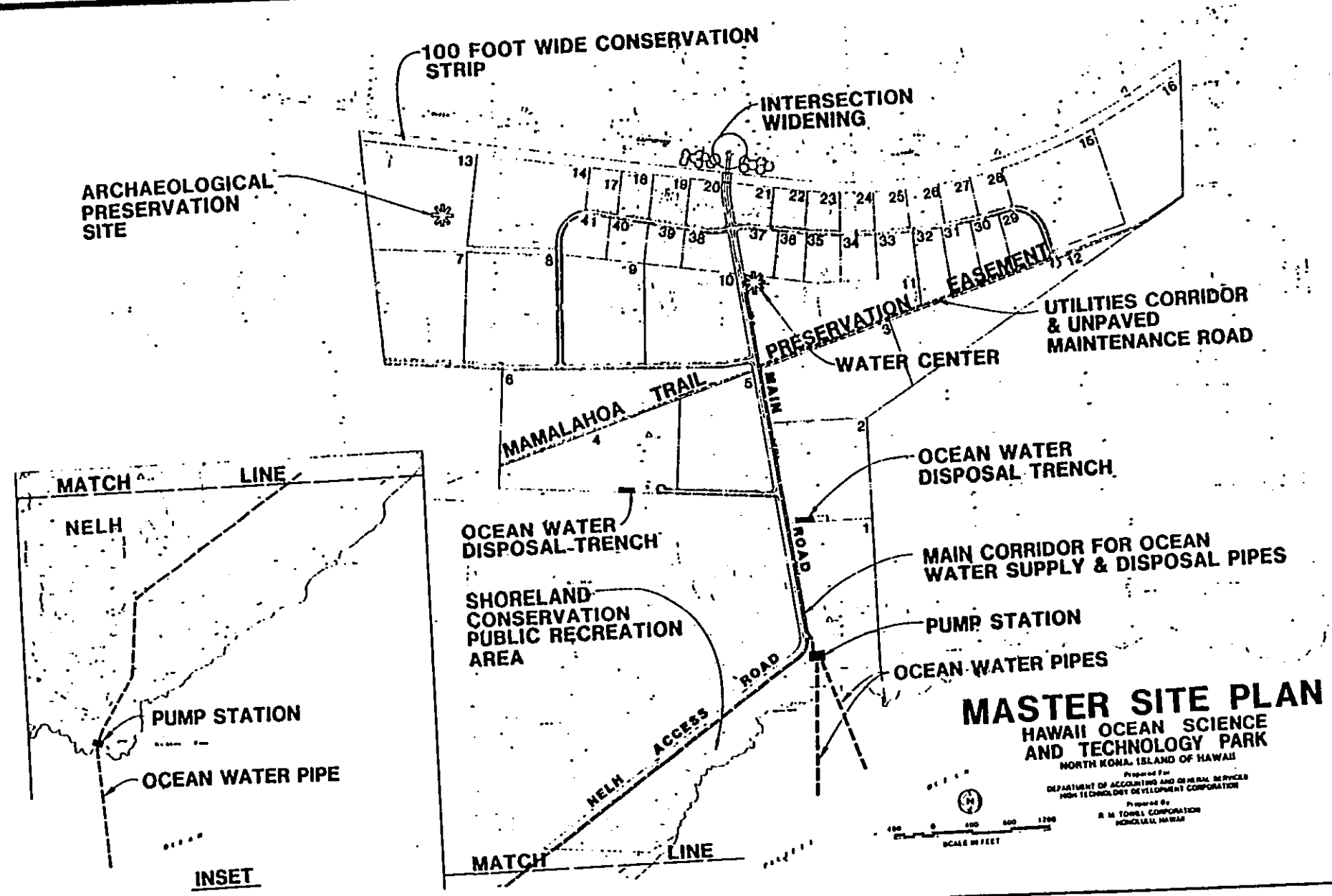


Figure III-4
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

92-111

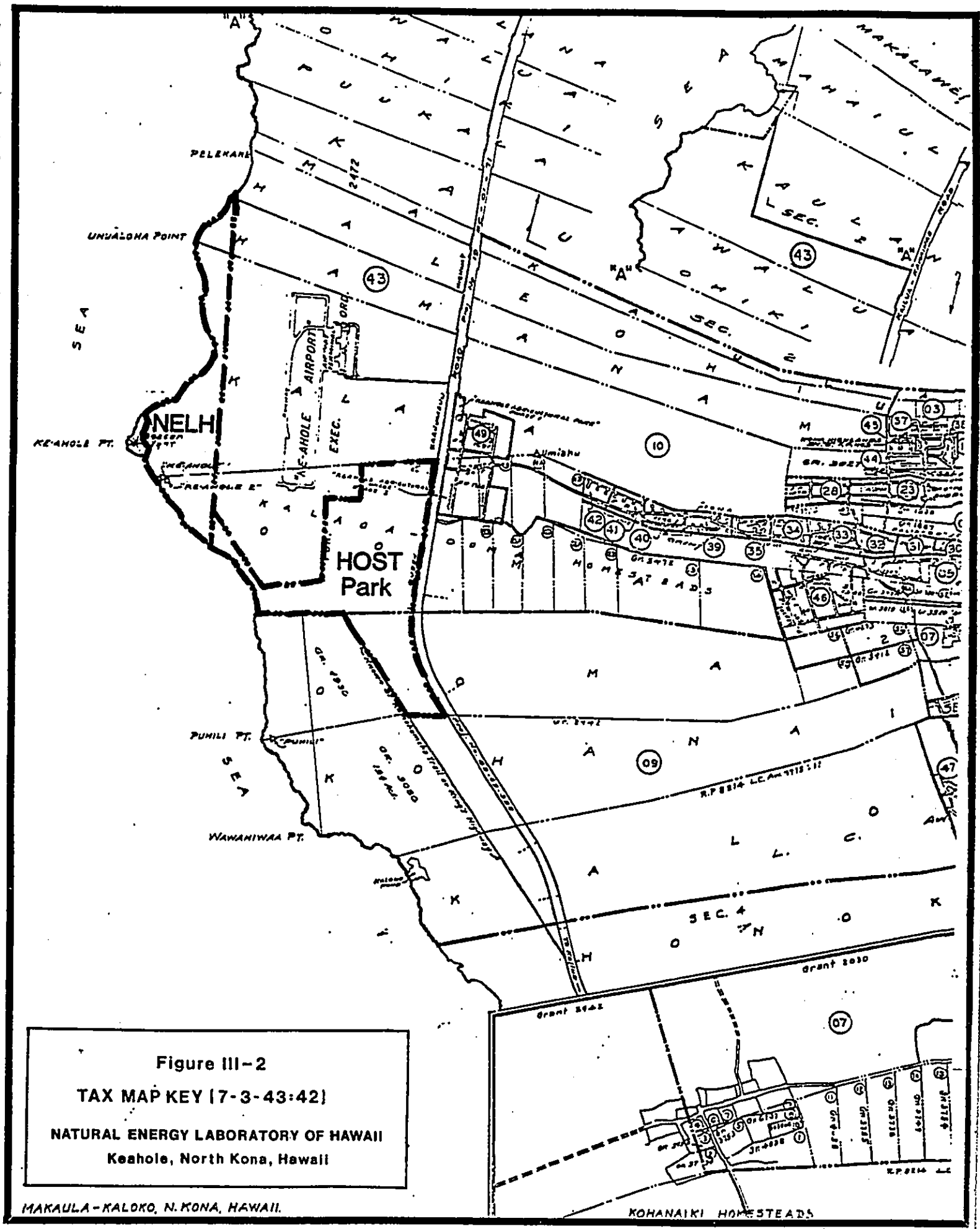


Figure III-2

TAX MAP KEY (7-3-43:42)

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona, Hawaii

3.0 Adjacent Land Uses (Figure III-3)

3.1 HOST Park

HOST Park is located to the north of NELH. The 547-acre site is being developed by the State of Hawaii High Technology Development Corporation (HTDC). All except 39 acres of ocean front land at the Park site have been classified Urban by the State Land Use Commission. The County of Hawaii General Plan Land Use Pattern Allocation Guide (LUPAG) Map designates the property as "Industrial" and the Hawaii County Council recently approved rezoning of the Urban portions of the parcel from Open to Industrial (ML-3A and MG-3A). Because the area is in the County of Hawaii Special Management Area, an SMA Permit (#239) was obtained. Proposed uses within the State Conservation District were approved by the BLNR in July, 1986 (CDUA HA-1862).

HOST Park is planned as a subdivision development with improvements, including access roads, roadway lighting, cold and warm ocean water systems, and potable water and electrical services. As shown on Figure III-4, the property will be subdivided into 25 lots of approximately 3+ acres for an approximate total acreage of 80 acres, and 16 lots of approximately 20+ acres for an approximate total of 350 acres. The lots in the subdivision will be leased to approved tenants by the HTDC. Each tenant will construct his own on-site improvements in conformance with the standards and criteria set forth in the Development Rules for the project. Construction of the first phase of infrastructure improvements is scheduled to begin in November, 1986. The primary users of HOST Park are anticipated to be a variety of high value mariculture species producers such as: microalgae; macroalgae; crustaceans; and mollusks.

3.2 Other Uses of Adjacent Government Land

A lighthouse operated by the U.S. Coast Guard occupies the tip of Keahole Point, seaward of NELH, and the Keahole Airport lies to the east of NELH. The State's Keahole Agricultural Park is located mauka of Queen Kaahumanu Highway in an easterly direction.

3.3 'O'oma II - Mixed Use Development

According to the Final EIS for 'O'oma II (Helber, Hastert et al., 1986), the landowner proposes to develop a multi-use complex on the + - 314-acre site. The proposed development will consist of a self-contained "intermediate resort" area including a hotel, multi-family residential units, an 18-hole golf course and clubhouse, and a marine park/visitor center. In addition, a major part of the development will be oriented toward growth of high-technology/aquaculture in the Keahole area, with land planned for light industrial uses and an office park.

A request to amend the Hawaii County General Plan to add 'O'oma II to the list of Intermediate Resorts and to change the existing Land Use Pattern Allocation Guide (LUPAG) Map from Open and Conservation to Intermediate Resort, Medium Density Urban and Industrial designations was submitted to the County of Hawaii in April, 1986. Shortly thereafter, a petition was filed with the State Land Use Commission to reclassify the property from State Conservation District to State Urban District (N. Nishikawa, 1986).

A CDUA (HA-1936) for consolidation and resubdivision of the parcel within the Conservation District has been accepted for processing by DLNR. This CDUA was submitted by the landowner in order to support a proposal to exchange 85 acres of the northern most portion of 'O'oma II with the State of Hawaii for 85 acres

of the existing HOST Park site. HOST Park lots affected by the exchange are anticipated to be lots 15, 16, 27 to 31 and a portion of 12 (Figure III-4). Environmental impacts of this land exhange are addressed in the 'O'oma II Final EIS (Helber, Hastert et al., 1986).

4.0 Existing Land Use, Facilities and Projects at NELH

(Figure III-5 illustrates the existing conditions at NELH)

4.1 Energy Projects and Facilities

Much of the current research at NELH is associated with open and closed cycle OTEC systems and related research. A CC OTEC experiment is in successful operation. Development of the pumping facilities necessary for the system involved much research into corrosion of pipes and cables in seawater, bio-fouling counter-measures, heat transfer, and water quality analysis.

Closed-cycle projects currently underway at NELH include the following (NELH, 1985):

- The Argonne Test Project which is testing biofouling as a function of heat transfer fouling resistance. Also, materials selection research is being conducted to find an aluminum alloy or aluminum alclad alloy that will allow a low heat transfer fouling resistance and provide resistance to corrosion attack.

- A large-scale test of aluminum heat exchanger elements by Alcan Aluminun, Inc. Several multi-tube heat exchangers of various alloys have been installed in the laboratory for continuous monitoring of heat transfer and corrosion with 6 ft/sec flow of both warm and cold water.

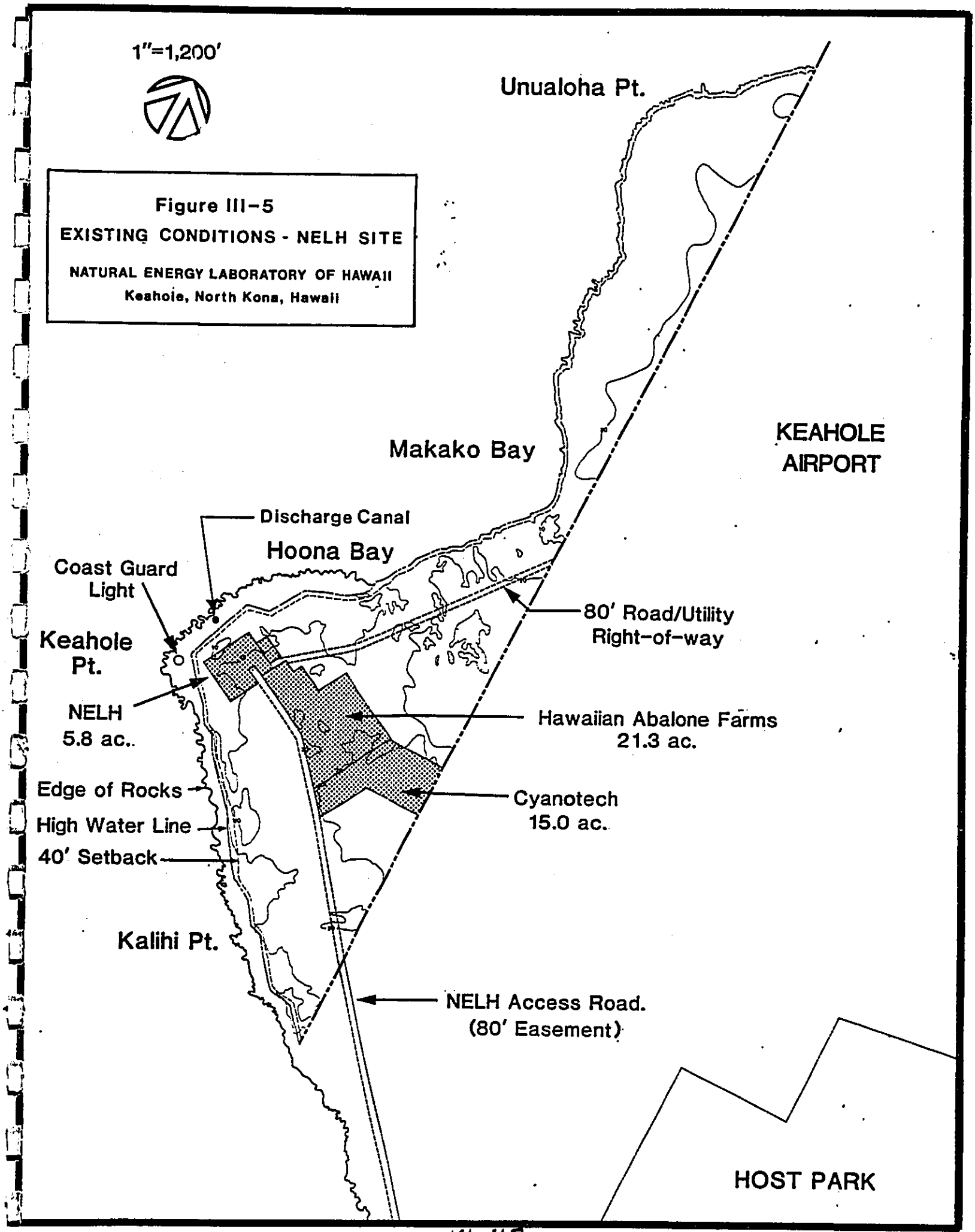


Figure III-5
EXISTING CONDITIONS - NELH SITE
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

- The ALCOA Project which is conducting tests to find a corrosion resistant aluminum material for closed-cycle heat exchangers.

Open-cycle projects currently being conducted at NELH include:

- Research on gas desorption--processes for the degassification of seawater. This project is designed to demonstrate the difference between degassification of fresh water and seawater.

- Research to solve problems of foaming and the release of non-condensable gases;

- Research on evaporator/condenser efficiency as a function of spout size, length, configuration and fluid velocity;

- Testing effects of evaporator and condenser configurations; and,

- Testing of gas desorption from the seawater (Larsen-Bassee, 1983; 1985).

Miscellaneous research includes:

- Materials research for the underwater cable project; and,

- The DUMAND (Deep Underwater Muon and Neutrino Detection) project which plans to deploy a large array of sensors in the deep ocean off Keahole Point.

Operational support facilities at NELH include:

- An extensive water quality laboratory to monitor flow, temperature, salinity, suspended solids, pH and alkalinity, nutrients, dissolved oxygen and residual chlorine; and,

- Monitoring of Environmental factors such as wind temperature and solar insolation on a multi-channel data logger.

Miscellaneous related project support activities include:

- Science, using the unique resources of the laboratory;

- Personnel training;

- Environmental studies;

- Equipment storage; and,

- Project staging for submersible and research vessel cruises.

4.2 Mariculture Projects and Facilities

4.2.1 Research and Development

Facilities for mariculture research are located in the main laboratory compound. Aquaculture tanks, which are all plumbed with both warm and cold seawater, include: ten 600-gallon fiberglass tanks, five 100-gallon plastic lined steel tanks, ten 800-gallon tanks divided into one cubic meter sections, and various tanks, larval basins and growout baskets for the culture of Maine lobsters which are housed in a 1000 square foot inflatable building.

Several species of macroalgae are currently produced at NELH. They are: *Macrocystis pyrifera* (giant kelp), *Porphyra tenera* (nori) and a mixture of species used for

stripping inorganic ions from wastewater. Research is ongoing to determine depth, flow and harvest manipulations necessary for optimization of nutrient stripping in shallow channels (Robichaux, unpublished).

NELh has completed negotiations with the West Coast Lobster Company for a 24-month facilities use agreement with NELH with an option to negotiate a commercial sublease when appropriate. The company initially proposes to use 2 acres of land with an option to expand an additional 3 acres if their project progresses well and the NELH Board approves. The firm will first conduct research and development activities to determine appropriate mixes, temperatures and other water conditions for their lobster. In addition, negotiations have been completed for an opihi culturing project and several more university-sponsored projects.

4.2.2 Commercial Demonstration

Hawaiian Abalone Farms (HAF) has leased 21.3 acres on the NELH site and is is currently operating a commercial demonstration module. HAF facilities include: two large million-gallon kelp tanks (each 15 feet high and 105 feet in diameter); several acres of shade cloth structures covering abalone tanks; and is currently expanding its kelp growing capacity by constructing 16 acres of 4-acre ponds.

Following one year of research and development, Cyanotech, Inc. has begun production of various marine microalgae at NELH. Their facilities, located on a 4-acre parcel adjacent to HAF, include lined raceways aerated by paddlewheels and a field house/processing facility where water is extracted and the algae is dried for packaging and shipment. The firm is initially producing Spirulina, a microalgae in great demand as a health food supplement.

Although Spirulina is normally grown in fresh water, the company scientists have demonstrated that it will grow in pure seawater.

4.3 Ocean Water Supply and Disposal Systems

4.3.1 Ocean Water Supply Systems

There are three 12-inch diameter ocean water intake pipes offshore Keahole Point serving NELH. These include two warm water intake pipes (WWP) and one cold water pipe (CWP). All of the intake pipes terminate at the shoreline near the Keahole Point Lighthouse. Three pumps are currently located in the waters just offshore of NELH, for the purpose of bringing cold water from 2000 feet below sea level. Two pumps located onshore bring warm water to the facility from nearshore waters.

A total of 15 future cold and warm water pipes were approved in CDUA HA-1862. Maximum size of any pipe not to exceed 48-inches and maximum total flow of all pipes not to exceed 142,000 gpm. Figure III-6 shows the offshore corridors for the future pipelines.

Of these 15 pipes, two CWP (one 36 - 40 inches in diameter and one 18 inches in diameter) and one WWP (24 - 28 inches in diameter) are presently being designed. Construction of the 18-inch CWP is planned for Winter 1986; the 36 - 40-inch CWP and the 24 - 28-inch WWP are anticipated to be deployed in Summer 1987. A pump station to service the larger cold and warm water pipes is being constructed makai of the NELH compound (Figure II-2); the pump station for the 18-inch pipe will be located offshore.

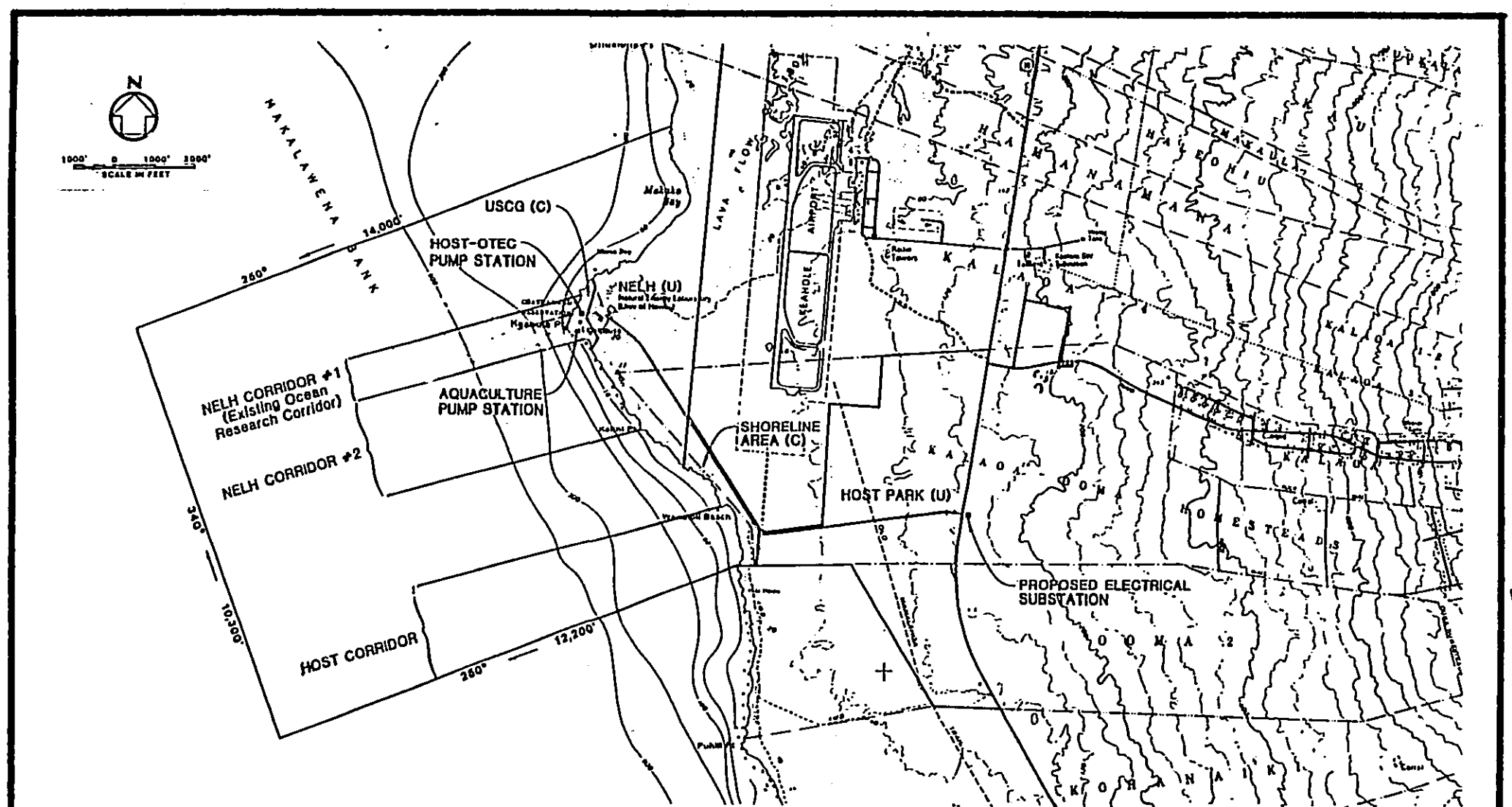


Figure III-6
PROPOSED
OFFSHORE PIPELINE CORRIDORS
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

R. M. TOWILL CORP.

4.3.2 Seawater Disposal Systems

The existing discharge from OTEC experiments at NELH consists of approximately 1,000 gpm of extracted seawater used in heat exchanger experiments. Up to 0.01 mgd of the discharge is used in biofouling experiments; a maximum 10,800 gallons per day of the discharge receives chlorination at a rate of 70 ppb. The extracted seawater enters Class AA waters via a natural, rough canal approximately 60 meters long and 15 meters wide which is located next to the laboratory facility. Discharge up to 1,500 gpm is permitted under National Pollutant Discharge Elimination System (NPDES) Permit No. HI 0020893 which expires March 31, 1991. The discharge is monitored daily in accordance with conditions of the NPDES permit.

Approximately 800 gpm (1.2 mgd) of ocean water used by Hawaiian Abalone Farms is disposed of into two injection wells which are located just behind the shoreline fronting the NELH facility. Approximately 200 gpm (0.3 mgd) of ocean water used in other mariculture operations is disposed of through surface spreading through a cinder layer placed over graded lava (HTDC, 1985).

4.4 Utilities

4.4.1 Electricity and Telephone

Electrical power to the area is supplied by the Hawaii Electric Light Company, Inc. (HELCO) via a conduit running under the runway from the substation at the Keahole Airport to the makai airport boundary fence. Electrical power is distributed to the NELH facilities via an overhead 12.47 KV line running along a utility corridor from the makai airport boundary to the NELH power center in the main compound.

Hawaiian Telephone Company has an existing 3-inch conduit serving the NELH facilities.

4.4.2 Water and Sewage

Fresh water for domestic use and fire protection is supplied by the Department of Water Supply, County of Hawaii, via a 4-inch water line connected to the 12-inch diameter transmission main located along Queen Kaahumanu Highway which conveys water from the Kahaluu water storage tanks to a 0.5 million gallon (MG) reservoir near the entrance to Keahole Airport. The capacity of the 4-inch diameter pipeline is approximately 200 to 400 gpm, 300,000 to 600,000 gpd. The current fresh water usage at NELH is approximately 25,000 gpd. There is no county sewer system in the area, and septic tanks are used.

4.4.3 Access

Access to NELH is via a two-lane 24 foot-wide asphaltic concrete paved road with an 80-foot easement width. The road is approximately two miles long from its intersection with the Queen Kaahumanu Highway to the NELH laboratory gate. There is no road to the northern portions of the NELH site and a jeep trail is the only other access to the coastal areas. The Queen Kaahumanu Highway intersection is currently unimproved and direct right and left turns are allowed there. There is a gate at the highway which is open during the day and closed at night.

B. THE TERRESTRIAL ENVIRONMENT

1.0 Geology, Topography and Soils

The Keahole Point region near NELH consists of primitive basalts of the Hualalai volcanic series, the principal effusive rock of Hualalai volcano (Stearns and MacDonald 1946). The series are composed of heterogeneous, poorly-layered, laterally and vertically restricted units of aa, clinker, and pahoehoe consisting predominantly of basalts and olivine basalts. Individual units extend laterally no more than several hundred feet and vertically less than 100 feet. The average lava flow thickness is about 10 feet. A late trachyte effusion from Puu Waawaa occurs about 15 miles northeast of Keahole. No unusual structural features exist in the region. The nearest rift zone is at least five miles to the north. There is no evidence of faulting or other regional deformation (Dames & Moore, Appendix C).

The topography of the NELH site at Keahole Point is generally level and varies from sea level to approximately 20 feet MSL. The coastline is rocky and contains intermittent coral and baltic (black) sand beaches, as well as basalt boulder beaches. The shoreline varies from level areas to elevations up to 15 feet which drop steeply into the ocean to depths of 10 to 20 feet. The nearly vertical areas of the shoreline have numerous caves and lava tubes extending horizontally under them (HTDC, 1985).

The U.S. Department of Agriculture Soil Conservation Service Soil Survey report for the area designates soil types as Aa (rLV) and Pahoehoe (rLW) lava flows. These lava flows have practically no soil covering and are bare of vegetation except for mosses, lichens, ferns and a few small ohia trees.

2.0 Climate

The climate in the Keahole region is arid in the coastal area but changes gradually to humid in the Hualalai undissected upper slope. The average temperature at the Keahole Airport is 75 degrees F with a maximum recorded temperature of 89 degrees F and minimum of 54 degrees F. The area receives little tradewind rainfall; instead, much of the moisture is accounted for by orographic showers that form within sea breezes which move onshore and upslope. The mean annual rainfall in the coastal region is less than 20 inches, with the wetter periods of the year occurring between May and September (HTDC, 1985).

Pan evaporation is typically high, in the general range of 0.18 inches per day for the winter and 0.36 inches per day for the summer as measured at Anaehoomalu (Kay et al., 1977). There is no pan evaporation measurement for the Keahole region.

The land masses of Mauna Loa, Mauna Kea and Hualalai block the prevailing northwest trades, and a land/sea breeze system predominates the area. The resulting winds are gentle offshore breezes during the night, switching to onshore during the day due to the heating of the land. Typical velocities range from 3 to 14 knots. The exception to this pattern occurs during the periods of so called "kona" weather during the winter months when low pressure fronts may cause strong southerly winds, in some instances approaching 30 to 40 knots (R.M. Towill, 1976).

Solar radiation at the site is constant, with the days cloud-free an estimated 95% of the year. The average daily total radiation on a horizontal surface is 2,019 BTU per square foot (HTDC, 1985).

3.0 Hydrology

Groundwater recharge in the area comes primarily from the small residual of rainfall after abstraction by evapotranspiration in the

upland area and to a lesser extent from the infrequent cyclonic-storm rain affecting the entire area. All groundwater discharges are natural as there is no groundwater development of any kind. These discharges are primarily diffused and not usually visible along the shoreline (Dames & Moore, Appendix C).

An unconfined Ghyben-Herzberg lens underlies the coastal region of western Hawaii from Keahole northward to beyond Kawaihae and southward to beyond Keauhou. In the Keahole vicinity, the lens is brackish, probably less than 125 feet thick and discharges freely along the coast in a narrow band a few feet wide in the intertidal zone (WRRC, 1980). The basal lens water does not meet the U.S. Drinking Water Standards even at the top of the lens and at a distance about 3 miles from the shoreline. Chloride, for example, measured to be about 5,000 milligrams per liter (mg/l) to 520 mg/l, and total dissolved solids (TDS) to be about 10,000 to 1,200 mg/l over this distance (Ibid.).

The brackish water of the lens flows toward the coast along a regional gradient of about 1 foot per mile. The head in well 4360-1 (Kalaoa), 3 miles inland of Wawaloli Beach, was 3.2 feet when drilled, implying an average gradient of 1.1 feet per mile. Kanehiro and Peterson (1977) gave an average gradient of 1-to 2-feet per mile north of Keahole for the reach between Kiholo and Puako. The brackish water discharges preferentially at indentations in the coast. Groundwater flow lines converge toward these indentations while diverging at head lands (Ibid.). the coastal part of the lens experiences appreciable ocean tidal influence. At distances of up to 336 feet inland, tidal efficiencies range from 69% to 100%. Further inland at 600 feet, the efficiencies decrease to 43 to 68% (WRRC, 1980).

4.0 Hazards

Keahole Point is sheltered from the major tsunami generation centers for the Pacific (the Aleutians and Chile); however, the

effects of local quakes such as the one occurring in Ka'u in 1868, reported to have been 7.5 on the Richter scale and to have generated a wave as high as 45 feet, are more severe. Earthquakes are frequent in the Kona area; a quake of the magnitude of 5 was recorded west of Kona in 1972.

As shown by Cox (1982), the near-shore 100-year tsunami runup height in the Keahole area is estimated to be approximately 9.3 feet; the Corps of Engineers estimate is 8.7 feet. Examination of flood insurance rate maps for the area indicates shoreline areas in zones V15 (areas of 100 year coastal flood with wave action; base flood elevations and flood hazard factors determined) and A4 (areas of 100 year flood; base flood elevations and flood hazards determined).

5.0 Vegetation and Fauna

5.1 Vegetation

The strand or beach zone vegetation forms a narrow to somewhat wide (up to 300 ft. in width) belt along the coast. Clusters of naupaka (Scaevola taccada) shrubs are frequently encountered. A few scattered, windswept thickets of kiawe (Prosopis pallida) are occasionally found along the landward edge of the strand. Other species found along the shore include hi'aloa (Waltheria indica var. americana), beach morning glory, Bermuda grass or manienie, and tree heliotrope. No rare, threatened or endangered plant species have been recorded in the project area. The native species that are found on the NELH site also occur in similar habitats throughout the West Hawaii area.

5.2 Avian fauna

Two species of endemic Hawaiian birds are known to exist in the Keahole region: the endangered Hawaiian stilt, known to be present in pond areas several miles to the north and south of the

site, may fly over the area and the Hawaiian Owl (Pueo) may feed on rodents in the area. The Hawaiian stilt prefers the pond areas north and south of the project site and the Hawaiian owl has a large home range over which it forages for rats and mice. Other common, indigenous birds which have been observed in the area are the golden plover, wandering tattler and ruddy turnstone, which are all found elsewhere in the world. Introduced species known to be present in the area include the Indian grey francolin, barred dove, common mynah, Japanese white-eye, house finch, house sparrow, cardinal and Brazilian cardinal, among other species.

5.3 Land mammals

The Indian mongoose, the common house mouse, roof rat, Polynesian rat, and feral cats are known to inhabit the undeveloped portions of the NELH Park sites.

5.4 Endangered and threatened species

The Hawaiian Hoary Bat, Hawaii's only endangered land mammal, is found from sea level to the 13,200-foot elevation and is known to occur in Kona. The bat probably feeds on insects along the coastal area of the project site during the evenings and night. No endemic birds are known to nest in the area, although the endangered Hawaiian stilt may fly over or occasionally feed there.

6.0 Historical/Archaeological Resources

A total of 10 archaeological studies have taken place in the NELH parcel. A Bishop Museum study (Clark 1984) summarized much of this work and concluded that all historic sites had been found--a total of 24. The State Historic Sites Section has recently conducted field-checks of many of these sites (Cordy, Appendix D). The majority of

sites are concentrated along the coast. The sites are composed of more than 60 individual features. Table 3-1 lists the sites and briefly describes them; Figure III-7 shows their location on the NELH property.

All of the sites still contain significant information on the prehistory of this area which must be recovered. NELH and the State Historic Sites Section have agreed that 1 site and a set of 6 sites are also significant as excellent examples of types of sites within the North Kona region and should be preserved. These are: (1) Site D15-12, a prehistoric permanent dwelling site which includes a walled enclosure with an internal house platform and external work structures, at least one petroglyph and salt pans; and (2) Sites D16-6 through -11, a complex of historic period (mid-1800s to early 1900s) dwellings and larger structures including two canoe-houses (Cordy, Appendix D).

C. THE MARINE ENVIRONMENT

1.0 Geology/Bathymetry

Figure III-8 shows the bathymetry off Keahole Point. Water depth increases rapidly with distance from the shore, with depths of 2,500 feet within a mile of the coast. The rocky basalt shoreline drops abruptly to water depths of about 15 to 20 feet, then the ocean bottom slopes gradually to a shelf break at about 40 to 50 foot depths. The shoreline and nearshore foundation material is primarily basalt. The nearshore bottom is virtually bare of sand or coral growths at depths less than 25 feet.

Surveys of the seafloor by submersibles show that the bottom consists of basaltic lava flow, coral and volcanic rubble and thin sediment. Lava flows from Hualalai form ridges and channels trending

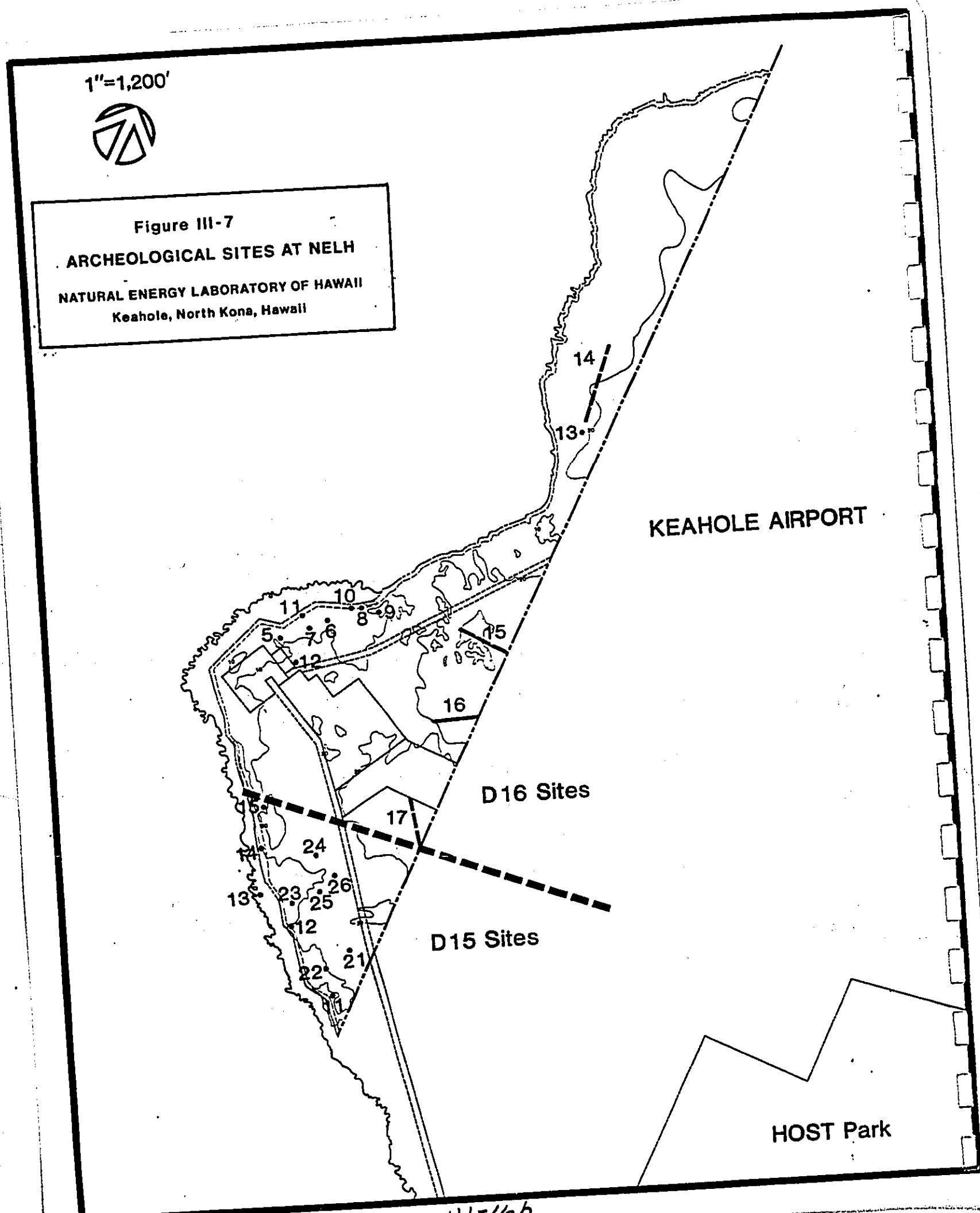
Table 3-1

List of Sites in the NELH Parcel

Site	Function	Nature
Kalaoa 4 -- North of NELH Lab (13 sites)		
D16-5	Permanent Dwelling	Enclosure with papamu
D16-6	Permanent Dwelling	Enclosure with internal enclosure & external platform
D16-7	Permanent Dwelling	Long, narrow enclosure & 2 platforms
D16-8	Permanent Dwelling	2-sided enclosure with cement foundation
D16-9	Permanent Dwelling	Long, narrow enclosure, C-shaped enclosure, modified anchialine pond
D16-10	Unknown	Enclosure
D16-11	Permanent Dwelling	Enclosure
D16-12	Permanent Dwelling	Enclosure, terrace
D16-13	Short-term occupa.	Cave
D16-14	Trail	Opihi-shell lined
D16-15	Trail	Opihi-shell lined
D16-16	Trail	Stepping stone
D16-17	Trail	Opihi-shell lined
Kalaoa 5 -- South of the NELH Lab (11 sites)		
D15-11	Permanent Dwelling	4 enclosures
D15-12	Permanent Dwelling	Enclosure, 2 platforms
D15-13	Permanent Dwelling	Platform
D15-14	Permanent Dwelling	Platform, 2 enclosures
D15-15	Permanent Dwelling	10 features = 2 enclosures, platform, 2 caves, 2 pools, etc.
D15-21	Unknown	8+ filled crevices*
D15-22	Unknown	Filled crevice*
D15-23	Unknown	Small platform, enclosure
D15-24	Short-term occupa.	Cave, C-shaped enclosure
D15-25	Short-term occupa.	Cave, platform
D15-26	Unknown	Stone cairn

*A 1986 fieldcheck indicates that these may not be historic sites (Cordy 1986). This is being further evaluated.

Source: Cordy, Appendix D


1"=1,200'
Figure III-7
ARCHEOLOGICAL SITES AT NELH
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii
KEAHOLE AIRPORT
D16 Sites
D15 Sites
HOST Park
14
13
11
10
8
9
5
7
6
12
15
16
17
24
26
23
25
21
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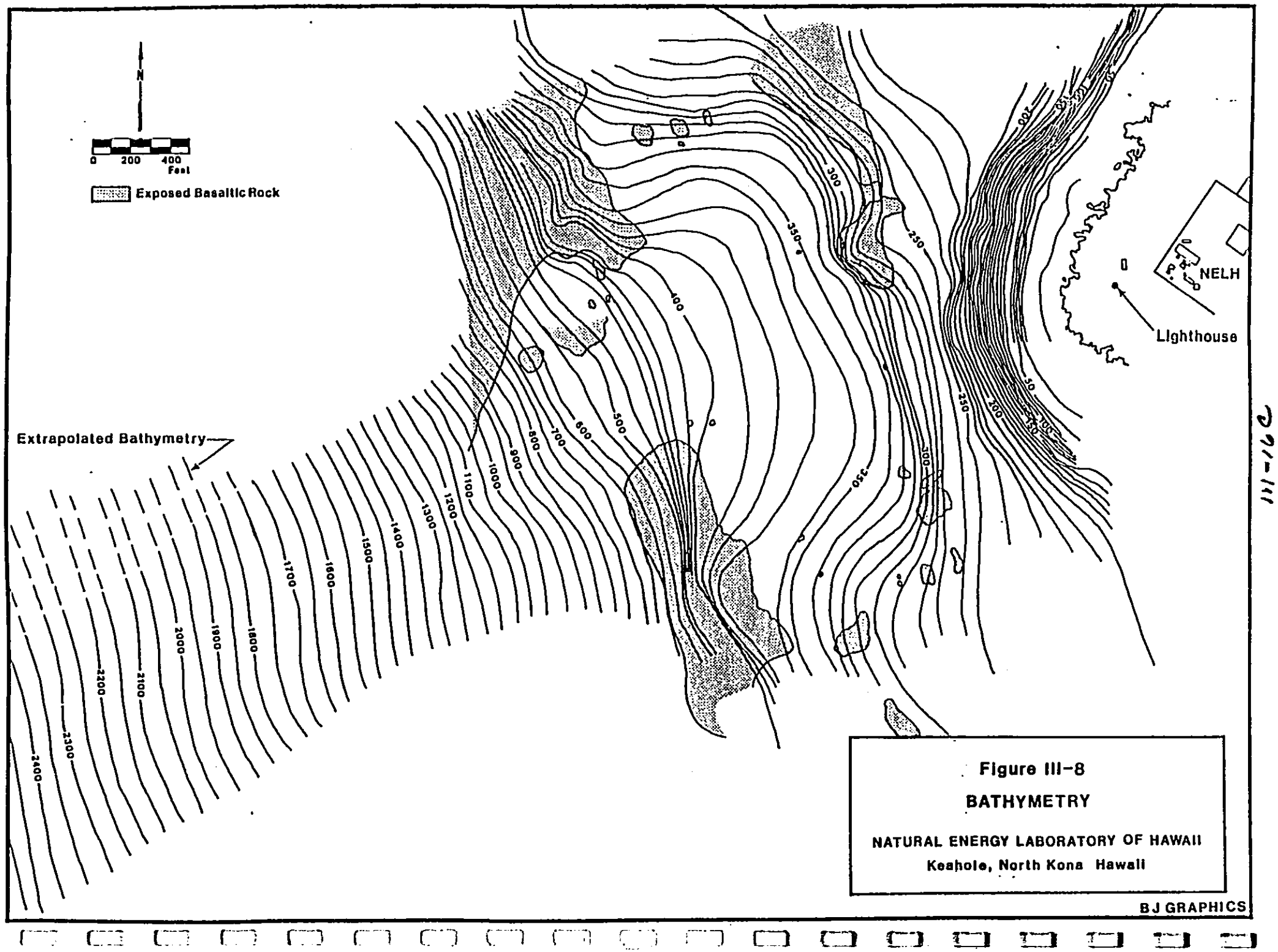


Figure III-8

BATHYMETRY

NATURAL ENERGY LABORATORY OF HAWAII

Keahole, North Kona Hawaii

perpendicular to the slope. Calcareous sand occurs in the channels and in patches where the slope is gentle.

2.0 Physical and Chemical Oceanography

Currents offshore Keahole Point are dominated by two processes. Tidal oscillations drive reversing currents with diurnal and semi-diurnal periods. Typical maximal tidal current speeds are 3/4 to 1 knot. Tidal currents may be obscured for extended time periods by large-scale eddies propagated from the Alenuihaha Channel. An eddy off leeward Hawaii persisted and was tracked for 2 months (Lobel and Robinson, 1984).

Offshore surface currents range in speed from 10-37 cm/sec or, on average, less than half a knot (Bathen, 1975). Deep currents have been measured in the range 1-10 cm/sec (Bretschneider, 1978).

At Keahole Point, the westernmost point on the island of Hawaii, currents are dominated by large eddies (approximately 100 km in diameter) that reverse from time-to-time. These eddies have a tendency to take nearshore water away from, rather than along, the coastline. In general, waters entering the nearshore marine environment around Keahole Point are not expected to remain in the nearshore area for very long (Noda, 1986).

The nearshore situation found at Keahole Point is different from that found in other areas of the state. For example, a nearshore coastal regime along the northwestern shore of Oahu results from reversing tides and the north equatorial current impinging upon the island of Oahu. In this situtation, waters hug the coastline all the way down to the western tip of Oahu. Marine Culture Enterprises (MCE), which is operating an aquaculture facility along this shore, has discovered that some of the aquaculture discharge water entering ocean gets trapped in this "nearshore coastal regime" resulting in algae being observed some distance from the discharge point. Because

there is no similar nearshore coastal regime off Keahole, this condition is not likely to occur at NELH and adjacent areas (Oceanit, Appendix A).

The wave climate of the Kona coast is typically characterized by two to four foot waves with periods of 9 to 15 seconds. Wave heights rarely exceed seven feet, except during the winter months. Larger waves are generated by local "kona" storms and distant storms in the north Pacific. The highest recorded wave along the west coast of Hawaii over the past 20-year period was 25.5 feet (R.M. Towill, 1976).

Sea surface temperatures in Hawaii vary relatively little annually or diurnally, ranging between 23-28.5°C. (Gundersen, 1974). The wind-mixed surface layer extends 50 to 100 meters deep; the bottom of the thermocline may extend to 150 meters.

Scalar (nondirectional) irradiance in the photosynthetically active wavelengths (400-700 nm) has been measured through the water column offshore NELH (Noda, et al., 1980). The photic zone extends to about 125 meters.

The results of water chemistry analyses on samples collected offshore of the NELH facility indicate that salinity always increases with depth in nearshore waters. Offshore there is a peak concentration at 30-150 meters with low surface values and even lower concentrations at 150-200 meters. Salinity values are highly variable spatially and temporally, indicating large scale, rapid water mass mixing or movement (Walsh, 1985).

Ocean water pH is maximal at the surface due to the combined effect of carbon dioxide uptake and oxygen evolution in the photosynthetic process. Decomposition and respiration increase with depth, consuming oxygen and depressing pH. A pH minimum generally coincides with the oxygen minimum.

Oxygen concentrations range between 4.8 and 6.3 ml/l in a mixed layer extending to about 90 meters below the ocean surface. Surface layer concentrations are at or above saturation values. A broad oxygen minima (1.0 ml/l) occurs between 450 and 900 meters (Noda, et al., 1980).

Three distinct nutrient layers have been identified in offshore depth profiles (Noda, et al., 1980). In the mixed layer, concentrations are low and uniform, the result of uptake by phytoplankton. In the aphotic waters between about 150 and 400 meters there is a rapid increase in nutrient values caused by dissolution of particulate material from above and vertical diffusion. Maximal values are found below 600 meters.

In general, inshore nutrient concentrations are low, but consistently higher than in offshore waters (Walsh, 1985). Offshore transects show that when nearshore salinities are lowest, nutrients are highest, clearly reflecting shoreline seepage of nutrient-rich, brackish basal water.

Coastal waters near Keahole are classified AA by the Department of Health (Chapter 54, Water Quality Standards). "Wet" criteria apply due to the volume of groundwater seepage. Waters classified AA are intended to remain as nearly as possible in their natural pristine state with a minimum alteration of water quality from any human-caused source or action. Offshore waters, beyond 100-fathom depths, are "oceanic," all Class A. The 1801 lava flow is a Class I, "protected reef community," sanctioned only for passive, non-consumptive uses. Other bottom areas, to 100-fathom depths, are Class II, "lava rock shorelines and solution benches."

Several studies (WRRC, 1980; R.M. Towill, 1982) have reported that coastal water quality standards are exceeded near the shore. This is not unusual as nutrient concentrations are generally elevated as a consequence of a high proportion of groundwater in very nearshore samples.

The quality of the surge channel water near Wawaloli Beach is influenced by the basal lens discharge to the extent that the coastal water quality standards are exceeded in terms of nitrogen and phosphorus (WRRC, 1980). The principal sources of the nutrients in the basal lens are, however, believed natural rather than man-made. The ocean water also exceeds the same nutrient standards (Dames & Moore, Appendix C).

3.0 Marine Biological Environment

(See GK & Associates, Appendix B, for a complete description of the marine biological environment)

The marine biological environment offshore of NELH/HOST Park was described in the HTDC FEIS (GK & Associates, 1985). Since then additional surveys in the area have been completed for neighboring projects. Dollar (1986) carried out a qualitative marine biological reconnaissance survey of the area fronting the proposed O'o'ma II resort development immediately adjacent to and bounded on two sides by the HOST Park. His description of the area conforms with those previously summarized. Briefly, the following species were observed:

The seaweeds Ahnfeltia concinna and Ulva fasciata, encrusting red algae, sea urchins and juvenile fish are visible within tidepools along the intertidal platform. Pocillopora meandrina, a sturdy coral able to rapidly colonize new surfaces, is dominant along a shallow, basaltic terrace extending from the shoreline to about 25 m offshore. Porites lobata, found primarily as thick-lobed colonies, is the dominant coral seaward of the terrace in a zone that extends offshore about 55m into waters about 10m deep. Beyond this the dominant "finger coral," Porites compressa, forms dense thickets. In addition to the corals, sea urchins and sea cucumbers are common on the reefs.

Six categories of reef fish were found, including juveniles, planktivorous damselfishes, herbivores, rubble-dwelling fishes,

swarming tetrodonts, and surge-zone fishes. The deep zone of finger coral harbors a high concentration of juvenile fishes. "Food fishes" are not abundant, but parrotfishes, goatfishes, taape (Lutjanus kasmira - an introduced snapper), jacks and groupers were observed.

4.0 Endangered and Threatened Species

The endangered Humpback whales are often observed nearshore off the northwestern coast of the island of Hawaii during winter months. The threatened green turtle is also occasionally observed in the area (HTDC, 1985).

5.0 Anchialine Ponds

The HTDC FEIS summarized the available literature on anchialine ponds within the site. Maciolek and Brock (1974) found three ponds on the present NELH site and six on the HOST Park site. The latter ponds have evidently filled in the intervening years, as recent surveys have failed to confirm their presence (Lee, 1986).

On September 27, 1986, the anchialine ponds at NELH were examined (GK & Associates, Appendix E). All three ponds were located, although at higher tides there is a very shallow surface interconnection between the two open ponds and they could be considered one pond. The more northerly pond covers an area of about 220 square feet and is about 125 feet inland from the ocean. Its bottom and sides are lava rocks with occasional reef rocks. Its maximum depth is about 1.5 feet and the salinity is 8 ppt. Deeper portions of this pond harbor growths of a green filamentous algae, probably Cladophora sp., and a large snail population. Neither shrimp nor fish were observed in this pond, but it does connect with the other exposed pond to the south, and the latter has fish in the adjoining portion.

The more southerly pond is slightly deeper than its neighbor (about 2.5 feet at the center). A single fish, possibly aholehole,

Kuhlia sandvicensis, and a crab (probably Metapograpsis sp.) were briefly observed in and around the deep portion which measured roughly 120 square feet. One portion of this pond is generally isolated from the latter area by a shallow rock sill; a population of the endemic shrimp, Halocaridina rubra, was seen in this area. The sill appears to be effective in preventing entry of fish into this portion of the pond.

A third area of this pond is a nearly isolated circular basin about four feet in diameter and two feet deep. This area also supports a population of Halocaridina rubra. Where these opaeula are present, green algae are not apparent, and the dominant benthic flora is the typical anchialine pond cyanophyte community (Lyngbya and Schizothrix).

The third pond is located about 100 feet south of the exposed ponds. It is relatively large, with a surface area of approximately 750 square feet. Depth is about three feet at the deepest. The pond lies beneath a fringing canopy of kiawe (Prosopis pallida). Scattered to dense stands of the beach naupaka (Scaevola taccada) and pickleweed (Batis maritima) surround it. This pond, which is slightly seaward of the two open ponds, exhibits and slightly higher salinity, 10 ppt. Although a very dense growth of filamentous green algae is present, neither fish nor shrimp were observed. The presence of the filamentous green algae indicates the absence of opaeula; when these shrimp are present they crop this algae down and the blue-green algal community is visible. Fish may be present in this pond, however, none were observed during the survey.

Photographs of the anchialine ponds at NELH are included in Appendix E.

PART IV: POTENTIAL ENVIRONMENTAL IMPACTS AND MITIGATING MEASURES

A. INTRODUCTION

The primary objective of this environmental impact analysis is to assess the effects of alternative methods of on-land disposal of seawater return flows that will be generated by proposed open-cycle (OC) OTEC experiments at NELH and evaluate the impacts of these effects on the terrestrial and marine resources on and offshore the Keahole facility. In addition, because the success of OTEC experiments is dependent upon the continued high quality of the ocean water resource, impacts on existing operations at NELH and cumulative impacts of combined OTEC and mariculture sea water return flow disposal are also addressed.

In many cases, the long-term environmental impacts of particular actions are unknown. Therefore, mathematical models are used to identify the degree of risk involved in undertaking a particular type of action and to predict appropriate thresholds where intervention should take place before irreversible harm is done to the environment. Modeling the effects of an action where the actual effects are unknown, although theoretical and based on stated assumptions of the behavior of a particular system, allow criteria to be developed that will enable the effects of the action to be monitored as development progresses. It also facilitates the formulation of recommendations for mitigating measures to minimize risks.

The environmental impact analysis of seawater return flow disposal will be based on the following discharge scenarios:

16,100 gpm of OTEC discharge into a canal;

16,100 gpm of OTEC discharge into injection wells;

16,100 gpm of OTEC discharge into a trench within the NELH compound (two locations); and

25,900 gpm of mariculture discharge into a trench makai of the NELH access road.

In addition, the following cumulative scenario is assessed:

42,000 gpm mixed OTEC and mariculture discharge into a trench makai of the NELH access road.

Figure IV-1 shows the discharge facility locations analyzed in each of the above scenarios.

The reviewer is directed to the following appendices for complete discussions of the assumptions, methodologies and models used in evaluating specific actions, technical analyses, impact assessments and related recommendations:

Appendix A: Disposal of Open Cycle Ocean Thermal Energy Conversion Water "Via Canal" - Oceanit Laboratories, Inc.

Appendix B: Impacts of OC OTEC and Mariculture Discharges from the Natural Energy Laboratory of Hawaii on the Nearby Marine Environment - GK & Associates

Appendix C: Technical Evaluation of Seawater Return Flow Disposal by Deep Injection Wells and Shallow Trench - Dames & Moore

Appendix D: Historic Preservation Concerns At NELH - Dr. Ross Cordy, Department of Land and Natural Resources, Historic Sites Section.

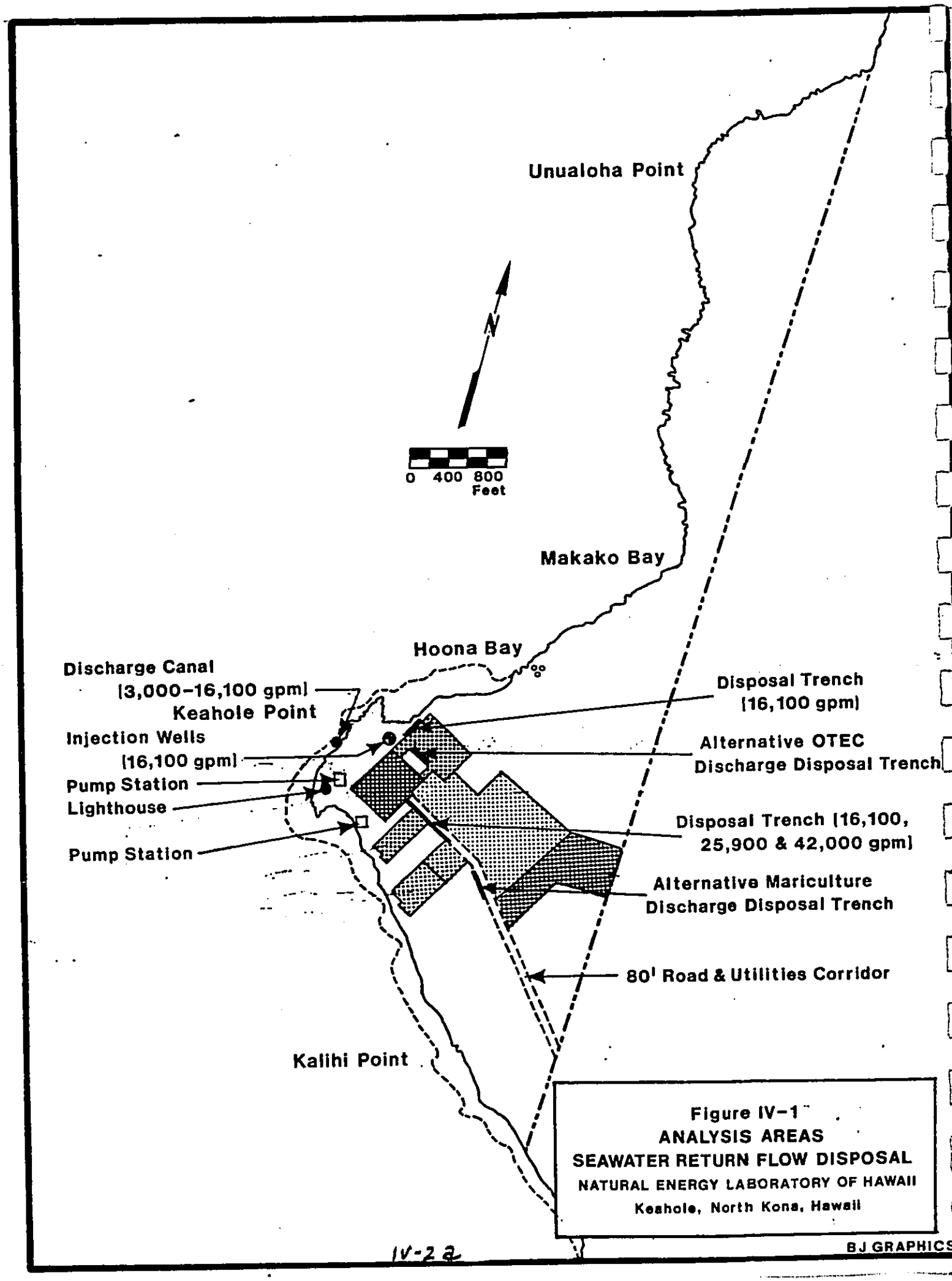


Figure IV-1
ANALYSIS AREAS
SEAWATER RETURN FLOW DISPOSAL
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Appendix E: Impacts of Open Cycle OTEC and Mariculture Discharges from the Natural Energy Laboratory of Hawaii on Nearby Anchialine Ponds - GK & Associates

Appendix F: Cost Estimate Data - Proposed Disposal Facilities Expansion at NELH - Dames & Moore

B. OC OTEC SEAWATER RETURN FLOWS

1.0 Characteristics of the Discharge Water

1.1 Overview

OC OTEC discharge water will be composed of warm seawater after it has been degassed and exposed to a low pressure environment, and cold seawater after it has been used for condensing water vapor. Nominal conditions for a 165 kW experiment are presented in Table 4-1.

Table 4-1: Nominal Conditions For A 165 kW Hybrid-Cycle OTEC Test Apparatus

	Warm Water	Cold Water
Flow Rate	9,600 gpm	6,500 gpm
Inlet Temperature	78° F	46.5° F
Outlet temperature	72° F	53.5° F
Mixed water temperature	64.5° F	
Outlet gas content	Deaerated	No change
Gas release (O_2 + N_2)	78	1 lb/hr

Source: U.S. Department of Energy, Argonne National Laboratory

Using worst case data from the NELH water quality monitoring program, assuming 1.5 : 1.0 proportions of warm to cold water, and assuming all parameters behave conservatively yields the following values: temperature -- 19.0°C; dissolved oxygen (in

the absence of degassing) -- 3.98 ppm; pH -- 7.79 units; nitrate plus nitrite -- 17.1 µg-at/l; phosphate -- 1.48 µg-at/l; and, silicate -- 41.2 µg-at/l. Discharge concentrations would be modified by the OC OTEC process. Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use. Lysing of cells in the evaporator could increase the concentrations of dissolved nutrients over those given above.

The OC OTEC process selected for experimental work at NELH does not produce dissolved metal ions and would very likely not utilize chlorination because direct contact heat exchangers would be used (L. Lewis, 1986).

1.2 Lysing Constituents

Due to the pressure decrease in the evaporator, lysing (disintegration or dissolution of tissues) of microoganisms in the OC OTEC water will occur because of the internal boiling due to the drop in pressure. This will change the available form of nutrients in the water into a more easily assimilated form. Table 4-2 illustrates the percent weight composition of the most prevalent elements found in microorganisms (Gaudy & Gaudy, 1980). Assuming that the organic content of warm seawater at NELH is approximately 100 µg/l, and that most of these materials are from living animals and plants, the increase in available nutrients in the mixed discharge water would be 14 µg/l of additional nitrogen or approximately 0.014 ppm. An increase to 1,000 µg/l of organic matter, would result in an increase of 0.14 ppm in the discharge plume -- an increase in nitrogen by up to 50% above that previously calculated using a 1 : 1.5 mixture of warm and cold seawater. Total nitrogen content will not change, lysing only changes the molecular state of the available nitrogen not the total nitrogen. Similarly, available phosphorus could increase

TABLE 4-2

Elemental cell composition [16].

Element	Percent Dry Weight
Carbon	50
Oxygen	20
Nitrogen	14
Hydrogen	8
Phosphorus	3
Sulfur	1
Potassium	1
Sodium	1
Calcium	0.5
Magnesium	0.5
Chlorine	0.5
Iron	0.2
All Others	0.3

Source: Gaudy & Gaudy, 1980.

by 0.003 to 0.03 ppm -- an increase of 5 to 60%, although the total phosphorus would remain constant.

1.3 Dissolved Gases Removed During OC OTEC

Degassing OC OTEC water prior to evaporation removes dissolved oxygen, nitrogen, carbon dioxide, and trace gases such as Ar, He, and Xe from seawater. Initial results indicate that about half of the nitrogen and oxygen normally found in cold deep seawater is removed under conditions that simulate OC OTEC degassification (Sansone, 1985). Later research done at NELH using warm and cold seawater indicates that up to 95% of the dissolved gases can be removed under OC OTEC conditions (Krock, 1986). The majority of the gases removed will be oxygen and nitrogen. Because most nitrogen in the seawater is in the form of nitrate, nitrite, ammonia and kjeldahl nitrogen, the nitrogen gas removed during degassification can be considered inert for most biological purposes and is not expected to result in a significant impact on the environment. Removal of dissolved oxygen will change the dissolved oxygen levels of the discharge water to values significantly below those found in the ambient water seawater --the discharge plume will be oxygen poor compared to surrounding waters.

From an OTEC system viewpoint, there are two considerations regarding the discharge of degassified seawater: the first is environmental, the second is related to the efficiency of the system. Due to the parasitic power losses that result from removing gases and pumping them to atmospheric pressure for disposal, there is interest in reinjecting the gasses back into the seawater prior to disposal. This would have a two-fold benefit; it would discharge much more environmentally-acceptable seawater and would decrease parasitic power losses associated with pumping the gases. According to Oceanit Laboratories (Appendix A), regassification of the discharge plume is of

interest and concern to all parties that they interviewed in preparing this study and will be addressed in one form or another in future OC OTEC efforts.

1.4 Trace Metals

Trace metals released in seawater from corrosion and erosion of metallic members within an OTEC facility could increase metallic ion concentrations in nearby and receiving waters. Based on calculations in Appendix A, if aluminum is the primary source of metallic ions, concentrations would be less than concentrations found in the ambient seawater.

1.5 Chlorine

Very little chlorine will be used in an OC OTEC operation because there are no warm seawater heat exchangers in the evaporator and, depending on the specific OC OTEC design, there may be no cold seawater heat exchangers in the condenser. In the event that heat exchangers are employed in the condenser, very little chlorine, if any, will be used to control biofouling because of the very low rate of biofouling found in cold seawater.

1.6 Nutrients From Mixing Warm and Cold Water

Nutrient levels in the discharge plume will change as a function of the cold:warm seawater ratio in the mixture. Table II-3 in Appendix A illustrates the nutrients present in OTEC discharge under the condition where 1.5 parts of the seawater is warm and 1.0 is cold.

If water is discharged into a ponding area, similar to the one existing at NELH, concentrations would decrease. Theoretically, if the physical parameters that cause the existing ponding

area to act as a reactor vessel could be scaled-up to accommodate the increase in discharge volume, concentrations could approach ambient seawater conditions.

2.0 Alternative Methods of Disposal

2.1 Disposal Via "Canal"

2.1.1 Analysis

Increasing the flow of the existing direct discharge of OTEC water via canal was analyzed. The model which was developed to estimate the concentrations of conservative and nonconservative materials that are discharged in the seawater outfall and track the paths of water particles as they leave the shore and enter the ocean is presented in Appendix A.

The advection process in a coastal area is controlled by longshore currents that are produced from wave action, ocean currents, wind stresses, etc. The resulting currents change their magnitude and direction as a result of prevalent dominating factors. The second type of currents are due to the tides. Usually the flood and ebb tides are in opposite directions.

Ocean mixing processes start to occur immediately after the used seawater is discharged. The seawater is discharged with a particular injection velocity that ultimately dies down due to the mixing entrainment. The nearfield is the region where this velocity is depreciated to about 10% of the injection velocity. The nearfield plume depends on the density difference between the discharged waters and the receiving waters, the velocities of discharge and receiving

water, and the characteristics of the diffuser and its alignment.

After the initial mixing, the particles are moved mainly by random motions due to turbulent diffusion and advection. The turbulent diffusion occurs in such a way that the standard deviation of the concentration of any effluent patch increases and the square root of the time elapsed.

In order to simulate advection the longshore mean current was estimated at 0.33 feet/sec and the amplitude of the semidiurnal tidal currents was 0.44 feet/sec (Bathen, 1975). Results from work done by Noda (1986) indicate that the currents at Keahole Point generally flow in the northern or southern direction.

A simulation model was run for the following test cases:

a) sinusoidal tidal current with period 12.5 hours and amplitude 0.44 feet/sec superimposed on a longshore current of 0.33 feet/sec flowing away from the OTEC warm water intake;

b) similar combination as in case a), except with the longshore current moving towards the OTEC warm water intake;

c) sinusoidal tidal current in the absence of any longshore current.

Calculations indicate that the concentrations under conditions a and b are extremely low, on the order of $1X10^{-10}$ times the concentration of the discharged seawater.

However, in the absence of a longshore current, the discharge plume has the potential of crossing directly over the warm water intake. The resulting concentration of the seawater plume at the warm water intake under the worst condition of coastal currents is estimated to be $6X10^{-3}$ of the concentration at the discharge outlet for a flow of 16,000 gpm. The worst conditions were found to occur when only ebb tidal currents were present (condition c). Under these conditions the highest concentrations occur 6 to 9 hours after the ebb tide begins.

In general, concentrations at the warm seawater intake were found to be sufficiently diluted during most tidal and current conditions so that the water quality at the warm seawater intake is not influenced from the discharge. However, during an ebb tide, without external currents, i.e., resulting from large cyclonic/anticyclonic gyres, trade-winds, etc., constituent concentrations of the discharged water will be diluted by approximately one part in 200 at the warm seawater intake. A 1 : 1.5 mixture of cold and warm seawater coupled with a dilution of one part in 200 results in levels of dissolved oxygen slightly below the ambient and total nitrogen levels slightly above the ambient.

2.1.2 Disposal Facility Requirements

The size of the "canal" with ponding area would increase as discharge volumes increase. It is recommended that this facility be shallow enough to allow shortwave radiation to penetrate wherever possible and warm the discharge -- as is currently done with the discharge flow of 1,000 gpm. If we assume a shallow basin that is 1.5 feet deep and we assume the discharge velocity in the existing

canal is approximately 1.4 f/m, the width of the canal at various discharge rates is as follows:

Discharge Flow (gpm)	Width of Canal (ft)
1,000	60
3,000	180
5,000	300
16,000	960

The analysis in Appendix A assumes that the disposal facility would be in approximately the same location as the existing discharge point (Figure IV-1). As shown in the preceding table, the canal and ponding area required for disposing of 16,100 gpm of discharge would require a very large land area. Before considering this disposal option for such a large discharge, a site study should be undertaken to determine whether or not this method of disposal is even possible, considering the implications of committing such an extensive area of shorefront land to this purpose.

2.2 Disposal Via Deep Injection Wells

2.2.1 Analysis

Disposal by deep injection wells takes advantage of the storage capacity, porosity, and the filtration effect of the lava formation to provide dispersion, diffusion and residence time before the water is discharged to the ocean. An analysis of discharge of OTEC water via deep injection wells, assumed to be located immediately makai of the NELH laboratory, is presented in Appendix C. The location analyzed is indicated on Figure IV-1.

The disposal of OTEC discharges by deep wells was modeled using an analytical computer model based on the Theis non-equilibrium equation. Because of temperature considerations, and relatively close proximity to the shoreline, the injected OTEC discharges were modeled based on the flow being confined to a zone from elevation -300 to -400 feet. Injection below -300 feet was selected based on injecting below the ocean thermocline.

It is anticipated that the discharge might actually not be confined to the -300 to -400-foot zone, but may go deeper due to lower temperatures and consequent higher densities relative to the ambient groundwater. There may also be a tendency for the sea water return to rise because of hydraulic head increases caused by injection. This tendency would, however, be somewhat counteracted by the density (temperature) gradients and by the constant head condition imposed by the ocean when the seawater return water reaches areas overlain by the ocean.

Upon emergence, it is calculated that 85% of the discharge will occur over a horizontal distance of 30,000 feet along the -300 foot bathymetric contour, an average of 660 gpd/foot (Figure IV-2). Assuming that the flow is distributed evenly between the -300 to -400 foot contour, the discharge flow would average 1.2 gpd/ft^2 of ocean bottom in this zone. Discharge would actually be greater in offshore areas in near proximity to the injection point. At these locations, the flow would be approximately 2.9 gpd/ft^2 between the -300 and -400 bathymetric contours. A minimum residence time of approximately three months is estimated.

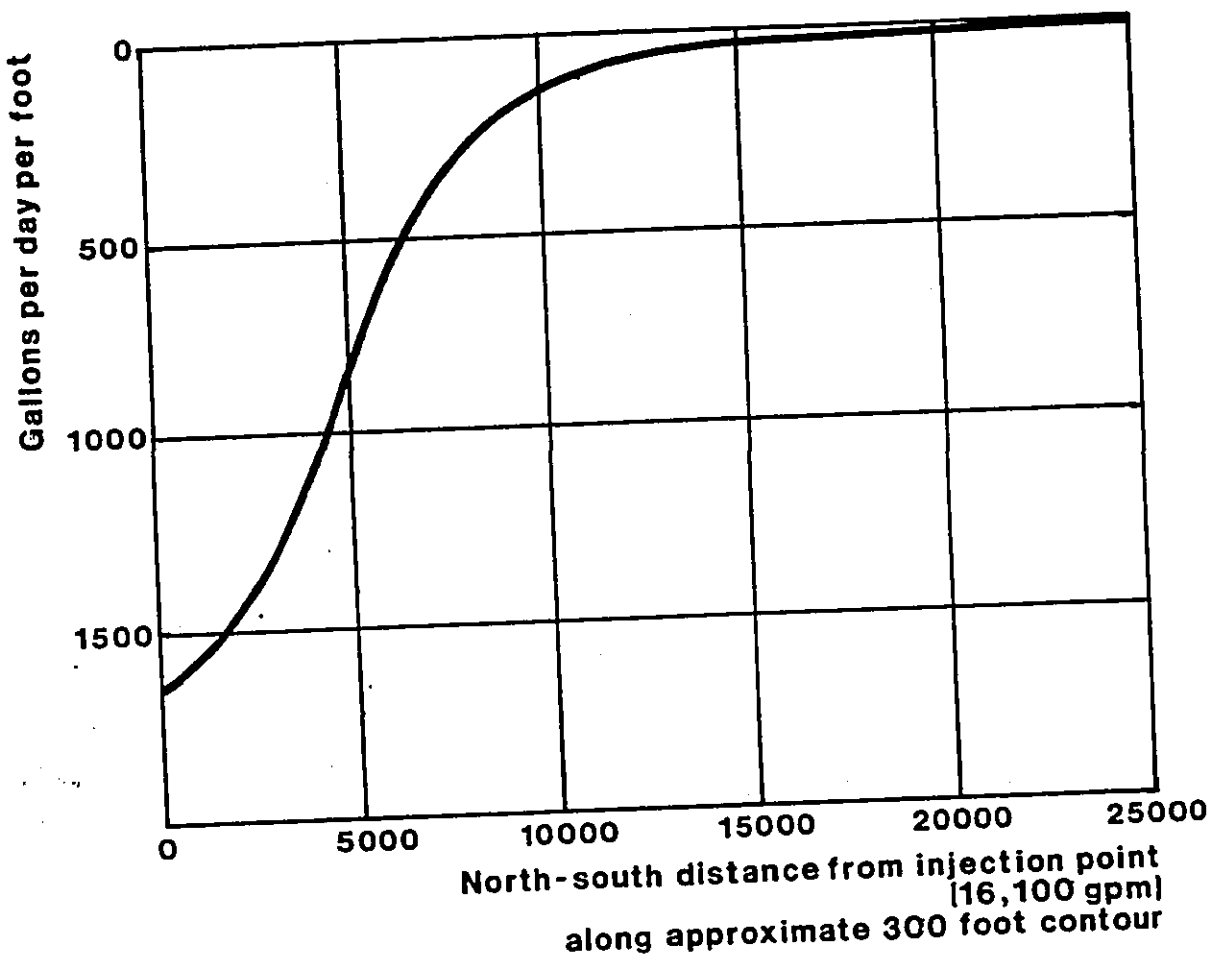


Figure IV-2
DISTRIBUTION OF DEEP WELL
INJECTION DISCHARGE
NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

2.2.2 Disposal Facility Requirements

For a disposal requirement of 23 mgd (16,100 gpm), it is estimated that 4 wells (2 primary and 2 backup) will be needed. The wells would be approximately 2 feet in diameter, 400 feet deep and spaced at least 100 feet apart. They would be cased with solid casing from 0 to 300 feet to limit discharge to a depth below 300 feet and with either open hole or slotted casings from 300 to 400 feet. The wells may need to be deepened if low permeability zones are encountered which reduce capacity. The wells would utilize gravity as the prime moving force and thus conserve energy.

It is estimated that each well could handle about 11.5 mgd (8,000 gpm). Therefore, for 23 mgd initial operation, only 2 of the 4 wells would be operating. The extra wells would be standby capacity for planned maintenance or in case of one or more wells becoming inoperative due to clogging. The piping system and well head design would require careful engineering for smooth operation and ease of maintenance.

2.3 Disposal Via Shallow Trench within the NELH Facility

2.3.1 Analysis

The disposal of OTEC discharges in a shallow trench was modeled for two alternative locations within NELH (Figure IV-1) using an analytical computer model based on the Theis non-equilibrium equation. For alternative location 1, parallel to and approximately 100 feet from the shoreline, the results of the model indicate that 67% of the discharge will occur over a distance of 600 feet along the shoreline, an average of 26,000 gpd/ft. Assuming that the flow is distributed evenly between the 0 to -50 bathymetric foot

contour, discharge seepage will average 26 gpd/ft^2 of ocean bottom in this zone. Discharge will be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 72 gpd/ft^2. Because of the proximity of the shoreline, minimum residence times will be less than one day.

For alternative location 2, perpendicular to and approximately 250 feet from the shoreline at the closest point, the model calculates that 80% of the discharge will occur over a harizontal distance of 4,100 feet along teh shoreline, an average of 4,500 gpd/foot. Assuming that the flow is distributed evenly between the 0 to -50-foot bathymetric contour, discharge seepage will average 4.5 gpd/ft^2 of ocean bottom in this zone. Discharge will be greater in offshore areas closest to the discharge trench. At these locations, seepage will be approximately 6.6 gpd/ft^2. Minimum residence times before emergence at the shoreline are estimated to be between one to two days.

The proximity of each proposed discharge trench location to the shoreline and the location on a point (Keahole) limits effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

In each case, the disposal plume would displace the existing groundwater flow in the immediate vicinity of Keahole Point. The area of displacement would vary with the amount of discharge and location of the trench. Flow nets showing flow patterns for 16,000 gpm of discharge into a

trench within the NELH compound are schematically depicted in Figures IV-3 and IV-4.

The advection of the plume in the coastal waters would be similar to that described for discharge via canal. The plume would be more diffused, however, and the constitutents of the water would be more diluted at the warm water intake than the canal plume.

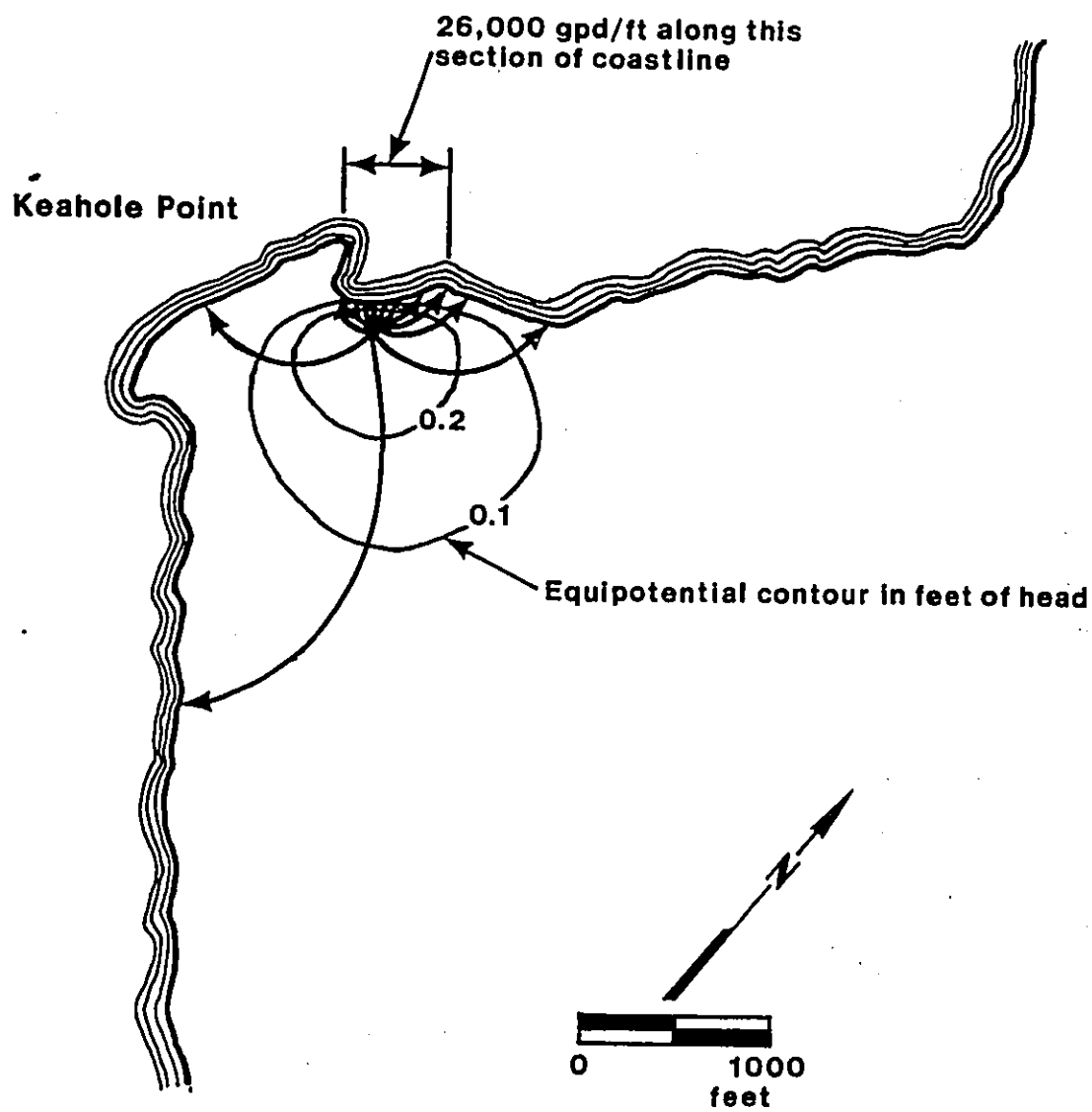
2.3.2 Disposal Facility

The disposal trench would utilize gravity as the prime moving force in order to conserve energy. In order to dispose of 23 mgd (16,100 gpm) of ocean water from OTEC activities, the required trench size for alternative location 1 would be 5 feet wide, 5 feet deep by 144 feet long. At alternative location 2, these dimensions would be 5 feet wide by 5 feet deep by 193 feet long. The design length should be extended by a factor of 2 for safety reasons. The trench could be filled with crushed lava or #2 gravel to increase the filtration effect of the lava formation and to provide greater dispersion, diffusion and residence time before the water is discharged to the ocean as underwater seepage flow along the coast.

3.0 Environmental Impact Analysis

3.1 Impacts on the nearshore marine environment

Of potential concern to the nearshore ecosystem are altered oxygen and nutrient concentrations and lowered temperatures. The dissolved oxygen concentration in the mixed discharge could be as low as 4 ppm (worst case without degassing) although typically concentrations of 5.5 ppm would be expected. Discharges containing reduced concentrations of oxygen will tend to depress



Discharge to disposal trench within NELH
(16,100 gpm)

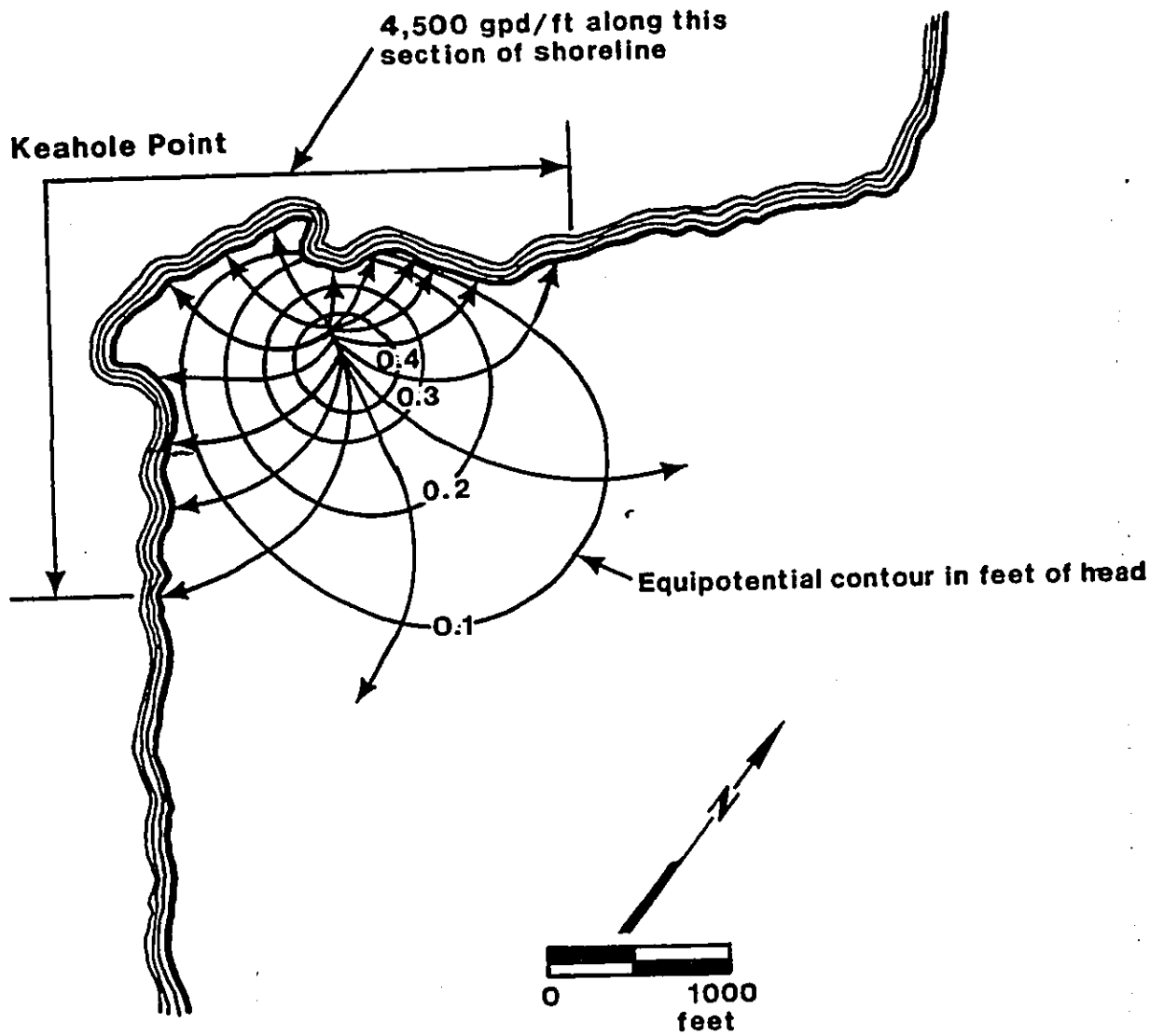
Figure IV-3

FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

IV-14a

Dames & Moore



Discharge to alternative disposal trench within NELH
[16,100 gpm]

Figure IV-4

FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

metabolic activity of the coastal community, but rapid mixing and dilution in the surge zone and advection will minimize the areal extent of this impact.

Canal discharge with ponding area would have the effect of aerating the discharge stream, probably to values near saturation. Photosynthesis in the canal would add oxygen during daylight hours, but respiration would decrease oxygen during the night.

Oxygen concentrations in waters disposed of into injection wells will remain at much the same oxygen concentration through the substratum which could potentially depress metabolic activity of resident marine communities. The low flux of discharged water through the bottom (1.2-2.9 gpd/ft^2) would tend to reduce the significance of this impact.

OTEC waters disposed of into a trench at NELH will not benefit from the turbulence and photosynthesis which would characterize passage through a canal. Oxygen concentrations would likely further decrease somewhat due to bacterial activity in the trench. Trench disposal would considerably diffuse entry of these waters to the sea and rapid mixing at entry would tend to mitigate impacts.

Discharge water temperatures are not anticipated to be below 19°C, and lethal impacts are not expected on any affected populations. Potential sublethal impacts could include reduced metabolic rates, especially of corals. This could retard reef growth and in the long-term alter community structure by changing the competitive balance among species. It could lead to avoidance by some motile species, and primary productivity could be lowered.

OTEC waters disposed of via injection wells would not receive an appreciable amount of warming in disposal, but would receive high dilution prior to entry into receiving waters and would enter waters of low ambient temperature. At -300 to -400 meters, ambient temperatures vary between about 20° and 25°C depending on depth and season. Impacts would be very slight.

Trench disposal will afford some warming and will greatly diffuse the flux and allow for high initial dilution in the receiving waters. It does not appear that the magnitude of the potential temperature depression would cause mortalities in the benthic community, but monitoring of community metabolism would be needed to provide quantitative estimates of impact.

Nutrient concentrations in OTEC discharges will be elevated over those of receiving waters. Nutrient subsidies could increase algal uptake rates, growth and standing crops. Fleshy macroalgae are notably sparse off the coast except in the surge zone where grazing is inhibited, so impacts of stimulation of the benthic algal community beyond the surge zone might be expressed as increased population sizes of herbivores and higher trophic levels rather than elevated algal standing crops. Offshore phytoplankton densities are very low in these clear, oceanic waters. Nutrient subsidies may increase uptake and growth rates, but the time lag between uptake and growth responses (on the order of a day), advection by offshore currents and grazing by herbivorous zooplankton would all act to minimize elevations of phytoplankton concentrations.

Complete nitrogen removal is not necessary. The offshore ecosystem is adapted to a constant influx of nutrient-rich brackish groundwater. Walsh (1984) found an inverse relationship between nitrogen and salinity in nearshore surface seawater samples which indicates that groundwater of about 8 ppt would be expected to have a nitrogen concentration very similar to that of

the mixed OTEC discharge. Thus nutrient concentrations in the OTEC discharge should not of themselves be a concern.

The offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would be expected to greatly increase macroalgal biomass because grazing is inhibited in the surge zone. The impact would primarily be aesthetic and its significance would depend on individual perceptions of the degree of visual degradation caused by its presence. As described in Section C-2.0 of Part III of this SEIS, because of the absence of a "nearshore coastal regime" in the Keahole area, this algae is not expected to be carried to onshore areas of adjacent properties.

Disposal via canal of 16,100 gpm of OTEC discharge would require a very large ponding area (± 900 ft) for complete nitrogen removal. About 920 pounds dryweight of algae would be produced daily in this situation. Without complete nutrient removal, the impact of canal discharge would likely be visible stimulation of the algal turf in the surge zone where grazing is inibited.

Disposal of OTEC waters via injection well would result in high nutrient concentrations at discharge because of the lack of opportunities for biological treatment within the disposal system. As for oxygen and temperature, however, the flux from injection wells will be most diffused at entry to the receiving waters. According to modeling done by Noda and Associates (1985) for the deep ocean outfall concept, the density of the plume would match ambient densities of -250 feet in summer and -380 feet in winter. The former is at the lower limit of the mixed layer, but above the top of the nutricline. Some stimulation of phytoplankton production is likely but mixing and advection would likely obscure these impacts. Entrainment of these waters in an eddy system could have the indirect impact of raising the bottom

of the photic zone and the nutricline depth range, but these would not be significant impacts.

The deep injection wells would provide a residence time of about three months, and would create seepage through the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation of the algal turf at the shoreline, it would come at substantial additional cost.

Algal uptake in trench disposal will be minimal. Bacterial action will serve to reduce nitrogen concentrations somewhat and flux into the receiving waters would be more diffused. As it appears that this water would be similar in nutrient content to existing groundwater flux, impacts would result not from concentrations themselves but from elevated flux rates. Where grazers have access to algal growth, it is likely that the same processes now acting to remove fresh algae from the benthos will adequately mitigate impacts. Some localized increase in fish population size could be expected.

Phytoplankton growth responses would lag nutrient uptake by a day or more, during which time advection would carry the cells away from the area and mixing would dilute cell concentrations. Impacts on phytoplankton would therefore be low and insignificant.

In summary, in comparison to ambient waters, OTEC discharges will be altered in some physicochemical parameters and will contain elevated concentrations of inorganic nutrients. OC OTEC will not introduce supplemental concentrations of heavy metals, and chlorine additions are unlikely. With appropriate mitigation, impacts of on-land disposal on the marine environment are anticipated to be low, insignificant and reversible; however, because of unknowns associated with OTEC discharge, a monitoring program should be a condition of any method chosen.

3.2 Impacts on Anchialine Ponds

Disposal of OTEC seawater discharge via canal would not impact the anchialine ponds at NELH. The deep well injection is not anticipated to significantly effect the thin lens of brackish water found in the general area. There will be no impact on the anchialine ponds on the NELH property from deep well injection.

Disposal of the waste waters of NELH and the HOST Park into trenches will displace the groundwaters beneath the existing anchialine ponds at NELH. The brackish water lens is the source of water for three ponds. It is possible that after some years, these ponds may begin to become more brackish, then saline as a result of the NELH discharge.

As stated in Appendix E (GK & Associates), it is now well documented that creation of anchialine habitat is possible. Borrow areas at Waikoloa were observed to flood at high tide. The Schizothrix community quickly established itself as did the opaeula and another endemic shrimp, Metabetaeus lohena (Army Corps of Eng., 1985). Test holes were colonized by opaeula within 10-14 days, indicating their ubiquitous nature in the water table. An artificial pond has been dug at Waikoloa to replace a portion of the habitat that has been lost through filling, and this pond is developing a typical anchialine ecosystem (Brock, 1986). Present plans at NELH do not include filling or otherwise physically altering any of the anchialine ponds there, so no habitat would be lost. Presumably this would mean that no replacement habitat is necessary if the displacement of groundwaters by NELH discharges does not reduce the quality of the habitat for the rare endemic shrimp species.

To the shrimp the primary differences between the groundwater and the NELH discharges would be the increased salinity and the reduced temperature. Brock (1985) reports that

opaeula are found at salinities between 2 and 30 ppt, and temperatures between 22 and 30°C. Personal observations by Brock are that the opaeula will tolerate salinities to at least 45 ppt. It therefore does not appear that replacement of the groundwaters with NELH discharge waters in the ponds will necessarily displace the endemic shrimp. Their diverse diet, consisting of detritus, benthic diatoms, phytoplankton, filamentous algae, vascular plant tissue and animal tissue (Wong, 1975), would allow ready adaptation if other components of the ecosystem would change. In sealed containers these shrimp seem to exist on bacterial films.

From the above, it does not appear that the impacts of disposal of NELH discharges into the ground will have a serious impact on the essential character of the nearby anchialine ponds. Nevertheless, the ponds should be monitored to observe any changes resulting from the NELH discharges. A monitoring program is outlined in Appendix B. Perhaps after establishment and thorough documentation of a new equilibrium condition, a restoration program could be implemented. This would consist primarily of fish removal.

3.3 Impacts on Existing Operations at NELH

Of the discharged nutrients, nitrite + nitrate could increase to levels significantly above the ambient. In OC OTEC research where lysing occurs, the usability of nutrients in the discharge is expected to increase. In addition, dissolved oxygen is expected to decrease. An increase in organic material would result in increased rates of biofouling in closed-cycle heat exchangers and low dissolved oxygen levels could adversely affect heat exchanger corrosion rates.

Impacts on OTEC experiments dependent on high integrity of warm intake water (such as materials testing) could be significant if degassed cold seawater is discharged via canal

without reoxygenation under ebb tide conditions. Because of the dilution that occurs at the intake under current conditions, impacts on other OTEC research not affected by nutrient loading and oxygen depletion considerations would be low and insignificant.

Existing operations at NELH, particularly those using the warm ocean water, are not anticipated to be adversely affected if OTEC seawater return flows are discharged into deep injection wells. The discharge plume is not expected to affect either the warm or cold water intakes.

Nutrients in the discharge via trench may also affect the warm water intake during ebb tide conditions. It may be desirable to reduce nutrients in the discharge to protect the warm water source and minimize biofouling of various experiments.

3.4 Impacts on the Terrestrial and Human Environment

Discharge via canal would not impact the flora, fauna or archaeological sites on the NELH property. The land (or rock) area required for a ponding area at 16,100 gpm of discharge would be very large (960 feet wide). Finding a suitable site of sufficient size may not be possible without seriously restricting the public shoreline area.

Discharge via deep injection well would not impact the flora, fauna or archaeological sites on the NELH property.

The primary effect caused by disposal in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but apparently is the source of water for some small stands of kiawe trees located about 1/4 mile north of Keahole Point. Trees that have deep root systems that reach the groundwater level may

not survive the displacement of the brackish water lens by the saline ocean water plume. If this should occur, they can be replaced with trees with a greater tolerance to salinity such as coconut palm (cocos nucifera), heliotrope (messershmidia argenta), or milo (phesbesia populnea) (Char, 1986).

The on-site anchialine ponds are not a habitat for sea birds, therefore, impact on avifauna would be insignificant. There will be no impact from trench disposal on archaeological sites. The trench will have minimal impact on recreational uses of the coastal area.

3.5 Mitigating Measures

3.5.1 Canal Disposal

If reduced temperatures are experienced at the point of entry to the sea, this would provide a small benefit to terms of slowing metabolic rates and therefore reducing oxygen requirements making it easier for resident species to accommodate any reduction in oxygen concentrations. If evidence is found of reduced nearshore oxygen concentrations, then further monitoring of benthic community metabolism would be warranted.

If degassing of the OTEC waters takes place, then reoxygenation through aeration pretreatment may be necessary prior to discharge to avoid severe metabolic stress to communities resident in the canal ponding areas and nearshore.

In canal disposal of OTEC water, uptake of solutes by aquatic vegetation could be important in the waste treatment process. Approximately five species of marine algae dominate effluent streams now existing at Keahole Point.

These communities are capable of removing inorganic nitrogen and phosphorus at rates of 1.2 $g/m^2/day$ and 0.67 $g/m^2/day$ respectively (Robichaux unpublished). In addition, they are effective in removing CO_2 at rates of over 26 $g/m^2/day$. Trace metals such as iron, copper and zinc are absorbed at rates in the range of 1-10 $micrograms/m^2/day$, when concentrations are non-toxic.

The only potential reason for reducing nutrient content in the discharge would be because stimulation of the nearshore algal turf is aesthetically unacceptable. In this case, treatment with RBC technology would be possible. This would require disposal of biomass generated in the process. If a commercially valuable seaweed could be utilized in a canal system and sufficient land area would be made available then this might be technically and economically viable.

If there are longshore currents present in addition to purely tidal currents, discharge flows of 16,100 gpm via canal are acceptable under the present warm seawater intake configuration. In the case where only tidal currents occur, discharge during the ebb tidal current cycle is of concern. Initial results indicate that the quality of the water at the warm seawater intake could be compromised. Therefore, an alternative disposal method should probably be as means to mitigate this impact would be costly and difficult to implement.

3.5.2 Disposal Via Injection Wells

Disposal of the OTEC discharges via injection wells will require reoxygenation through aeration and possibly warming to avoid damage to corals and other sessile biota in

the area of seepage. Offshore monitoring of oxygen concentrations is recommended.

3.5.3 Disposal Via Trench

Reoxygenation through aeration pretreatment may be necessary prior to discharge to avoid severe metabolic stress to communities resident in the nearshore area. Filling the trench with crushed lava or #2 gravel would be expected to increase the filtration effect of the lava formation and to provide greater dispersion, diffusion and residence time before the water is discharged to the ocean as underwater seepage flow along the coast. This would not enable maintenance of the trench, but the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required.

The operation of the trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench can then be incrementally extended to handle more disposal quantity if required.

C. MARICULTURE SEAWATER RETURN FLOWS

1.0 Characteristics of the Discharge Water

At full development, it is estimated that approximately 25,900 gpd of mixed warm and cold seawater discharge will be generated by mariculture operations at NELH. Cold, nutrient rich and pathogen free ocean water will be pumped to the operations from pipelines

deployed in waters off Keahole with intakes at approximately the -2100-foot depth. Warm ocean water will be provided either by pumping it ashore from approximately the -60-foot depth, warming the cold water on-site, or by re-using water from OTEC or other mariculture operations. The overall ratio of cold to warm water resulting from all operations is estimated to be 1:4.

Constituents of discharge derived from mariculture operations can be characterized by examination of solute levels resulting from continuous operation and from periodic manipulations to the system such as harvesting, cleaning or feeding which typically result in brief, low-volume, but concentrated, pulses of waste material. Sparrow (1979) found that up to 25% of the wastes from typical salmonid hatcheries were generated in cleaning the tanks. Waste products of mariculture can be characterized as: organic wastes from crop metabolism and unused feeds, inorganic fertilizers, antibiotics and other disease treatments, chemicals used for maintenance of water quality or facility disinfection, and larvae or other propagules (G.K. & Associates, Appendix B).

Please refer to Appendix B for a detailed description of various constituents of mariculture discharge water. It should be noted that actions described in Appendix B and below are also relevant to future activities at HOST Park.

2.0 Seawater Return Flow Disposal

2.1 Analysis

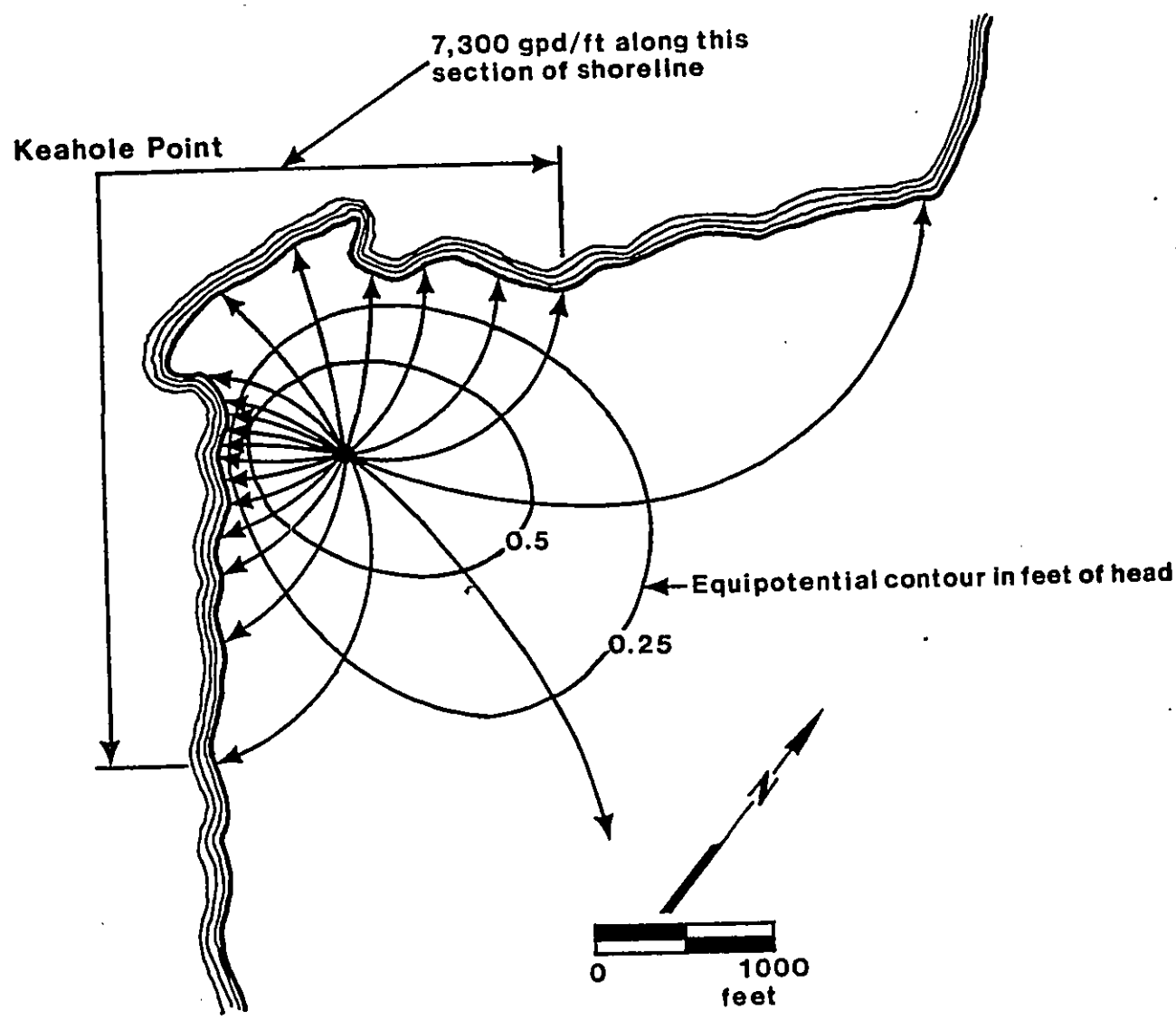
The proposed disposal method for mariculture discharges analyzed in this SEIS is via a trench located along the makai side of the NELH access road towards HOST Park. The location modeled for this analysis is roughly parallel to and approximately 750 feet from the shoreline at a ground elevation of approximately 10 feet above sea level (Figure IV-1).

Disposal in a shallow trench was modeled using an analytical computer model based on the Theis non-equilibrium equation (Dames & Moore, Appendix C). Based on results of the model, it is estimated that 85% of the discharge will occur over a distance of 4,300 feet along the shoreline, an average of 7,300 gpd/ft (Figure IV-5). If the flow is assumed to be distributed evenly between the 0 to -200-foot bathymetric contour, it will average of 1.9 gpd/ft^2 of ocean bottom in this zone. Discharge will be greater in offshore areas closest to the discharge trench. At these locations, the flow will be approximately 4.2 gpd/ft^2. Minimum residence time of 29 to 62 days was calculated (see Appendix C).

Waste water discharged from mariculture facilities would be subjected to a variety of processes or treatment mechanisms as it (1) flows through trenches enroute to the disposal trench, (2) infiltrates into the aquifer system, and (3) mixes with the ground water underlying Keahole Point. The principal mechanisms include biological absorption, physical filtering, precipitation reactions, and dilution.

Trench disposal will serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for nitrifying bacteria. After entering the aquifer, the rate of adsorption and oxidation of organic chemicals and metabolites is considerably slowed. Inorganic ions in the effluent, including ammonia, will pass through the ground relatively unaffected due to the short residence time (less than 62 days) and lack of soils or clays in the Keahole Point region.

The algal community in the existing outfall at NELH transforms roughly 20% of the inorganic material absorbed into dissolved organic nitrogen and phosphorus which is released into the discharge stream. Oxidation of other organic materials,



Discharge to disposal trench along roadway to NELH
(25,900 gpm)

Figure IV-5

FLOW NET

NATURAL ENERGY LABORATORY OF HAWAII
Keahole, North Kona, Hawaii

Dames & Moore

ammonia, and other chemicals would proceed at rates consistent with the temperature and sunlight. A limited reduction of BOD and suspended solids could be expected through settling and absorption of dissolved solutes in the trench due to the rapid flows and net production of dissolved organics.

Organic material entering the disposal trench system will be remineralized to end products which depend largely on the amount of available oxygen. Under aerobic conditions, carbohydrates and proteins are oxidized to CO_2, H_2O, NO_3, SO_4, and microbial cell tissue. In the absence of oxygen, the same inputs become reduced end products such as methane, hydrogen, ammonium, hydrogen sulfide, and a variety of intermediate products such as organic acids, alcohols, amines and mercaptans. It is likely that the proposed disposal trench will be predominantly aerobic; however, pockets of particulate accumulation may provide reducing environments which allow denitrification of nitrates and nitrites to ammonia, nitrogen gas or nitrous oxide.

2.2 Disposal Facility Requirements

Trench dimensions for disposal of 37 mgd (25,900 gpm) would be approximately 5-feet wide by 5-feet deep by 362-feet long. Although the available length of the disposal area is more than 2,000 feet, if necessary the length of the trench can be shortened by digging a deeper trench. A ten foot wide by ten foot deep trench would require a theoretical trench length of 158 feet, without allowing for any safety factors.

In order to allow for non-homogeneity of the hydrogeologic characteristics of the proposed disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage, the actual excavation should probably be twice the theoretical trench length.

One construction option being considered is trench excavation, and replacement with a perforated pipe and large boulder or crushed lava backfill. This would preclude maintenance of the trench, however, the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required during the phased development of NELH activities.

The operation of the trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench could then be incrementally extended to handle more disposal quantity as NELH facilities expand.

3.0 Environmental Impact Analysis

3.1 Impacts on the marine environment

Mariculture experimentation at the NELH will result in discharges with the following components and characteristics of most concern:

- o elevated concentrations of plant nutrients;
- o increased concentrations of dissolved and particulate organic matter; and
- o pulses of chemicals used to clean facilities or maintain water quality in culture containers (especially chlorine and copper compounds).

Discharges from mariculture operations will be subject to rapid dilution, advection, low toxics concentrations, algal

uptake capacity, and warming in culture and disposal systems, therefore, impacts of mariculture discharged in the trench will be insignificant. Some stimulation of the algal turf along the shore is likely due to restricted opportunities for grazing by herbivorous fishes. Visual impact could be significant to some observers.

Formalin (dilute formaldehyde) is used in mariculture operations to reduce bacterial, fungal and parasitic infections. The probable concentrations of formalin appearing in effluent will be absorbed by bacteria and algae in the supply and disposal trenches. It is recommended that any formalin used as a disinfectant be diluted out into the discharge stream as necessary to prevent high concentrations from appearing in the disposal trench.

Cutrine-plus and copper control are more used to reduce phytoplankton populations in ponds or biofoulines in tanks. Triethanolamine is toxic to algae and bacteria in concentrations in the range of 2-60 ppm but the copper complex would not be expected to appear in the discharge in concentrations higher than 1 ppm. Federal regulations restrict the discharge of copper from power plants and other point sources to concentrations less than 1 ppm.

Trench-disposal will filter out particulates, and organics will be acted upon by bacteria in the pores of the substrate. (See Section B 3.1) Chlorine and copper-based derivatives are not expected to appear in the combined waste waters in toxic concentrations.

Certain chemical additives, unknown at the present time, could potentially impact the marine environment. For example, Isopods and other parasites have been reported to infest oysters grown in dense cultures and natural waters. At the present time,

there is no effective chemical for treatment of these endoparasites; however, if some treatment is developed, the nature of the chemical should be investigated prior to its introduction into the discharge system, as it may significantly impact the resident epifauna.

Importation of exotic species to Hawaii is controlled by a multi-tiered review and permit system administered by the Plant Quarantine Branch of the Hawaii Department of Agriculture. All potential imports and the facilities for holding them must undergo a thorough review prior to approval. Disposal of mariculture effluents into a trench will effectively preclude escape of these species under normal operating conditions.

3.2 Anchialine Ponds

Impacts on anchialine ponds will be the same as those discussed in Section B 3.2. Flownets showing flow patterns for mariculture discharge is presented in Figure IV-5.

3.3 Impacts on Existing Operations at NELH

Certain materials testing experiments could be affected by higher nutrient levels in the discharge waters if they reach the warm water intake.

3.4 Impacts on the Terrestrial and Human Environment

Impacts on the terrestrial and human environment will be similar to those discribed in Section B 3.4.

3.5 Mitigating Measures

Pretreatment requirements may include warming and possibly nutrient and process chemical removal. Appendix B discusses in

detail and evaluates various means of mariculture waste pretreatment.

Of the metals which may be present in the mariculture discharge, copper is the element which requires closest monitoring. At levels in the range of 1-10 ppb copper is an essential plant nutrient; however, in concentrations of 0.5 ppm and over it becomes extremely toxic and is commonly used as an herbicide. Management of the disposal system to provide treatment of mariculture effluents requires that copper concentrations in the effluent be maintained below toxic levels.

Chlorine and copper-based derivatives are not expected to appear in the combined waste waters in toxic concentrations, but if removal of these compounds is necessary then an activated carbon pretreatment system is recommended.

Using mariculture for treatment of wastes has been suggested. The primary purpose of a mariculture waste facility at NELH would be to reduce the nutrient content of the effluents. Algal uptake experiments at NELH indicate that only a small percentage of the nutrients in the waste waters would be removed in an open trench system. To significantly reduce nutrient loading would require a very large land area, probably more land than is available, and certainly more than would be desirable to commit to this use. This is not to say that some treatment would not occur incidental to mariculture operations at NELH. Algae culture will serve to reduce nutrient loading; but culture of higher organisms will increase loading.

Accumulation of algal biomass beyond the densities which may be supported in non-limited growth will hinder biological absorption of pollutants. Consequently, removal of the algae on a regular basis would be required. In addition, the accumulation of algae and other fouling organisms may reduce the permeability

of the trench. Biofouling may be controlled by periodic scraping or enlarging the trench, or by introduction of grazing animals which may be of commercial value. Trade-off between land area and efficiency of nutrient stripping needs more research and economic evaluation.

A more fundamental question than whether mariculture waste treatment is appropriate is whether nutrient removal is necessary. Although it may be desirable to reduce nutrients in the discharge to protect the warm water source and minimize biofouling of various experiments, nutrient enrichment of the waters offshore Keahole Point could be beneficial to the local fishing industry.

D. COMBINED SEAWATER RETURN FLOWS GENERATED BY OTEC AND MARICULTURE OPERATIONS

1.0 Characteristics of the Discharge Water

At full development, it is estimated that approximately 42,000 gpm (60 mgd) of mixed warm and cold water discharge will be generated by OTEC and mariculture operations at NELH. For comparison, the maximum projected waste water volume anticipated at full development of the adjacent HOST Park (estimated to be at least 10 years in the future) is about 100,000 gpm, about 80% of which would be warm water. The relative maximum volumes of water to be disposed of at NELH are as follows:

OTEC--23 mgd (16,100 gpm--6,500 gpm cold, 9600 gpm warm)
Mariculture Uses--37mgd (25,900 gpm).

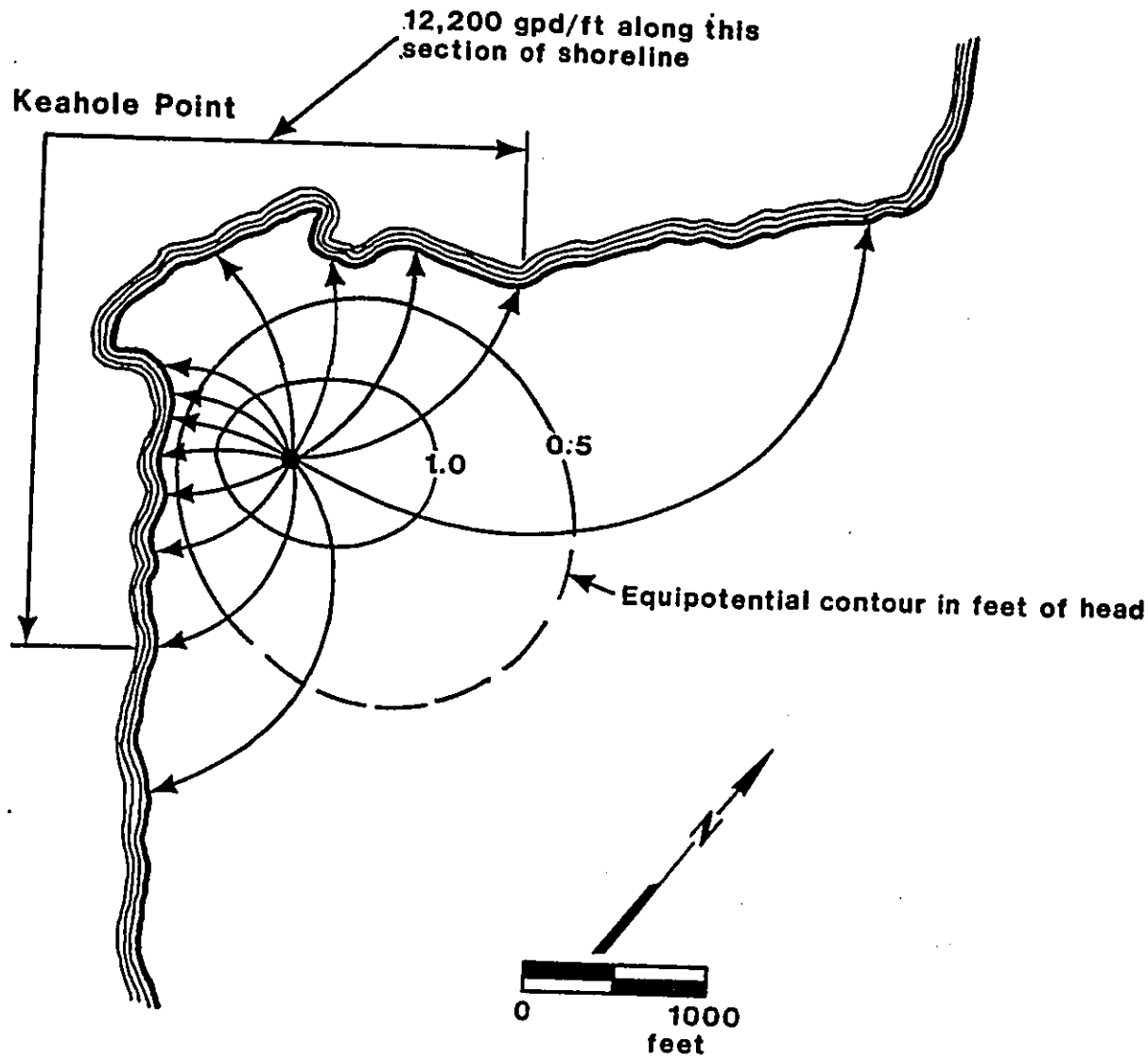
2.0 Disposal Via Trench Along the NELH Access Road

2.1 Analysis

The disposal of combined OTEC and mariculture discharges of 42,000 gpm in a shallow trench was modeled using an analytical computer model based on the Theis non-equilibrium equation (Dames & Moore, Appendix C). The modeling indicates that 77% of the discharge would occur over a shoreline distance of 3,800 feet, an average of 12,200 gpd/foot. If the flow is assumed to be distributed evenly between the 0 to -200 foot bathymetric contour, it would average of 3.2 gpd/ft^2 of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 5.9 gpd/ft^2. Minimum residence times of 18 to 38 days were calculated using an expanding sphere and expanding cylinder model (Appendix C).

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Pt. Flow nets showing flow patterns for the combined discharge is presented in Figure IV-6.

Dames and Moore (Appendix C) noted the probable occurrence of lava tubes and other zones of high permeability in the subsurface geology. If lava tubes are present in close proximity to the diffusion trench, effluents may have a hydrologic residence time considerably less than expected, and suspended solids passing into the receiving water will be higher than expected. If no direct channels are encountered, the lava structure is expected to provide a matrix for accumulation of bacterial biomass which allows limited biological treatment.



Discharge to disposal trench along roadway to NELH
(42,000 gpm)

Figure IV- 6

FLOW NET

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Keahole, North Kona, Hawaii

Dames & Moore

2.2 Disposal Facility

The disposal trench location analyzed in Appendix C is along the makai side of the NELH access road towards HOST Park roughly parallel to and approximately 750 feet from the shoreline (Figure IV-1). The ground elevation in the area is approximately 10 feet above sea level.

Disposal trench dimensions for a disposal quantity of 60 mgd (42,000 gpm), would be approximately 5-feet wide, 5-feet deep, and 587-feet long. Although the available length of the disposal area is more than 2,000 feet, if necessary the length of the trench can be shortened by digging a deeper trench. A ten foot wide by ten foot deep trench would require a theoretical trench length of 256 feet, without allowing for any safety factors.

3.0 Environmental Impact Analysis

3.1 Impacts on the Marine Environment

Impacts of discharge on the marine environment will be similar to those described in preceeding sections' analysis. Trench disposal will serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for nitrifying bacteria. Discharges will be subject to rapid dilution, advection, low toxics concentrations, algal uptake capacity, and warming in culture and disposal systems, therefore, impacts of combined OTEC and mariculture discharges on the marine environment will be insignificant. Warming and aeration of these waters should be adequate to minimize negative impacts on nearshore biota.

3.2 Impacts on Anchialine Ponds

As described in Section B 3.5, disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Point. The existing ground water will be severely impacted, however, it is in itself of relatively insignificant value. Impacts on anchialine ponds will be similar to those previously described.

3.3 Impacts on Existing Operations at NELH

Impacts will be similar to those described in Section B 3.3.

3.4 Impacts on the Terrestrial and Human Environment

Impacts will be similar to those described in Section B. 3.4.

3.4 Mitigating Measures

Mitigating measures would be similar to those described previously for trench disposal.

E. CUMULATIVE IMPACTS

At maximum development, the adjacent HOST Park anticipates an eventual discharge of 100,000 gpm into a trench. This discharge will be increased gradually from an initial flow of 6800 gpm in 1987 to full development of the park in approximately 10 years or later.

HOST Park discharges into shallow trenches will reflect the mixture of park uses as it develops. The area of influence of the combined NELH and HOST Park plumes would be dominated primarily by the HOST Park mariculture plume and secondarily by the NELH mariculture

plume. The combined area influenced would include waters along the coast fronting the NELH, the HOST Park and adjacent properties from the shoreline out to bottom depths of at least -200 feet. Concentrations of discharge waters would be highest directly offshore of the respective disposal trenches and less at increasing distances. Concentrations of plume tracer parameters could be expected to exhibit a relative minimum offshore between the two mariculture plumes.

The offshore bathymetry of the area of concern indicates that the -200 feet contour lies at only about 600-800 feet offshore. Beyond this, the bottom slopes more gently to depths of -400 feet at about 2,000 feet offshore. The benthic community out to depths of approximately -200 feet is dominated by several species of coral, encrusting algae and sea urchins. Beyond this the rocky slope grades into a sandy plain harboring large aggregations of taape (Lutjanus kasmira).

In the water column above the benthos are populations of phytoplankton, zooplankton (including fish eggs and larvae), micronekton and nekton. Marine mammals and threatened or endangered species may also pass through these waters.

Degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. Present plans for both facilities include a gradual increase in volumes of water to be used. This will allow a monitoring program to provide early detection of any impacts. In addition, the potential impacts are reversible. That is, if discharges are halted, the affected ecosystems could be expected to revert to baseline conditions.

Disposal of the waste waters from NELH and HOST Park into trenches will displace the groundwaters beneath the existing anchaline ponds at NELH. Because of the extent of the resultant subsurface plume, it does not appear to be possible to mitigate this impact by altering the locations of the trenches. As stated in Sections B and C, the

anchialine ecosystem is expected to adapt to increased salinities and impacts are anticipated to be minimal.

OI Consultants, Inc. (1985, 1986) examined the anchialine ponds at Kohanaiki, a land parcel immediately south of O'oma II which is slated for resort development. The comprehensive baseline survey of anchaline ponds of the Kona coast by Maciolek and Brock (1974) identified the Kohanaiki ponds as having exceptional value, and potential impacts on these ponds were addressed in the modeling and analysis done for the HTDC FEIS. The OI surveys found a number of ponds not previously mentioned in the literature, bringing the total number known from that area to about 60. However, the biota of many of the ponds originally surveyed in 1972 by Maciolek and Brock (those in the northern half of the parcel, closest to the HOST Park/NELH site) has changed appreciably. Topminnows (Poeciliidae) are now present in these ponds, evidently at the expense of crustaceans and many algal species. The ponds in the southern half of the parcel remain of exceptional value in that they evidence the rich algal diversity and endemic crustacean fauna formerly found in the northern ponds. If the subsurface plume should reach these ponds, estimated to be 10-30 years (HTDC, 1985), the impacts on the anchialine ecosystems should be insignificant.

The recent surge of resort development planning for West Hawaii has implications for operations at NELH. Adjacent to and south of the HOST Park site are the proposed O'oma II and Kohanaiki developments, respectively. Each is anticipated to include golf courses and substantial other landscaped areas. Domestic wastes are projected to be disposed of into or onto the ground. Coastal waters nearby may receive additional nutrient subsidies as well as rations of various pesticides and other pollutants typical of urban runoff. Although it is anticipated that these will quickly be advected out to sea, there is a potential long-term impact to the warm water intakes at NELH and HOST Park. This situation should be carefully monitored and appropriate mitigating measures taken if adverse impacts occur or it

may be that in the latter part of the next decade the purpose and use of the NELH facility may have to depend less on the pristine quality of the warm water for such things as materials testing.

F. OVERALL MITIGATING MEASURES

1.0 Water Quality Monitoring Program (Appendix B)

The previous EIS (HTDC, 1985) and the CDUP for NELH specify development of monitoring programs for offshore waters and anchialine ponds. It is recommended that monitoring of appropriate water quality and other parameters be done. The goals of the monitoring program should be to protect the natural ecosystems present in the anchialine ponds and coastal waters and to maintain the quality of the warm and cold source waters for NELH and HOST Park. Implementation of the monitoring program should take place as soon as possible to provide adequate baseline data for the selected parameters at the selected monitoring locations prior to initiation of construction or operation of the proposed facilities.

The monitoring program, which is outlined in Appendix B, has been designed to detect the effects of all major anticipated environmental perturbations including ocean, anchialine ponds, shoreline seepage points (e.g., the springs at Wawaioli), and offshore sites. The HOST Park Development Plan includes construction of a series of monitoring wells behind the shoreline, and these should be used to monitor subsurface NELH discharges as well. Offshore sampling locations and depths have been suggested in the plan (Figure 3, Appendix B).

Parameters to be monitored should be varied depending on the impacts which are possible at a given state of development. For example, during construction turbidity, habitat loss and protected species activities should be documented. Immediately following pipeline deployment a program to monitor new submarine surfaces for

blooms of the ciguatera-causing algae, Gambierdiscus toxicus, should be implemented. Baseline and operational monitoring should include both biological and water quality parameters. Water quality parameters should include temperature, salinity, dissolved oxygen, turbidity, nutrients, indicators of fecal contamination, chlorophyll, chlorine residuals and copper. Consideration should also be given to including petrochemicals and chlorinated hydrocarbons, as specified inthe management plan for the Waikoloa ponds. Biological monitoring should include documentation of faunal assemblages offshore and in the anchialine ponds, as well as human activities in the area. Measures of variability should include species present, biomass, density, diversity, frequency of occurence and others if appropriate. Along the shoreline of NELH/HOST Park the distribution and abundance of fleshy macroalgae should be closely monitored. Recreational fishing effort and catch composition should also be monitored.

To understand the offshore dynamics of the system, ongoing current measurements will be required. Data on disposal rates, tidal state and basic climatology will also be necessary to evaluate results of the monitoring program.

The suggested frequency of monitoring has been designed to allow early detection of the potential effect anticipated. Frequency should be greatest during construction and start-up and later be reduced when consistent patterns are established with confidence. The monitoring plans should be frequently reevaluated to provide for modifications based on new results as they become available.

2.0 Reoxygenation Through Aeration

Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use. Lysing of cells in the evaporator will increase the concentrations of dissolved nutrients over those given above. If degassing of the OTEC waters does take place, then a reoxygenation through aeration pretreatment may be

necessary prior to discharge to avoid severe metabolic stress to communities resident in the canal and nearshore.

According to some scientists contacted by Oceanit Laboratories (Appendix A), reaeration could be easily accomplished by a fountain or any other turbulent motion in the air. However, it would be environmentally and economically beneficial to reinject the removed gases into the water prior to discharge. Research at U.H. indicates that this is very possible. One scientist says that his research will include effects of degassification. Reinjection studies will be part of his research effort at NELH.

Another scientist says that the DOE will be looking at degassification and regassification problems associated with OC OTEC. The impact on the environment from discharging oxygen-poor water is a concern. One possibility would be to reaerate by using a spout. Another possibility is with a hydraulic pump that could recombine the gases removed in an earlier state of the OC OTEC operation.

In any event, monitoring will be an important consideration of any research done on this problem as the degree of environmental impact of discharging oxygen-poor water is unknown. The proposed monitoring program should provide early detection of any adverse impacts so that alternative disposal methods can be instituted. As stated previously and in Appendix B, any adverse impacts on the environment are reversible and the ultimate mitigating measure would be to cease discharging oxygen poor water in a manner that affects the nearshore environment.

G. COMPARISONS AND RECOMMENDATIONS

1.0 Comparative Analysis of Disposal Alternatives

Based on current available information, environmental impacts of on-land disposal of OC OTEC return waters are assumed to be minimal (and reversible) for all alternative disposal methods evaluated. Because there are many unknowns associated with the process, however, this assumption must be tested during the scoping period, prior to full discharge of 16,100 gpm. Of the optional methods and locations for disposal of the OTEC water analyzed, the most environmentally beneign is deep injection, but trench disposal appears to be acceptable and very much less costly.

Based on existing research, it is assumed that OC OTEC return waters will be characterized by low dissolved oxygen, low temperature, high nutrient concentrations and possibly a very small amount of chlorine, but no additional heavy metals. The low dissolved oxygen concentration could cause some sub-lethal reductions of metabolic rates of nearshore communities and reaeration may be required. This mitigation would be required for all three disposal methods evaluated.

Discharges via either canal or very nearshore shallow trench have the potential to elevate nearshore nutrient concentrations. Some effect may be experienced at the warm water intake. It should be noted, however, that several studies (WRRC, 1980; R. M. Towill, 1982) have reported that coastal water quality standards are exceeded near the shore. This is not unusual since nutrient concentrations are generally elevated as a consequence of a higher proportion of groundwater in very nearshore samples. Elevated nutrients could be beneficial to commercial and recreation fishing activities that take place in the area.

As proposed, the deep injection wells would provide the greatest residence time, about three months, and would create seepage through

the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation of the algal turf at the shoreline, it would come at substantial additional cost.

Theoretically, discharge into a canal with ponding area appears to be an environmentally acceptable method of disposing of OC OTEC return flows. The 1,000 gpm of seawater currently discharged by this means does not produce a nutrient-rich plume or any measureable adverse environmental impact with mixtures of 1:1 to 1:6 cold to warm seawater. This is because the inter-tidal ponding area transforms the nutrients into algae and seaweed. However, before the same type of ponding area can be used for larger discharge volumes, additional investigations would be required to determine the physical characteristics that cause the pond to act as a "reactor vessel" that adds oxygen, removes nutrients and increases the discharge water temperature to approximately that of the ambient seawater. For this reason, and the fact that the land area for a ponding area might be prohibitively large in relation to the area available to NELH and that without additional studies NPDES permit requirements would be difficult to meet, discharge of 16,100 gpm of OC OTEC waters via canal was determined to be unfeasible at the present time. It is strongly recommended, however, that additional research be undertaken before this method is completely rejected for all projected volumes of discharge.

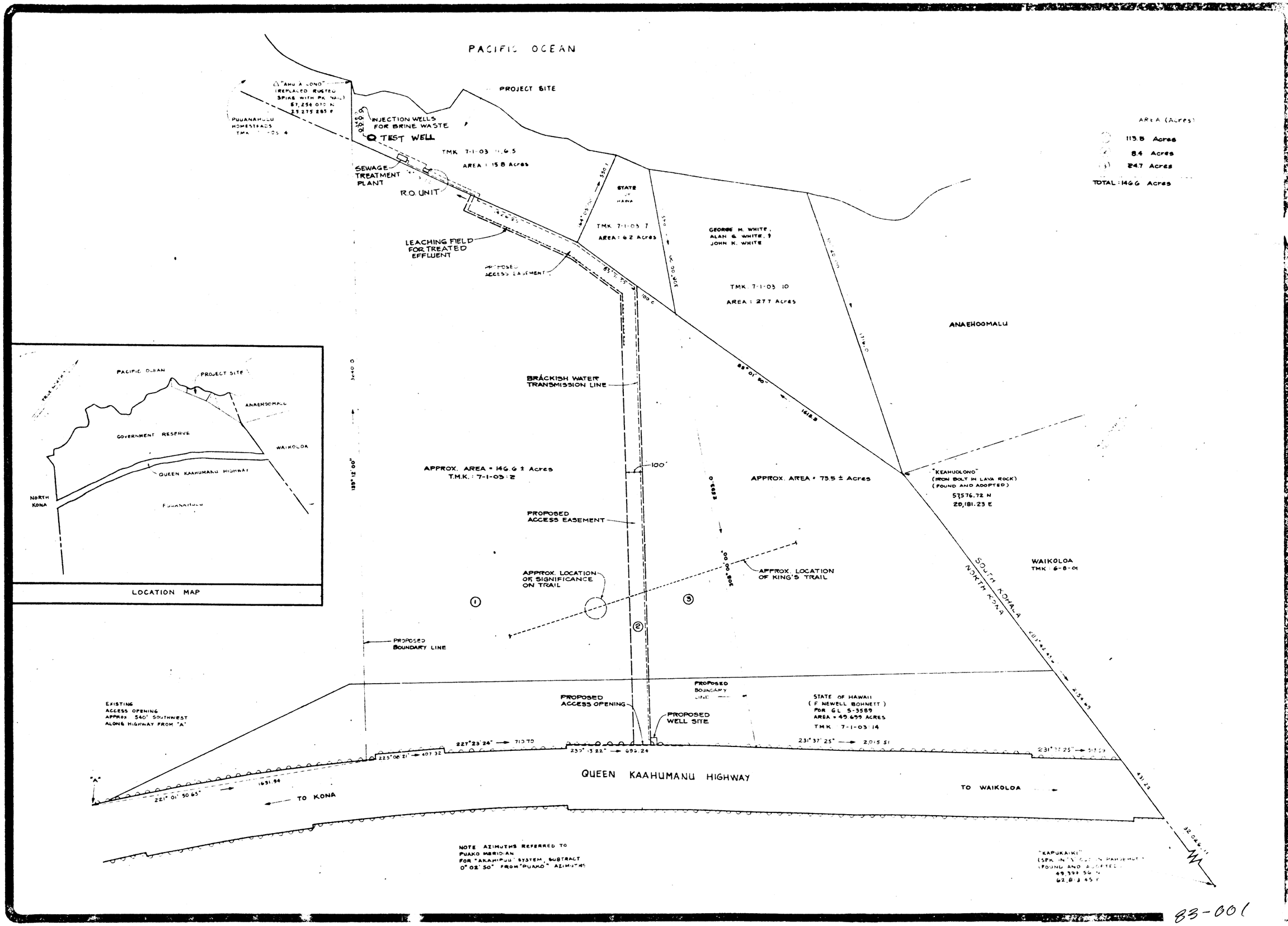
Trench disposal would serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for nitrifying bacteria. Pretreatment requirements would primarily be for reoxygenation through aeration. Although the rate of discharge per unit area is greater for the trench discharge within NELH than for deep injection wells (for a trench along the NELH access road the rate is slightly less) rapid dilution, advection, low toxics concentrations, algal uptake capacity, warming in culture and disposal systems, and reaeration, if necessary, will act to mitigate most impacts.

Disposal of the waste waters into trenches will displace the groundwaters beneath the existing anchialine ponds at NELH. The area of displacement would vary with the amount of discharge and location of the trench. Disposal deep injection wells would not affect this system. Because of the extent of the resultant subsurface plume, it does not appear to be possible to mitigate this impact by altering the locations of the trenches. The anchialine pond ecosystem which may be affected by this plume is expected to adapt to he change in salinity of the water (Brock, 1986).

A cost comparison between trenches and deep injection wells is presented in Appendix F. In general, deep injection wells are approximately 15 times more costly to construct and operate than disposal by trench within NELH. Without empirical data from monitoring a trench system, the theoretical minimal improvement in avoiding impacts to the environment by disposing via injection wells does not appear to warrant the additional cost.

2.0 Recommendations

Although based on current assumptions concerning OTEC discharge water, the analysis shows that all three methods of disposal are environmentally acceptable generating only insignificant (but reversible) impacts, there are still many unknowns associated with the processes involved. It is therefore recommended that OTEC discharge be disposed of into a research trench to be constructed in the NELH compound for discharge quantities in the range of 3,000 to 5,000 gpm. A research trench for volumes up to 5,000 gpm would be approximately 5 feet by 5 feet by 45 feet long. It has been suggested that a full-sized trench with a capacity of 16,100 gpm is required for initial testing of the full ocean water system. Although this would be more costly if research and monitoring indicate that an alternative method should be used during the 16,100 gpm 165 kW experiment, it is stil in keeping with this recommendation.



SAMUEL O. HIROTA INC.

NORTH KONA-KAPALAOA DEVELOPMENT

PROPOSED ACCESS TO PROPERTY FROM QUEEN KAAHUMANU HIGHWAY

FIGURE 4

30 MARCH 1981

83-001

UNDERGROUND UTILITIES:

1. UNDERGROUND UTILITIES SHOWN ON THIS MAP HAVE BEEN OBTAINED FROM AVAILABLE SOURCES OTHER THAN SAM O. HIROTA, INC.; THE ACCURACY AND COMPLETENESS OF THIS INFORMATION ARE NOT GUARANTEED.

2. THE CONTRACTOR SHALL VERIFY THE INVERTS AND THE EXACT LOCATION OF ALL EXISTING UTILITIES BEFORE COMMENCING WORK.

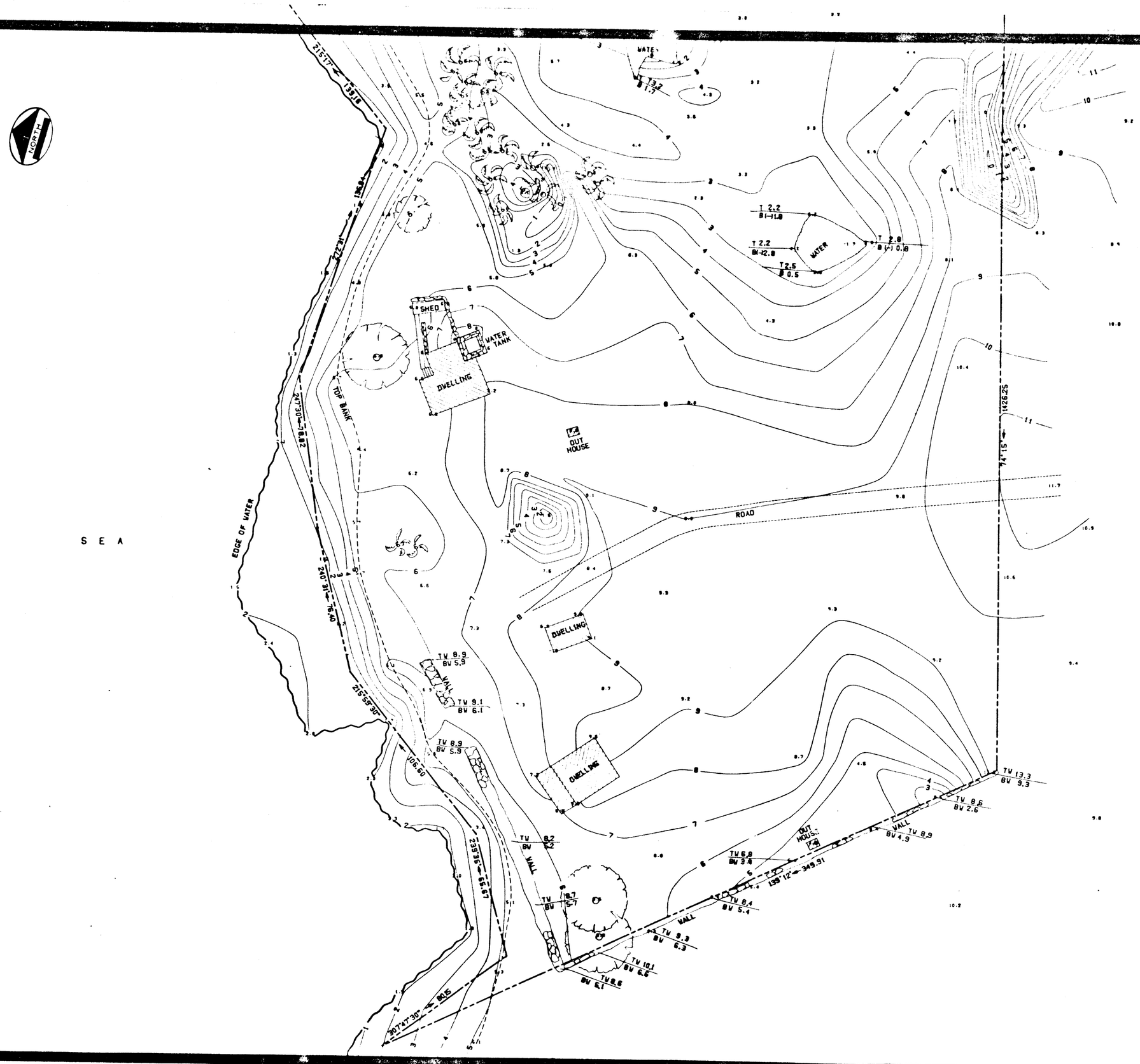
TOPOGRAPHIC NOTES:

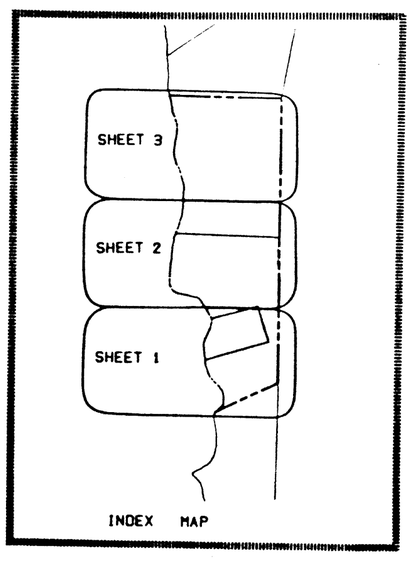
1. THIS TOPOGRAPHIC MAP WAS PREPARED FROM FIELD WORK DONE BY THE STADIA METHOD. ACCURACY OF SURVEY BEING ± 1 FOOT (HORIZ.)

2. WRITTEN DIMENSIONS SHOWN ON THIS MAP SHALL HAVE PRECEDENCE OVER SCALED DIMENSIONS.

3. NORTH ARROW REFERRED TO TRUE NORTH.

4. BENCH MARK: INFORMATION OBTAINED FROM
R.M. TOWILL CORP. KEAHUO BORY
ELEV. = 27.26





SAM O HIROTA, INC.
ENGINEERS AND SURVEYORS
345 QUEEN ST., SUITE 500
HONOLULU, HAWAII 96813

TOPOGRAPHIC SURVEY MAP
FOR
NORTH KONA-KAPALAOA DEVELOPMENT
FIGURE 6
HONOLULU, NORTH KONA, HAWAII

JAMES T. HAMASAKI
REGISTERED PROFESSIONAL ENGINEER
No. 3483
HAWAII

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION

NO.	DATE	REVISIONS	BY

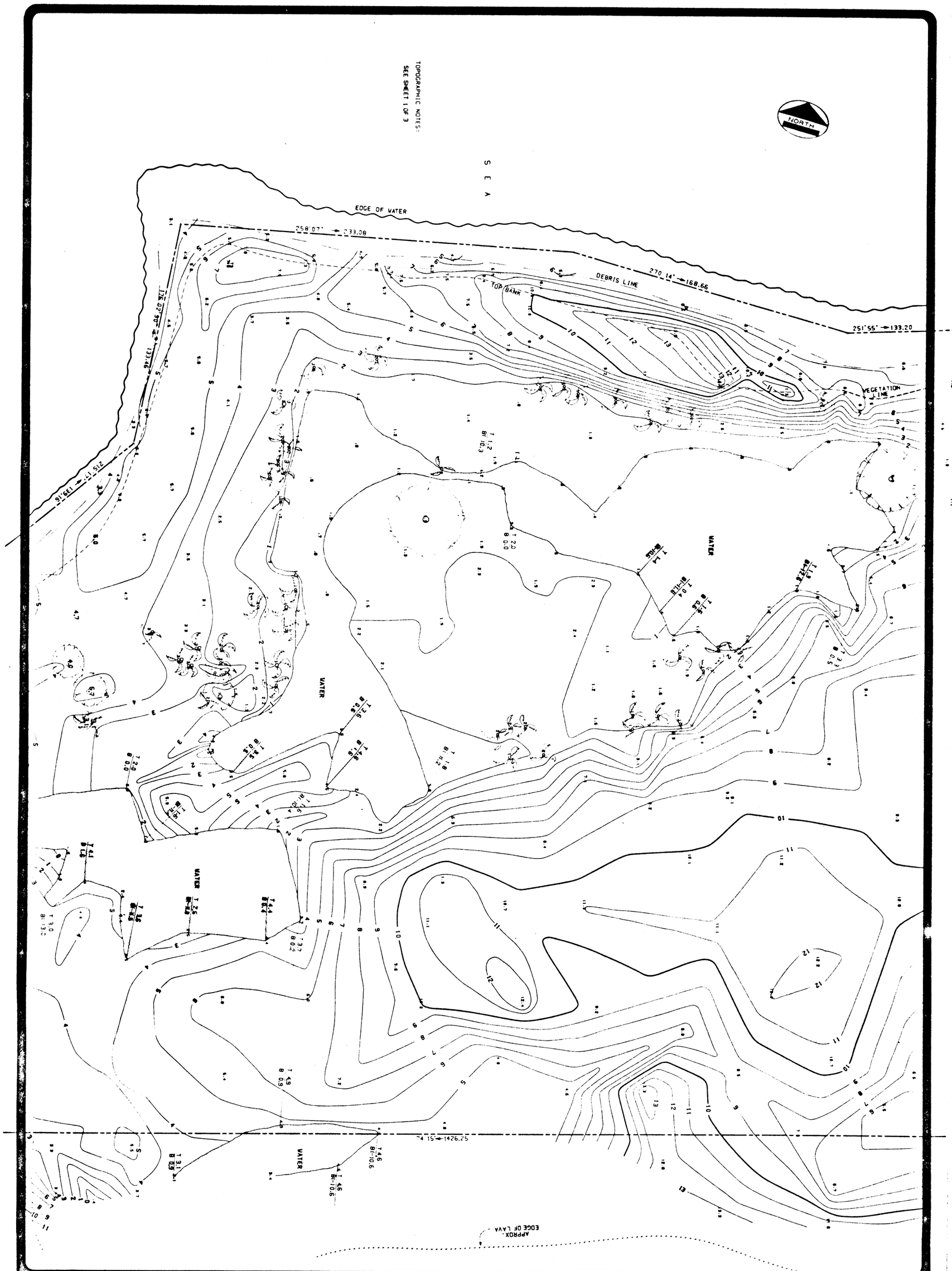
DESIGNED BY
DRAWN BY Y.Y.
CHECKED BY

DATE AUG. 9, 1979
JOB NO. 792200
FIELD 79-122

SCALE 1 inc 20 FT.
7-1-83 5/8/11

SHT 1 OF 3 SHTS

83-002



NO.	DATE	REVISIONS	BY	CK

DATE AUG. 9, 1979	SCALE 1 IN = 20 FT.	DESIGNED BY
JOB NO. 792200	F.B. NO. 7-1-031 5/6/11	DRAWN BY Y Y
F.B. NO. 292:22		CHECKED BY T.H.

JAMES Y. HAMASAKI
REGISTERED PROFESSIONAL LAND SURVEYOR
No. 3683
HAWAII, U.S.A.

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION.

SHT 2 OF 3 SHTS

TOPOGRAPHIC SURVEY MAP

FOR

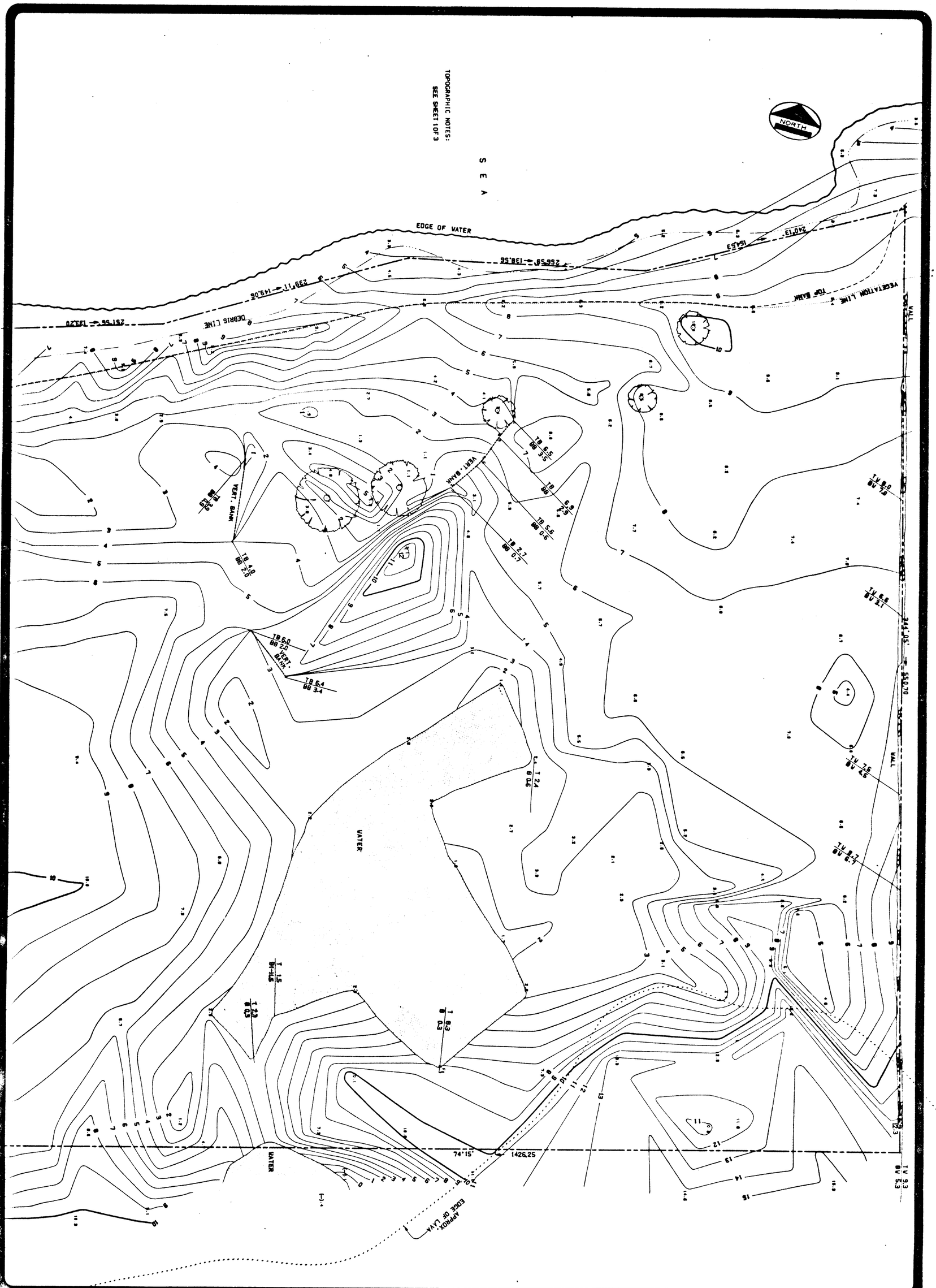
NORTH KONA-KAPALAOA DEVELOPMENT

FIGURE 6-A

PUUANAHULU, NORTH KONA, HAWAII

SAM O. HIROTA, INC.
ENGINEERS AND SURVEYORS
345 QUEEN ST., SUITE 500
HONOLULU, HAWAII 96813

83-003



NO	DATE	REVISIONS	BY	CK

DATE AUG. 9, 1979
JOB NO 792200
F.B. NO 292:22
SCALE 1 IN = 20 FT.
T.M.K. 7-1-031:5/6/11
DESIGNED BY
DRAWN BY Y Y
CHECKED BY T M

JAMES T. HAMASAKI REGISTERED PROFESSIONAL LAND SURVEYOR No. 3483 HAWAII U.S.A.

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION

TOPOGRAPHIC SURVEY MAP

FOR

NORTH KONA-KAPALAOA DEVELOPMENT

FIGURE 6-B

PUUANAHULU, NORTH KONA, HAWAII

SAM O. HIROTA, INC.
ENGINEERS AND SURVEYORS
345 QUEEN ST., SUITE 500
HONOLULU, HAWAII 96813

SHT 3 OF 3 SHTS

83-004

2.2 Impacts and Mitigating Measures

Subdivision of land will involve the surveying and staking out of boundary pins so that land parcels can be readily located, identified, and verified. Subdivision will provide conveyable real estate property title and rights for individual or collective development of NELH Board approved projects. Development of the parcels will result in added jobs, more people and associated people oriented impacts. The vacant areas on the site will become available for higher and more beneficial uses. The lessee will be bound by covenants in his lease and by rules and regulations governing NELH.

Roadways must be located, graded, paved, and marked to permit access to each parcel. Since the lava flow is geologically recent, little flora, fauna, or environmentally sensitive areas will be disturbed. Roadways will permit access to each property and will facilitate economical and efficient movement of people and products to their desired destinations.

Tenant improvements on their land will facilitate economic activity. All plans are subject to approval by the NELH Board of Directors as well as appropriate State and County agencies. Right of approval of improvement plans will insure that the improvements enhance the aesthetics of the property.

At a minimum, septic tanks and seepage fields will be constructed for domestic sewage treatment and disposal. No hazardous wastes or process waters will be allowed to be disposed of in the septic tank. Planting of grass and shrubs above the leaching fields could enhance the beauty of the area and reduce the amount of sewage effluent that could reach the ocean.

Drainage can be handled with swales, ponding areas, seepage pits and other on-site drainage improvements. Drainage

improvements are necessary to protect people and property from flooding, and to assure that storm runoff will be handled in an environmentally safe manner.

The capacity of the existing 4-inch diameter potable water line at NELH is 300,000 to 600,000 gpd. Because of the projected increase in activity at the site, NELH will be requesting a water commitment from the County of Hawaii for 300,000 gpd.

K. SOCIO-ECONOMIC IMPACTS

Socio-economic impacts were addressed in the HTDC FEIS and are incorporated by reference.

L. SOCIO-CULTURAL ATTRIBUTES AND RECREATIONAL RESOURCES

1.0 Historic/Archaeological Sites

Actions described in this SEIS have the potential of disturbing and/or destroying historic/archaeological sites. Please refer to Appendix D, which was prepared by Dr. Ross Cordy of the State Historic Sites Section, for an evaluation of the sites at NELH, and assessment of potential impacts and a proposed archaeological preservation/mitigation plan.

Briefly, as discussed in Appendix D, adverse impacts to all of NELH's sites could occur as a result of land alteration, pipeline expansion and increased public access to the site. Mitigation plans have therefore been developed by NELH in consultation with the state's Historic Sites Section (DLNR HSS); some have already been put into effect.

Seven sites in the two site groupings that are significant as examples of types have been set aside for preservation. These are sites D15-12 and D16-6 though D16-11 (Figure III-7). These sites are in "no build" areas, and buffers to prevent direct and indirect damage have been determined in consultation with the DLNR HSS. The remaining 17 sites, those signficiant solely for their information content, will be protected until archaeological data recovery occurs. To ensure protection, the borders of the accessible sites have been marked in company with DLNR HSS staff and will be surveyed in on base maps, so their locations will be known to present and future users at NELH.

Archaeological data recovery plans have been prepared in detail by the DLNR HSS. These plans are summarized in Appendix D, Table 4. To ensure that data recovery work is done correctly, the DLNR HSS and the County of Hawaii Planning Department will review and approve each detailed scope of work, verify the satisfactory conclusion of fieldwork, and review and approve the final archaeological report.

2.0 Recreational Resources

Impacts on recreational resources were addressed in HTDC FEIS and are incorporated by reference. Of the alternative methods of disposal, only direct discharge by canal has the potential of affecting recreational resources. It is very unlikely that this method will be used for the discharge of 16,100 gpm of OTEC water because of the very large land area that would be required (960 feet wide). Discharge via this method will be restricted to the lower volumes of water provided for in the NPDES permit, thus minimizing the impact on recreation resources.

M. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

1.0 Construction Impacts

1.1 Traffic:

There will be an unavoidable increase in traffic during the construction period in order to bring construction equipment and materials to the site. This impact will be intermittent but it will continue for some time into the future as various projects come on-line.

1.2 Air Quality:

Increased traffic and the use of heavy construction equipment will lead to the temporary generation of emissions from internal combustion engines. Construction activities will lead to increased dust and particulate matter in the air. These impacts will be mitigated by existing governmental regulations which air quality.

1.3 Vegetation:

Construction of portions of the disposal systems and future land development activities at NELH may destroy some vegetation. Vegetation in the area is generally sparse and scattered. Native species that are found in the project area also occur in similar habitats throughout the West Hawaii area so there will be minimal impact on the total island populations of the native components.

1.4 Terrestrial Fauna:

Resident fauna in the areas directly disturbed by construction will be affected. Other fauna inhabiting the

site may be temporarily frightened away. The area has a low concentration of wildlife because of its sparse vegetation. There are no known officially designated endangered or threatened terrestrial species that inhabit the project site.

1.5 Archaeological Sites:

Archaeological sites directly affected by construction activities will be destroyed. Archaeological data recovery plans have been prepared in detail by the DLNR Historics Sites Section. To ensure that data recovery work is done correctly, the Historic Sites Section and the County of Hawaii Planning Department will review and approve each detailed scope of work, verify the satisfactory conclusion of fieldwork, and review and approve the final archaeological report.

1.6 Recreation Activities:

Some disruption of beach recreation can be expected during the construction period due to concerns for public safety.

2.0 Operations

2.1 Water Quality

Potential degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. A proposed water quality monitoring program has been designed to provide insights to an understanding of these impacts. Present plans for NELH include a gradual increase in volumes of water to be used. This will allow the monitoring program to provide early detection of any impacts. In addition, the potential impacts are

reversible. That is, if discharges are halted, the affected ecosystems could be expected to revert to baseline conditions.

2.2 Seawater Return Disposal

The on-land disposal of ocean water into a shallow trench could disrupt and displace the existing brackish water lens for some distance inland and along the coast. In the long term, trees with deep root systems that reach groundwater level may not be able to survive the change in salinity caused by the ocean water plume. This can be mitigated by planting trees with a greater tolerance to salinity.

The anchialine ponds on the project site will slowly lose their brackish character. Because the species of endemic shrimp present in one of the ponds has been observed to tolerate greater salinities than anticipated from NELH discharges and their diverse diet would allow ready adaptation if other components of the ecosystem would change, it does not appear that the impacts of disposal will have a serious impact on the essential character of the ponds. The ponds will be monitored, however, in order to observe any changes resulting from the discharges.

OC OTEC discharges containing reduced concentrations of oxygen will tend to depress metabolic activity of the coastal community, but trench disposal will considerably diffuse entry of these waters to the sea and rapid mixing at entry would tend to minimize this impact. Reoxygenation by aeration is a suggested mitigating measure for this potential impact.

Potential sublethal impacts from discharging seawater at temperatures cooler than the ambient water temperature of the receiving waters could include reduced metabolic rates, especially of corals. This could retard reef growth and in the long-term alter community structure by changing the competitive

balance among species. Trench disposal will afford some warming and will greatly diffuse the flux and allow for high initial dilution in the receiving waters. It does not appear that the magnitude of the potential temperature depression would cause mortalities in the benthic community, but monitoring of community metabolism is required to provide quantitative estimates of impact.

Nutrient concentrations in OTEC discharges will be elevated over those of receiving waters. The offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would be expected to greatly increase macroalgal biomass because grazing is inhibited in the surge zone. The impact would primarily be aesthetic.

In OC OTEC research where lysing occurs, the usability of nutrients in the discharge is expected to increase. In addition, dissolved oxygen is expected to decrease. An increase in organic material could result in increased rates of biofouling in closed-cycle heat exchangers and low dissolved oxygen levels could adversely affect heat exchanger corrosion rates. A monitoring program is required to provide quantitative estimates of this impact if it should occur.

Disposal of mariculture discharges into a shallow trench may result in some stimulation of the algal turf along the shore due to restricted opportunities for grazing by herbivorous fishes. Visual impact could be significant to some observers. Because of the absence of a "near-shore coastal regime" in the Keahole area, this impact is anticipated to be localized in the general vicinity of discharge facility.

Certain chemical additives used in mariculture operations, unknown at the present time, could potentially impact the marine environment. The nature of all new chemicals should be reported

and investigated prior to its introduction into the discharge system as it may significantly impact the resident epifauna.

N. THE RELATIONSHIP BETWEEN SHORT TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The energy research activities at NELH will benefit society by developing renewable energy resources. The knowledge gained will be disseminated throughout the scientific community and effects will be felt worldwide. In addition, as techniques for cold water mariculture are continually refined, new industries may develop which will utilize the techniques being developed in Hawaii and many will choose Hawaii as the location of their production facilities. This could further enhance the opportunities for economic diversification in the state.

The major tradeoff of disposal of OC OTEC and mariculture discharges into shallow trenches rather than injection wells or outfalls will be between potential sub-lethal impacts to some nearshore biota and the extremely high cost of avoiding these impacts completely. The State of Hawaii is actively seeking high-tech mariculture and energy enterprises to diversify the economy of the state. An environmentally acceptable, cost-effective disposal technique might make the difference between success and failure of these businesses.

The proposed water-quality monitoring activities at NELH will enhance knowledge of coastal and ocean processes and facilitate the development of standards for OTEC, mariculture and other ocean-related research and development activities throughout the state and the world. This item is top priority because preservation of the integrity of the cold and warm ocean water resources is fundamental for the continued growth and success of the proposed projects.

The on-land disposal of seawater return flows and other activities will result in a commitment of land within and adjacent to

the NELH site. If monitoring discloses that there are adverse effects, the trenches and canal can be filled and any injection wells can be plugged. Therefore the commitment only needs to be of a temporary nature.

This SEIS has been prepared to disclose the potential implications of proceeding with the alternative disposal methods. It will be the responsibility of various state, federal and county officials to evaluate the tradeoffs between research goals and effects on the natural environment and to make informed decisions based on knowledge of the potential consequences. Mitigating measures, as outlined in this report, should be incorporated into the design of the disposal facilities.

O. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The construction and operation of the alternative disposal methods and other NLEH development activities discussed in this SEIS will involve the irretrievable commitment of certain natural and fiscal resources. Major resource commitments include land, money, construction materials, manpower and energy. The impacts of using these resources should be weighed against the economic and research benefits to the residents of the state and developing countries.

Land committed to the projects is adjacent to airport industrial activities and thus would be a continuation of an existing land use pattern. The capital committed to the construction of the disposal facilities and other NELH improvements described in this SEIS will be irrevocably committed, although some may be recovered in the lease rents paid by future commercial tenants. The commitment of resources required to accomplish the project includes labor and materials, which are mostly unrenewable and irretrievable. Benefits will accrue to the County of Hawaii construction industry. The operation of the project will create new jobs for West Hawaii residents, but will also increase

the consumption of potable water and petroleum-generated electricity which also represents the irretrievable commitment of resources.

If properly monitored, almost all of the potential negative environmental effects of the project on natural resources can be reversed and/or mitigated.

P. SUMMARY OF UNRESOLVED ISSUES

- Various approaches to reoxygenation of degassed OC OTEC waters are being discussed. The process is in the research stage. Although reaeration could easily be accomplished by a fountain or any other turbulent motion in the air, it is believed that it will be environmentally and economically beneficial to reinject the removed gases into the water prior to discharge. This would remove the problem of discharging deoxygenated water. The specific process for this mitigating measure is unresolved and will be the subject of research. Monitoring of effects of degassed discharged water on nearby marine communities will serve to minimize the potential of adverse impacts until this is accomplished.

- A proposed water quality monitoring plan has been presented in this SEIS. Public input from the SEIS review process and further discussions with NELH, National Marine Fisheries Service, Fish and Wildlife Service and the State Department of Health will be required before a specific plan is finalized and funded. Reporting requirements and enforcement provisions have yet to be developed.

PART V: THE RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS, POLICIES AND CONTROLS FOR THE AFFECTED AREA

A. STATE LAND USE LAW

The NELH site is in the Urban District, therefore there is no conflict.

B. HAWAII COASTAL ZONE MANAGEMENT OBJECTIVES AND POLICIES

The relationship of the proposed project to the objectives and policies of the Hawaii State Coastal Zone Management Program (HRS 205A-2) was discussed in the HTDC FEIS. Modification of the proposed action will not result in reduction of public access to the shoreline, destruction of historic sites or degradation of scenic and open space resources. The regional water quality monitoring program that has been recommended will "improve the technical basis for natural resource management."

The CZM objective relating to coastal ecosystems is to "protect valuable coastal ecosystems from disruption and minimize adverse impacts on all coastal ecosystems." The research trench, the NELH ponds and the nearshore area will be monitored for changes in these systems. Because the initial flows are anticipated to range between 3,000 and 5,000 gpm for two to three years, injection wells can be constructed if the results of the monitoring program indicate adverse environmental impacts. Any potential impacts are expected to be reversible.

The proposed modifications are also in conformance with CZM policies and objectives regarding economic uses, coastal hazards and managing development.

Coastal Zone Consistency Certification is being addressed through the U.S. Army Corps of Engineers permitting process.

C. CONSERVATION DISTRICT POLICIES AND REGULATIONS

The proposed disposal facilities will be constructed in the State Urban District, although waters from canal disposal will traverse Conservation District Lands. A Conservation District Use Permit (CDUP) for use of approximately 2940 acres of ocean waters and submerged lands for ocean research, alternative energy and mariculture research, and commercial mariculture and energy activities and facilities, including construction of up to 15 additional warm and cold water intake pipelines, was approved by the Board of Land and Natural Resources on July 23, 1986. Conditions on this permit require monitoring of anchialine ponds -- as described in this SEIS -- and approval of an acceptable seawater disposal system for OC OTEC water. This SEIS is directed towards fulfilling the latter condition.

D. HAWAII WATER QUALITY STANDARDS AND PERMITS

1.0 Ocean Discharge

Coastal water quality is protected by the federal Clean Water Act (33 USC 1251 et. seq.) and the State Environmental Quality Act (Chapter 342, HRS), administered by the Hawaii State Department of Health. The two applicable regulations are Water Quality Standards and Water Pollution Control, Chapters 54 and 55 of Title 11, Administrative Rules.

The waters off Keahole are classified as AA in the Water Quality Standards. The objective of this class is to keep these waters in their natural pristine state as nearly as possible with an absolute minimum of pollution. Uses to be protected in this classification include oceanographic research.

The Water Pollution Control rules define the requirements for National Pollution Discharge Elimination System (NPDES) permits. The NELH Seacoast Test Facility has a NPDES permit for flows of 2.16 mgd (1500 gpm) valid until March, 1991.

If the canal discharge option is chosen, the permit will need to be modified at the point in time the flows are expected to exceed the 1500 gpm amount.

2.0 Underground Injection Wells (UIC)

Groundwater quality is protected under the Hawaii Safe Drinking Water Act (Chapter 340E HRS). Under this Act, rules have been adopted to regulate injection wells (Chapter 23, Administrative Rules, Underground Injection Control). Even though the NELH site is in an exempted aquifer area, that is, designated as unsuitable as an underground source of drinking water, a permit is required from the Department of Health if injection wells are used.

3.0 Trench Discharge

Discharge into a trench is not covered by any specific environmental regulation. NPDES permits apply only to direct discharges to surface waters; a UIC permit is required only for a well, defined as "a bored, drilled or driven shaft, or a dug hole, whose depth is greater than its widest surface dimension."

However, Section 33 of Chapter 342 contains a general prohibition against the discharge of any pollutant into state waters, which by definition include ground water. Although a specific permit would not be required, the proposed trench disposal system would need review by and approval of the Department of Health before it is implemented.

E. HAWAII COUNTY SPECIAL MANAGEMENT AREA

In the Keahole area, the special management area runs from the ocean to Queen Kaahumanu Highway. A Special Management Area Use Permit (SMA 77) controls uses on NELH property. The County Planning Department will be requested to review the recommended disposal method and facility for conformance to this permit.

F. POLICIES AND PLANS INCORPORATED IN THIS SEIS BY REFERENCE

The Hawaii State Plan: Objectives and policies (Part I) and priority guidelines (Part II) in relation to the economy, energy, etc., as described in the HTDC FEIS.

Environmental Policy: Chapter 344, HRS - State Environmental Policy Act - Conforms

Air Quality: Federal Clean Air Act, as amended (42 U.S.C. 1857h-7 et seq. and State Environmental Quality Act (Chapter 342 HRS) - No effect expected

Fish and Wildlife Habitat: Fish and Wildlife Coordination Act (16 U.S.C. Sec.661 et seq.) - Coordination is being accomplished through U.S. Army Corps of Engineers permit process.

Historic and Cultural Properties: National Historic Preservation Act of 1966, as amended (16 U.S.C. 1251 et seq.) - No historic sites will be disturbed by construction of disposal facilities.

Hawaii County General Plan: As discussed in the HTDC FEIS, the proposed action conforms to County of Hawaii economic and energy policies.

G. AN INDICATION OF WHAT OTHER INTERESTS AND CONSIDERATIONS OF GOVERNMENTAL POLICIES ARE THOUGHT TO OFFSET THE ADVERSE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION

The various federal, state and county agencies which have issued or are processing permits for the implementation of the proposed projects at NELH and the adjacent HOST Park that were described in the HTDC FEIS, have imposed conditions and restrictions that will help insure that adverse environmental impacts are properly monitored and mitigated. The most significant consideration that will offset adverse effects is the importance of the pristine quality of the nearshore and offshore water resource to the success of OTEC and other activities at NELH. This will ensure that all activities, whether on land or in the water, will be monitored in order that the integrity of these waters is not compromised.

PART VI: LIST OF NECESSARY REVIEWS AND/OR APPROVALS

The following list of necessary reviews and/or approvals does not include compliance activities to be undertaken by the U.S. DOE.

Federal

Clean Water Act (33 USC 1251 et. seq.)
-Administered by the State. See Department of Health

Federal Aviation Agency (FAA)
-Notice of construction within 20,000 feet of airport runways (14 CFR 77)

U.S. Coast Guard
-If required, license to construct facilities on Coast Guard land.

State of Hawaii

Department of Agriculture
-Mariculture operations culturing exotic species: Permit to import non-indigenous species.

Department of Health
-Trench Disposal: Review and approval for compliance with Section 33, State Environmental Quality Act (Chapter 342, HRS)
-Disposal Via Canal: Existing National Pollution Discharge Elimination System (NPDES) Permit must be modified if discharge exceeds 1500 gpm.
-Underground Injection Wells (UIC): Permit required even though proposed site is in an exempted aquifer area.
-Mariculture operations involving shellfish: Shellfish Sanitation Certificate.
-Individual domestic wastewater disposal systems: Permit required.

Department of Land and Natural Resources
-Satisfaction of and request to remove condition #8 -- approval of an acceptable seawater disposal system for 16,100 gpm of OTEC water -- from CDUA HA-1862.
-Historic Sites review.
-Approval of plans for construction within the Conservation District.
-Approval of all NELH tenants' subleases.

Hawaii County

Special Management Area (SMA) Use Permit
-Amend existing SMA #77 if required.
Subdivision Application and Approval.

Plan Approval and Various Construction Permits.

PART VII: AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONSULTED IN THE PREPARATION OF THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

A. AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONTACTED

This SEIS was prepared under a contract with R.M. Towill Corporation, the prime contractor for planning and engineering of HOST Park and the HOST/DOE ocean water supply systems.

The following individuals and firms were contacted for professional services and/or specialized advice during the preparation of the SEIS. Sub-consultants in the preparation of this SEIS are indicated with an asterisk (*).

*Dames & Moore	Hydrology and Seawater Return Flow Disposal Via Deep Injection Wells and Shallow Surface Trenches
*GK & Associates	Water Quality, Mariculture Characteristics, Marine Impacts and Anchialine Ponds
*Oceanit Laboratories, Inc.	OTEC Characteristics and Discharge of OTEC Water Via Canal

Federal Agencies

U.S. Department of Commerce, National Marine Fisheries Service

Mr. John J. Naughton	Western Pacific Program Office

U.S. Department of Energy

Dr. Carmine Castellano	
Dr. Lloyd Lewis	Ocean Systems Division, Washington, D.C.
Dr. C. B. Panchal	Argonne National Laboratory
Dr. Terrence Penney	Solar Energy Research Institute
Dr. David Johnson	
Dr. John W. Shupe	Director, Pacific Site Office, Honolulu

U.S. Department of the Interior, Fish & Wildlife Service

Mr. John Ford	Office of Environmental Services

State Agencies

Department of Accounting and General Services

Mr. Ralph Yukumoto	Planning Branch
Mr. Jerry Nishida	Project Management

Department of Health

Mr. Dayton Frain	Environmental Permits Branch
Mr. Steve Chang	
Mr. Brian Choy	Environmental Planning

Department of Land and Natural Resources

Mr. John Corbin Mr. William Brewer	Aquaculture Development Program
Mr. Dean Uchida	Planning Office
Dr. Ross Cordy	State Parks, Outdoor Recreation and Historic Sites

Department of Planning and Economic Development

Dr. Takeshi Yoshihara Mr. Gerald Lesperance	Energy Division

Natural Energy Laboratory of Hawaii

Dr. Thomas Daniel	Laboratory Director

High Technology Development Corporation

Mr. William Bass	Executive Director
Ms. Kay Yamada	Real Estate Specialist
Mr. George Meade	HOST Park Manager

University of Hawaii

College of Engineering

Dr. Paul Yuen	Dean
Dr. Hans-Jurgen Krock	Chairman, Department of Ocean Engineering
Dr. John Craven	Prof. Em, Department of Ocean Engineering

College of Tropical Agriculture and Human Resources

Mr. David Robichaux Mr. Mark Underwood	Department of Agricultural Engineering

Hawaii Institute of Marine Biology

Dr. Richard E. Brock

Hawaii Natural Energy Institute

Mr. E. Chipman Higgins

County of Hawaii

Planning Department

Mr. Albert Lono Lyman	Director

Other Institutions, Private Businesses and Organizations

Mr. David K. Barclay	Argent Chemical Laboratory
Mr. Steven Katase	Hawaiian Nori Company
Mr. Richard Krauss	Aquaculture Research Corporation
Dr. Noam Lear	
Dr. Kelly Moorhead	Cyanotech, Inc.
Mr. Garret Myamoto	Oceanic Institute
Mr. Peter Steel	Hawaiian Abalone Farms
Mr. Bruce Tsuchida	R.M. Towill Corporation
Mr. Bud Vuillimot	R.M. Towill Corporation
Ms. Andrea Wangler	Hawaiian Electric Company

B. COMMENTS ON THE SEIS PREPARATION NOTICE (NOP)

The SEIS Preparation Notice (NOP) was officially filed with the State Office Of Environmental Quality Control on July 16, 1986. Comments on the NOP were requested on or before August 22, 1986. All comments received up to October 5, 1986 were acknowledged. A total of 20 letters were received; 9 expressed "no comment" and therefore did not require a response. No letters were received by individuals requesting to be consulted parties. The following agencies, organizations and individuals received copies of the NOP; those identified with asterisks (*) responded; respondents with substantive comments are identified by double asterisks (**) and their comments are included in this section of the draft SEIS.

Federal

Advisory Council on Historic Preservation

U.S. Department of the Army
* Army Engineer District
Army Engineer Operations Branch

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
** National Marine Fisheries Service, Western Program Office

U.S. Department of Energy

U.S. Department of the Interior
Environmental Protection Agency, Region IX
Environmental Services
** Fish & Wildlife Sevice
* Geological Survey

U.S. Department of Transportation

United States Coast Guard

State

Board of Directors, High Technology Development Corporation
Board of Directors, Natural Energy Laboratory of Hawaii
Department of Accounting & General Services
* Department of Budget and Finance
** Department of Health
** Department of Land & Natural Resources
* Department of Planning and Economic Development
* Department of Transportation
Office of Environmental Quality Control
University of Hawaii
** Environmental Center
Hawaii Institute of Marine Biology
** Hawaii Natural Energy Institute
J. K. K. Look Laboratory of Oceanographic Engineering
Pacific International Center For High Technology Research
Sea Grant Marine Advisory Program
* Water Resources Research Center

State Legislature

Senate

President
Senators, Island of Hawaii
Senate Committees
Economic Development
Energy
Finance
Tourism and Recreation

House of Representatives

Speaker
** Representatives, Island of Hawaii
House Committees
Finance
** Ocean & Marine Resources
Planning,Energy, Ecology and Environmental Protection
Water, Land Use, Development & Hawaiian Affairs

County of Hawaii

Mayor's Office
** County Council
Housing and Community Development Office
* Parks and Recreation
** Planning Department
* Public Works Department
Research and Development

Organizations and Individuals

Conservation Council, Hawaii Island
Construction Industry Legislative Organization, CILO
Mr. Gerald Cysewski, Cyanotech
Hawaii Audubon Society
Hawaii Electric Light Company (HELCO)
Hawaii Leeward Planning Conference
* Hawaiian Telephone Company
Mr. George Lockwood, Hawaiian Abalone Farms
** Mrs. Mae Mull, Hawaii Island Chapter, Hawaii Audubon Society
Dr. Edward K. Noda, Oceanographic Consultant
Sierra Club, Hawaii Chapter

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region • Western Pacific Program Office
2570 Dole St. • Honolulu, Hawaii 96822-2396

August 20, 1986 F/SWR1:JJN

RECEIVED
AUG 25 1986
NELH

The Natural Energy Laboratory of Hawaii
220 S. King Street, Suite 1280
Honolulu, Hawaii 96813

ATTENTION: Mr. Jack P. Huizingh, Executive Director

Gentlemen:

Subject: Environmental Assessment (EA) and Supplemental Impact Statement Preparation Notice - Development Plan For The Hawaii Ocean Science and Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Action To Permit Alternative Methods of Seawater Return Flow Disposal At NELH.

The National Marine Fisheries Service (NMFS) has received the subject Supplemental Impact Statement Preparation Notice and EA for the modification to the proposed action. We offer the following comments for your consideration in preparing the Supplemental Environmental Impact Statement (SEIS).

NMFS was involved in the development of the original EIS for the subject project, the final of which was accepted by the Governor in September 1985. We understand that, subsequently, the U.S. Department of Energy (DOE) learned that because of Federal budget cuts it would be unable to fund the proposed expansion of OTEC facilities at NELH to the level they had originally proposed. The mixed-water discharge pipe that was to be used to dispose of the 16,100 gpm of seawater that will be used in forthcoming OTEC experiments will not be funded. Alternative disposal methods for this seawater, including direct disposal via canal, trenches and deep injection wells (and/or a combination thereof), are being investigated.

NMFS concurs with your conclusion that the on-land disposal of OTEC seawater flows may have different impacts than those described in the accepted Final EIS. We understand that NELH is presently preparing a supplemental EIS for the purpose of assessing the environmental impacts of alternative methods of seawater return flow disposal. In addition, the cumulative impacts that could occur as a result of on-land disposal of seawater return flows from both OTEC experiments and future research, development and mariculture operations at NELH are also being reevaluated.

In our original comments on the Draft EIS (report dated August 21, 1985) one of our major concerns dealt with the possibility of on-land disposal of seawater. NMFS continues to feel that potential impacts from on-land disposal, via canal, trenches or deep injection wells, could have major adverse impacts on anchialine pond and neashore marine biota.

In conclusion, NMFS considers the evaluation of on-land disposal of seawater from OTEC experiments to be critical. Please refer to our original report on the project Final EIS for a more detailed description of our concerns. For further assistance in preparation of the Supplemental EIS, please contact Mr. John J. Naughton of my staff.

Sincerely yours,

Doyle E. Gates

Doyle E. Gates
Administrator

cc: F/SWR, Terminal Is., CA
F/M4, Washington, D.C.
EPA, Region 9, (P-5)
FWS, Honolulu
Corps of Engineers, Honolulu
Hawaii State Div. of Aquatic Resources
MCM Planning (Ms. Marilynn Metz)

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. Doyle E. Gates, Administrator
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Gates:

Thank you for commenting on the subject NOP. Your concerns will be addressed in the draft SEIS. Mr. George Krasnick, biological oceanography consultant to the project, will be contacting Mr. Naughton for assistance in preparing his draft SEIS report.

We look forward to your comments on the dEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 ALA MOANA BOULEVARD
P.O. BOX 50167
HONOLULU, HAWAII 96850

IN REPLY REFER TO:
ES
Room 6307

RECEIVED
AUG 25 1986
NELH

AUG 22 1986

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Re: Environmental Assessment and Supplemental Impact Statement Preparation Notice, Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at the Natural Energy Laboratory of Hawaii (NELH)

Dear Mr. Huizingh:

We have reviewed the Environmental Assessment (EA) and notice of preparation for the Supplemental Environmental Impact Statement (SEIS) and offer the following comments for your consideration.

General Comments

The SEIS is being prepared because the mixed-water discharge pipe that was proposed as a means to dispose the seawater from Ocean Thermal Energy Conversion (OTEC) experiments will not be funded by the Department of Energy. The SEIS will discuss alternative methods to dispose the seawater including direct disposal via a canal, trenches, deep lined injection wells, and/or a combination of these techniques.

Our primary concerns with the alternative methods of disposal of seawater from the NELH are the potential long-term adverse impacts to anchialine ponds and nearshore marine water quality and fishery resources from altered nutrient and salinity levels, and reduced temperatures.

Specific Comments

a. Page 21. Anchialine Ponds. We disagree with the statement that the anchialine ponds on the NELH site "are not considered biologically significant." The proposed development of numerous luxury resorts along the West Hawaii coastline may affect a substantial number of anchialine ponds and the cumulative loss of anchialine ponds may be significant. We strongly urge that potential impacts to anchialine ponds be a factor in selecting the disposal method.

CONSERVE AMERICA'S ENERGY

Save Energy and You Serve America!

b. The discussion of the proposed disposal methods should discuss the effects of lava tubes intercepting the flow field.

c. We support the additional analyses to determine an appropriate disposal method.

We appreciate the opportunity to comment.

Sincerely,

for Ernest Kosaka
Project Leader
Office of Environmental Services

cc: MCM Planning
CE, Operations Branch
NMFS - WPPO
EPA, San Francisco
DLNR

The Natural Energy Laboratory of Hawaii

October 13, 1986

Mr. Ernest Kosaka, Project Leader
Office of Environmental Services
U.S. Department of the Interior
Fish and Wildlife Service
P.O. Box 50167
Honolulu, Hawaii 96850

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Kosaka:

Thank you for commenting on the subject NOP. Your concerns will be addressed in the draft SEIS.

In response to your specific comments:

a. The anchialine ponds at NELH have been surveyed again as part of the preparation of the draft SEIS. Two of the three ponds are very small (120 sq. ft. and 220 sq. ft.) and shallow (2 feet deep at the deepest point at high tide). The third pond is larger (750 sq. ft.) and deeper (3 feet deep at its deepest at high tide). Only one of the smaller ponds supports a typical anchialine pond community. The draft SEIS will address the significance of these small, shallow ponds in relation to the cumulative effect of losing larger, more significant ponds to resort development. The ponds will not be dredged or filled and they will be monitored for a minimum ten years under the conditions of the CDUA permit issued by the Board of Land and Natural Resources for construction of the proposed offshore pipelines.

b. The effects of lava tubes intercepting the flow field will be addressed to the extent possible in the dSEIS.

We look forward to your comments on the dSEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

RECEIVED
AUG 2[illegible] 1986
NELH

LESLIE S. MATSUBARA
DIRECTOR OF HEALTH

In reply, please refer to:
EPHSD

August 18, 1986

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 S. King St., Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

Subject: Environmental Assessment and Supplemental Impact Statement Preparation Notice - Development Plan for The Hawaii Ocean Science & Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH

Thank you for allowing us to review and comment on the subject preparation notice.

The comments in our letter and memorandums dated April 25, 1985, August 21, 1985 and March 4, 1986 (all attached), still apply.

Sincerely,

for JAMES K. IKEDA
Deputy Director for
Environmental Health

Attachments

cc: DHO, Hawaii

7-3-43:33 (Fr.
7-3-43: 3, 4, 5

FILE COPY

April 25, 1985

Mr. William M. Bass, Jr.
Executive Director
High Technology Development Corporation
Central Pacific Plaza, Suite 252
220 S. King St.
Honolulu, Hawaii 96813

Dear Mr. Bass:

Subject: Environmental Impact Statement Preparation Notice - Development Plan for the Hawaii Ocean Science & Technology Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii at Keahole, N. Kona, Hawaii

Subsequent to our letter dated April 22, 1985, the following additional comments were generated by our staff.

Surface Disposal of Wastewater

Aquatic developments, proposed by the H.O.S.T. Park, may be subject to one of the following NPDES regulations:

A. Aquaculture Projects

The EPA defines an aquaculture project as a managed water area in which "discharged pollutants" are used for the maintenance or production of harvestable freshwater, estuarine, or marine plants and animals. The State does not have delegation to issue this type of NPDES permit. Therefore, aquatic projects involving the use of wastewater sources would be directed to EPA.

B. Concentrated Aquatic Animal Production Facilities

A hatchery, fish farm, or other facility is a concentrated aquatic animal production facility if it contains, grows, or holds fish species or aquatic animals in ponds, raceways, or other similar structure which discharge at least 30 days per year. These operations are point sources subject to the State NPDES Program. Facilities that may be exempted from permit requirements include the following:

1. Cold Water Aquatic Animals (i.e., Salmon and Abalone):

   a. Facilities which produce less than 20,000 pounds harvest weight of aquatic animals per year; and

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b. Facilities which feed less than 5,000 pounds of food during the calendar month of maximum feeding.

2. Warm Water Aquatic Animals (i.e., Prawn, Shrimp and Catfish):

a. Closed ponds which discharge only during periods of excess runoff; or

b. Facilities which produce less than 100,000 pounds harvest weight of aquatic animals per year.

Specific permit requirements or exemptions will be reviewed by the Department on a case-by-case basis with respect to the water quality standards of the receiving water.

Subsurface Disposal of Wastewater

Even though the subject site is located in an area which has been designated as an exempted area under the Underground Injection Control (UIC) Program, the permitting of the injection wells will depend upon the quality and content of the wastes. If the wastestream will contain industrial wastes, close scrutiny will be required to assure that the wastes are not hazardous in accordance with 40 CFR 261. The disposal of wastes of this nature would result in the classification of the injection wells as Class IV wells which are prohibited under the State UIC Program.

This condition is also applicable to any individual disposal systems which may be proposed by the tenants.

Sincerely,

Melvin K. Koizumi

MELVIN K. KOIZUMI
Deputy Director for
Environmental Health

cc: DHSA, Hawaii

FILE COPY

August 21, 1985

MEMORANDUM

To: Ms. Letitia N. Uyehara, Director
Office of Environmental Quality Control

From: Deputy Director for Environmental Health

Subject: Draft Environmental Impact Statement (EIS) - Development Plan for Hawaii Ocean Science & Technology Park and Proposed Expansion of Natural Energy Laboratory of Hawaii, Keahole, North Kona, Hawaii

Thank you for allowing us to review and comment on the subject draft EIS. We provide the following comments.

Shellfish Sanitation

Shellfish sanitation requirements need to be addressed for the applicable type of aquaculture projects. They should comply with Chapter 35 of Title 11, Administrative Rules, Department of Health.

Surface Disposal of Wastewater

Aquatic developments, proposed by the H.O.S.T. Park, may be subject to one of the following NPDES regulations:

A. Aquaculture Projects

The EPA defines an aquaculture project as a managed water area in which "discharged pollutants" are used for the maintenance or production of harvestable freshwater, estuarine, or marine plants and animals. The State does not have delegation to issue this type of NPDES permit. Therefore, aquatic projects involving the use of wastewater sources would be directed to EPA.

B. Concentrated Aquatic Animal Production Facilities

A hatchery, fish farm, or other facility is a concentrated aquatic animal production facility if it contains, grows, or holds fish species or aquatic animals in ponds, raceways, or other similar structure which discharge at least 30 days per year. These operations are point sources subject to the State NPDES Program. Facilities that may be exempted from permit requirements include the following:

1. Cold Water Aquatic Animals (i.e., Salmon and Abalone):

   a. Facilities which produce less than 20,000 pounds harvest weight of aquatic animals per year; and

   b. Facilities which feed less than 5,000 pounds of food during the calendar month of maximum feeding.

2. Warm Water Aquatic Animals (i.e., Prawn, Shrimp and Catfish):

   a. Closed ponds which discharge only during periods of excess runoff; or

   b. Facilities which produce less than 100,000 pounds harvest weight of aquatic animals per year.

Specific permit requirements or exemptions will be reviewed by the Department on a case-by-case basis with respect to the water quality standards of the receiving water.

Subsurface Disposal of Wastewater

Even though the subject site is located in an area which has been designated as an exempted area under the Underground Injection Control (UIC) Program, the permitting of the injection wells will depend upon the quality and content of the wastes. If the wastestream will contain industrial wastes, close scrutiny will be required to assure that the wastes are not hazardous in accordance with 40 CFR 261. The disposal of wastes of this nature would result in the classification of the injection wells as Class IV wells which are prohibited under the State UIC Program.

This condition is also applicable to any individual disposal systems which may be proposed by the tenants.

Proposed Ocean Outfall

The proposed mixed-seawater (wastewater) discharge of 16,000 gpm (23 MGD) for the forthcoming OTEC experiments at NELH is subject to the above-mentioned surface disposal requirements. If the ocean outfall disposal is selected over on-land disposal for the full development flow of 183 MGD (HOST Park 144 MGD and NELH 39 MGD), these will also be subjected to the surface disposal requirements.

In accordance with the Administrative Rules (AR), of the Department of Health, Title 11, Chapter 54, Water Quality Standards, the receiving water is classified as Class AA, which requires that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration by human activity. The beneficial uses shall be protected so in the strict interpretation and intent of the Ar, no construction activity and disposal are desirable in Class AA waters.

Proposed On-Land Disposal

The on-land disposal of shallow surface trench and deep injection wells are being considered. Either on-land disposal method will affect the existing nature of the anchialine ponds which will violate conformance to the basic water quality criteria applicable to all waters as contained in Section 11-54-04. According to the draft EIS, it was noted the anchialine ponds are "not of high natural value," which should be further addressed such as a comparison to other anchialine ponds in the vicinity.

At the Waikoloa Resort Development, artificially created anchialine ponds are being considered because of the proposed development and degradation of some of the existing anchialine ponds due to destructive human intrusion. As part of this consideration, very intense long-term bio-monitoring of the anchialine pond biota is proposed.

Another concern is the "leakage" of the harmful prophylactics for the control of disease that may be used in aquatic rearing facilities and the domestic sewerage that may enter the anchialine ponds. Pretreatment of some sort should be considered when necessary for each individual wastestream (prior to commingling), aside from dilution.

Class AA Water Status

For the waters along the NELH and HOST Park to remain a Class AA water and pristine for aquatic rearing purposes, it is recommended that stringent controls be developed, imposed and enforced on the tenants.

Please address air, water, solid wastes and sewage control commitments in the construction plans. We reserve the right to impose future environmental restrictions on the project at the time final plans are submitted to this office for review.

Melvin K. Koizumi

MELVIN K. KOIZUMI

cc: Mr. William M. Bass, Jr.
Ms. Marilynn C. Metz

RECEIVED AS FOLLOWS

COPY

[illegible] 1986

[illegible]

Board of Land and Natural Resources

From: Director of Health

Subject: Conservation District Use Application & Final EIS
File No. HA-[illegible]
Applicant: Hawaii Ocean Sciences & Technology Park, Keahole, Hawaii

The High Technology Development Corporation (HTDC) letter (item No. 4) of August 29, 1985, in response to a memorandum to the Office of Environmental Quality Control (OEQC) from the Department dated August 21, 1985, indicates that a Zone of Mixing (ZOM) is not required. It should be emphasized that a ZOM is not required, if the effluent water quality (WQ) meets both the basic WQ criteria and the specific WQ criteria for open coastal waters for Class AA waters. It appears that the specific WQ criteria is not mentioned in the EIS. The Administrative Rules (AR), Title 11, Chapter 54, Water Quality Standards, Section 11-54-06(b)(3) contains the specific WQ criteria.

Unless stringent controls are applied to the effluent WQ and treatment requirements, degradation will come to the point where the intake water may not be pristine enough to serve as rearing media for the aquatic facilities.

Please be informed that we have no objections to granting the permit.

LESLIE S. MATSUBARA

cc: OEQC
High Technology Dev. Corp.

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. James K. Ikeda
Deputy Director for Environmental Health
State Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Subj: Environmental Assessment and Supplemental Notice of Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Ikeda:

Thank you for commenting on the subject NOP. Comments from your letters of April 25, 1985, August 21, 1985 and March 4, 1986 will be addressed in the dSEIS.

We look forward to your comments on the draft SEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

RECEIVED
SEP 2 : 1986
NELH

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES

EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

SEP 1 9 1986

DOCUMENT NO.: 1707B

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

SUBJECT: Environmental Assessment and Supplemental Impact Statement Preparation Notice-Development Plan For the Hawaii Ocean Science & Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Plan Action To Permit Alternative Methods of Seawater Return Flow Disposal At NELH

We have completed our review of the subject document and offer the following comments:

As the EA notes (p. 17), NELH is working with this Department on an archaeological mitigation plan to preserve sites and protect others until archaeological data recovery can occur. We will soon be providing NELH with details for data recovery. NELH has already agreed to preservation of specific sites. The EA notes that the plan will be in the Draft EIS. This action is acceptable for our concerns.

There are no public park concerns but environmental impacts on public use of the shoreline area should be addressed. Impacts on public use of nearshore and offshore waters could be of particular concern.

The initial proposal called for disposal of 16,100 gpm of seawater return flow by a mixed-water (warm and cold) discharge pipe in offshore areas. Budget cuts have since forced consideration of alternate seawater disposal methods, including direct disposal by canal, trenches, deep injection wells and/or a combination thereof. The disposal method chosen must not degrade the intake water vital to the facility operation.

Our concern is for the protection of groundwater resources. Although no adverse impacts are expected (page 21, item B), monitoring of the onland disposal seawater to assess the impact to groundwater should be included as it was in the Final EIS for the project.

We appreciate the opportunity to comment on your document. Should you have any questions, feel free to contact our Office of Conservation and Environmental Affairs at 548-7837.

Very truly yours,

SUSUMU ONO, Chairperson
Board of Land and Natural Resources

cc: OEQC
MCM Planning
P.O. Box 27506
Honolulu, Hawaii 96827
Attention: Ms. Marilynn C. Metz

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. Susumu Ono, Chairperson
Board of Land Natural Resources
P.O. Box 621
Honolulu, Hawaii 96809

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Ono:

Thank you for commenting on the subject NOP. In response to your specific concerns:

a. Impacts on public use of the affected shoreline will be addressed in the draft supplemental statement.

b. Monitoring of onland disposal seawater to assess the impact to groundwater will be a recommended mitigating measure in the draft statement. In addition, a regional offshore monitoring program is also being proposed.

We look forward to your comments on the dEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

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☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341

University of Hawaii at Manoa

Environmental Center
Crawford 317 • 2550 Campus Road
Honolulu, Hawaii 96822
Telephone (808) 948-7361

RECEIVED
AUG 25 1986
NELH

August 21, 1986
PN:0048

Mr. Jack P. Huizingh
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh

Environmental Assessment / Supplemental Impact Statement
Preparation Notice
HOST and NELH
Keahole, North Kona, Hawaii

The above cited document outlines the potential environmental impacts to be discussed in the supplemental EIS being prepared to address alternative methods of seawater return flow disposal at the Natural Energy Laboratory of Hawaii, Keahole Point, Hawaii. This review was prepared with the assistance of Keith Chave, Oceanography; Frank Peterson, Geology; and Walington Yee, Environmental Center.

In general the document is an excellent example of scholarly work that clearly outlines and succinctly addresses the major issues that will be encountered by the proposed project. The drafters of this Environmental Assessment/Preparation Notice should be commended for a job well done. We offer the following comments for your use in developing the draft supplemental EIS.

It is proposed that the SEIS will have a comprehensive evaluation of the various waste disposal alternatives so as to assure non-contamination of the intake water supplies to NELH or HOST operations. In this discussion, consideration should be given to the possiblity of clogging problems either in drainage ditches or injection wells. The dimensions and physical characteristics of the proposed disposal trenches should be fully explained in the text and appropriate dimensional and geographical illustrations provided to assure that the reader of the SEIS will fully understand what is being proposed and where it will reside. For example, the lining of the trenches, if any, should be indicated. If lining is not anticipated then the potential seepage effects of the effluent on the nearshore coastal environment should be discussed in the SEIS. Biological clean-up of nutrients in the waste effluent should be systematically evaluated along with the other methods of disposal.

With regard to closed-cycle seawater discharge (p.8) it is stated that trace metals in the discharge would decrease rapidly as the metal becomes acclimated to the environment. The data on which this statement is based should be referenced in the document.

The list of candidate species (p. 9) contains a number of organisms incorrectly listed under the "Crustaceans" heading. Oysters (Crassostrea, (note spelling correction) Ostrea) Abalone, Opihi, Giant Clams (Tridacna) and Scallops, should be listed under a general "Mollusca" heading.

On page 15 para. 6, lines 4-5 it is incorrectly stated that Kiholo and Puako are several miles south of Keahole. They are north.

The anchialine ponds on the NELH site are said to have no biological significance. However, since so many of the existing ponds along the Kona coast have been destroyed, can the Keahole ponds still be considered of little biological significance?

We appreciate the opportunity to comment on this document and look forward to reviewing the draft supplemental EIS when it is completed.

Yours truly,

Jacquelin N. Miller
Acting Associate Director

cc: Patrick Takahashi
MCM Planning
OEQC
Keith Chave
Frank Peterson
Walington Yee

The Natural Energy Laboratory of Hawaii

October 14, 1986

Ms. Jacquelin N. Miller
Acting Associate Director
Environmental Center
University of Hawaii at Manoa
Crawford 317
2550 Campus Road
Honolulu, Hawaii 96822

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Jackie:

Thank you for the compliments on the subject NOP. In response to your specific concerns:

a. The possibility of clogging problems will be addressed in the dSEIS. The dimensions and locations of the various disposal facilities will be described in the document. It is not anticipated that the trenches will be lined, therefore, the seepage effects of the seawater on the nearshore coastal environment is discussed. Biological cleanup of nutrients will also be addressed.

b. The rapid decrease of trace metals in the discharge will be documented in the dSEIS.

c. The list of candidate species has been corrected as you suggest.

d. We are aware that Kiholo and Puako are north, however, the word processor keeps forgetting. We will correct it again and hope that this time it stays corrected. Thanks for pointing the error out to us.

e. The anchialine ponds at NELH have been surveyed again as part of the preparation of the dSEIS. Two of the three ponds are very small (120 sq. ft. and 220 sq. ft.) and shallow (2 feet deep at the deepest point at high tide). The third pond is larger (750 sq. ft.) and deeper (3 feet deep at its deepest at high tide). Only one of the smaller ponds supports a typical anchialine pond community. The draft SEIS will address the significance of these small, shallow ponds in relation to the cumulative effect of losing larger, more

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The Natural Energy Laboratory of Hawaii

significant ponds to resort development. The ponds will not be dredged or filled and they will be monitored for a minimum ten years under the conditions of the CDUA permit issued by the Board of Land and Natural Resources for construction of the proposed offshore pipelines.

We look forward to your comments on the draft SEIS.

Best regards,

Jack

Jack P. Huizingh
Executive Director

cc: MCM Planning

File

RECEIVED
AUG 1 8 1986
NELH

University of Hawaii at Manoa

Hawaii Natural Energy Institute
Holmes Hall 246 • 2540 Dole Street • Honolulu, Hawaii 96822

August 6, 1986

The Natural Energy Laboratory of Hawaii
220 S. King Street, Suite 1280
Honolulu, Hawaii 96813
Attention: Mr. Jack P. Huizingh, Executive Director

Dear Mr. Huizingh:

As requested by your letter of July 23, 1986, I have reviewed the Development Plan for The Hawaii Ocean Science and Technology (HOST) Park and Expansion of the Natural Energy Laboratory of Hawaii (NELH) dated July 1986.

This document is in accord with the facts known to me at this time, with the addition to paragraph 3.0 Open-Cycle OTEC Research of the following sentences on page 8. "These tests lead to the integration of the acquired information into a system which produces electrical energy and fresh water. This integration will be attempted in an Open Cycle OTEC test of about 200 KW output at the NELH.

I have retained the copy of the draft document as it contains much information about the NELH in a concise authoritative format.

Sincerely,

E. Chipman Higgins

Hope this is helpful
Chip

ECH:sm

cc: Patrick K. Takahashi
MCM Planning

The Natural Energy Laboratory of Hawaii

August 21, 1986

Mr. Chipman Higgins
Hawaii Natural Energy Institute
University of Hawaii
Holmes Hall 246
2540 Dole Street
Honolulu, Hawaii 96822

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Higgins:

Thank you for commenting on the subject preparation notice. Your suggested addition to paragraph 3.0 will be incorporated into the draft EIS. We are looking forward to your comments on the draft EIS.

Best regards,

Jack P. Huizingh
Executive Director

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NELH File

RECEIVED
JUL 28 1986
NELH

HOUSE OF REPRESENTATIVES
STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

July 25, 1986

Mr. Jack Huizingh
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

I acknowledge receipt of your letter dated July 23, 1986, regarding alternative methods of seawater return flow disposal.

Please be assured that if I have any comments - it will be sent to you prior to your August 22, 1986 deadline.

I also want to thank you for sending me a copy of your "Environmental Assessment and Notice of Preparation of Supplemental Environmental Impact Statement: Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH".

With warm personal regards.

Sincerely,

WAYNE METCALF
Hawaii State Representative
Third District

WM:to

The Natural Energy Laboratory of Hawaii

August 21, 1986

The Honorable Wayne Metcalf
Room 325
State Capitol
Honolulu, Hawaii 96813

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Representative Metcalf:

Thank you for your letter concerning the subject preparation notice. We look forward to your comments on the preparation notice and on the forthcoming draft EIS. We will send you a copy of the draft EIS when it is available.

Best regards,

Jack P. Huizingh
Executive Director

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HOUSE OF REPRESENTATIVES
STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

RECEIVED
AUG 05 1986
NELH

July 31, 1986

543lp

The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, HI 96813
Attn: Mr. Jack Huizingh

Dear Mr. Huizingh:

Thank you for the opportunity to comment on the environmental assessment and preparation notice entitled: Development Plan for the Hawaii Ocean Science and Technology (HOST) Park and Expansion of the Natural Energy Laboratory of Hawaii (NELH). I would appreciate it if the final environmental impact statement addresses the following questions:

(1) Discharges from the existing OTEC experiments and the Hawaiian Abalone Farm are currently being disposed of via a canal and two injection wells respectively. Since both disposal methods are among the alternatives under consideration, has NELH developed data on the impact of the various discharges on the brackish water lens and the open ocean that can be applied to the planned changes?

(2) When fully developed, discharges from the OTEC experiments and mariculture projects may contain a wide variety of chemicals and particulates. Have the specific types of projects already been determined? If not, on what basis can the quality of the discharges be discussed with any accuracy?

(3) According to the environmental assessment (p. 21), there are three anchialine ponds on the NELH site that would be impacted by the disposal of discharge from injection wells and trench. Are there additional anchialine ponds near the NELH site that may also be affected by such disposal methods?

I look forward to reviewing the environmental impact statement on this project.

Sincerely,

PETER APO
Chairman
Committee on Ocean and Marine
Resources

cc: MCM Planning

The Natural Energy Laboratory of Hawaii

August 26, 1986

The Honorable Peter Apo, Chairman
Committee on Ocean and Marine Resources
State of Hawaii
State Capitol, Room 439
Honolulu, Hawaii 96813

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Representative Apo:

We appreciate your careful review of the subject preparation notice. In response to your specific comments:

1. NELH has a continuing water quality program that monitors the canal and nearshore waters. Several intensive studies have also been made which indicate no adverse affects from the canal system. The studies that are being conducted in conjunction with the supplemental EIS will address the effects on the environment of increasing the seawater return flows by a substantial factor.
2. There is general agreement on the types of projects (both OTEC and mariculture) that will likely locate at NELH. The environmental impact analysis will attempt to characterize and project the effects of various chemicals and other substances that are used in these projects and their impact on the biological resources of the area. Acceptance of projects at NELH also requires the users to inform the Board and staff of the environmental aspects of their operations. In some cases, and, because NELH is a research and development facility, there are unknowns associated with each new project. Continuation and expansion of the existing monitoring program will be an important component of the disposal system(s) selected. The purity of the source waters is vitally important to the success and future of NELH.
3. NELH has 3 anchialine ponds located on its property in the northern portion past the end of the jeep trail. Although experts have stated that the ponds on the NELH site are biologically insignificant, they will be monitored as a condition of the recently approved CDUA for the project. The draft EIS will discuss the anchialine ponds in the area and identify those that might be affected by this project.

Thank you for your informed and perceptive comments on the subject NOP. We will address your concerns in the draft EIS and look forward to your comments at that time.

Best regards,

Jack

Jack P. Huizingh
Executive Director

☐ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 548-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341

STEPHEN K. YAMASHIRO
Chairman & Presiding Officer
SPENCER KALANI SCHUTTE
Vice Chairman

RECEIVED
AUG 0 . 1986
NELH

COUNTY COUNCIL
County of Hawaii
Hawaii County Building
25 Aupuni Street
Hilo, Hawaii 96720

JAMES L. K. DAHLBERG
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TAKASHI DOMINGO
ROBERT N. HERKES
LORRAINE R. JITCHAKU-INOU
RUSSELL S. KOKUBUN
MERLE K. LAI
Council Members

August 5, 1986

In Reply Refer To: C-705

Mr. Jack P. Huizingh, Executive Director
The Natural Energy Laboratory of Hawaii
220 South King Street, Suite 1280
Honolulu, Hawaii 96813

Dear Mr. Huizingh:

Thank you for your letter of July 23, 1986, informing us as to the status of the Seawater Return Flow Disposal project.

Please be informed that your communication has been referred to the Council's Committee on Economic Development, and will be discussed at its meeting on Tuesday, August 12, 1986, at the Honokaa District Courthouse.

We will provide assistance in the preparation of the supplemental EIS as requested and whenever possible.

Very truly yours,

Stephen K. Yamashiro
COUNCIL CHAIRMAN

The Natural Energy Laboratory of Hawaii

August 21, 1986

Mr. Stephen K. Yamashiro, Chairman
Hawaii County Council
25 Aupuni Street
Hilo, Hawaii 96720

Subj: Environmental Assessment and Supplemental EIS Preparation Notice - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Yamashiro:

Thank you for your letter concerning the subject preparation notice. We look forward to comments from the Committee on Economic Development. We hope that you will also review the forthcoming draft EIS. A copy will be sent to you when it becomes available.

Best regards,

Jack P. Huizingh
Executive Director

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COUNTY OF
HAWAII

PLANNING DEPARTMENT

25 AUPUNI STREET • HILO, HAWAII 96720
(808) 961-8288

DANTE K. CARPENTER
Mayor

ALBERT LONO LYMAN
Director

ILIMA A. PHANAIA
Deputy Director

RECEIVED
AUG 13 1986
NELH

August 7, 1986

Mr. Jack P. Huizingh
Executive Director
The Natural Energy Laboratory
of Hawaii
220 South King Street, Suite 1280
Honolulu, HI 96813

Dear Mr. Huizingh:

Environmental Assessment and Supplemental Impact Statement Preparation Notice - Modification of Proposed Action To Permit Alternative Methods of Seawater Return Flow Disposal at NELH

Thank you for the opportunity to review the Environmental Assessment and Supplemental Environmental Impact Statement (EIS) Preparation Notice for the above-captioned matter.

According to the Preparation Notice, a Supplemental EIS is being drafted to evaluate on-land discharge scenarios since Federal funding for the construction of the mixed-water discharge pipe to dispose of the anticipated 16,100 gpm (23 mgd) of seawater is not available. Alternative disposal methods for this seawater, including direct disposal via canal, trenches, and deep injection well are being investigated.

It appears that the assessment on environmental impacts of alternative methods of seawater return flow disposal has already been discussed in Appendix C (Technical Evaluation of Seawater Return Flow and Wastewater Disposal Systems at NELH/HOST Park, Danes & Moore, June 1985) of the Final EIS for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii. We therefore question the need to prepare a Supplemental EIS.

Enclosed for your information are comments from the County of Hawaii Department of Public Works.

Sincerely,

ALBERT LONO LYMAN
Planning Director

NH:aeb

enclosure

cc: MCM Planning
P. O. Box 27506
Honolulu, HI 96827
Attn: Ms. Marilyn C. Metz

DEPARTMENT OF PUBLIC WORKS
COUNTY OF HAWAII
HILO, HAWAII

Memorandum

DATE July 31, 1986

RECEIVED
AUG 13 1986
NEH

TO : Planning Department

FROM : Chief Engineer

SUBJECT: Environmental Assessment and Supplemental Impact Statement Preparation Notice
Development Plan for HOST and Proposed Expansion of NELH
Keahole, N. Kona, Hawaii

We have reviewed the subject document and our comments are as follows:

The alternative disposal method whether canal, trench or injection well shall not be located within the road right-of-way.

HUGH Y. ONO
Chief Engineer

961-8321

DHM/acs

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mr. Albert Lono Lyman, Director
Hawaii County Planning Department
25 Aupuni Street
Hilo, Hawaii 96720

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mr. Lyman:

Thank you for commenting on the subject NOP. The SEIS is being written because the on-land disposal of OTEC water was not discussed in the previous EIS. In response to the concerns of the Department of Public Works, disposal facilities will not be located in the road right-of-way.

We look forward to your review of the draft SEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

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For the Protection of Hawaii's Native Wildlife

HAWAII AUDUBON SOCIETY

P.O. BOX 22832
HONOLULU, HAWAII 96822

P. O. Box 275
Volcano, HI 96785

August 22, 1986

RECEIVED
AUG 25 1986
NELH

The Natural Energy Laboratory of Hawaii
220 S. King Street, Suite 1280
Honolulu, HI 96813
Attention: Mr. Jack P. Huizingh, Executive Director

Dear Mr. Huizingh:

Thank you for sending me the Environmental Assessment and Supplemental Impact Statement Preparation Notice — Development Plan for the Hawaii Ocean Science 7 Technology (HOST) Park and Proposed Expansion of the Natural Energy Laboratory of Hawaii (NELH) at Keahole, North Kona, Hawaii: Modification of Proposed Action to permit Alternative Methods of Seawater Return Flow Dispersal at NELH.

The concerns of the Hawaii Audubon Society focus on adverse impacts on native terrestrial and aquatic habitats from the several proposed alternative projects.

In particular, the Society will be looking for evaluations of potential damage to the following elements from the alternative systems for disposing of ocean water discharges from OTEC experiments and mariculture processes: damage to strand vegetation communities, damage to marine biota, damage to Hawaiian Stilt and Hawaiian Owl habitat, damage to ground water quality and to offshore water quality.

Thank you for the opportunity to make these comments.

Sincerely yours,

Mae E. Mull

Mae E. Mull
Member, BoaRD OF Directors and
Island of Hawaii Representative

The Natural Energy Laboratory of Hawaii

October 14, 1986

Mrs. Mae Mull
Hawaii Island Representative
Hawaii Audubon Society
Volcano, Hawaii 96785

Subj: Environmental Assessment and Supplemental EIS Notice of Preparation - Modification of Proposed Action to Permit Alternative Methods of Seawater Return Flow Disposal at NELH, Keahole, North Kona, Hawaii

Dear Mrs. Mull:

Thank you for commenting on the subject NOP. Damage to strand vegetation communities and Hawaiian Stilt and Hawaiian Owl habitat were addressed in the previous EIS which was accepted by the Governor on September 20, 1985. Damage to marine biota, ground water quality and offshore water quality will be addressed in the draft SEIS.

We look forward to your review of the draft SEIS.

Best regards,

Jack P. Huizingh
Executive Director

cc: MCM Planning

☐ 220 South King Street, Suite 1280 • Honolulu, HI 96813 • (808) 543-7017
☐ P.O. Box 1749 • Kailua-Kona, HI 96745 • (808) 329-7341

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APPENDIX A

DISPOSAL OF OPEN CYCLE OCEAN ENERGY
CONVERSION WATER "VIA CANAL"

OCEANIT LABORATORIES, INC.

Oceanit Laboratories, Inc.
coastal & offshore engineering services • research & development

Disposal of Open-Cycle Ocean Thermal Energy Conversion (OC OTEC) Water "Via Canal" at the Natural Energy Laboratory of Hawaii (NELH) Keahole Point, Hawaii

November 1986

1188 Bishop Street, Suite 1801, Honolulu, Hawaii 96813
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EXECUTIVE SUMMARY

Direct disposal of open-cycle Ocean Thermal Energy Conversion (OC OTEC) water, up to 16,000 gallons per minute (gpm), "via canal" at the Natural Energy Laboratory of Hawaii (NELH) will not affect the warm seawater intake system during most environmental conditions. However, when there is no longshore current other than tidal and currents flow in the ebb direction, i.e., towards the warm seawater intake, the materials discharged may compromise the water quality at the warm seawater intake by increasing nutrient levels and decreasing dissolved oxygen levels by a few percent from normal ambient levels. This change could interfere with controls on existing experiments that rely on the quality of the warm seawater.

In the event that heat exchangers are used for producing fresh water, no significant impact is expected from the discharged metallic ions resulting from heat exchanger corrosion. Furthermore, the small amounts of fresh water produced, and the resulting salinity changes, are not expected to have a significant impact on the marine receiving waters. In the event that chlorination is required to control biofouling, no significant impact is expected so long as the concentrations are kept below the current levels of chlorination for the

closed-cycle research projects, i.e., 0.1 ppm (parts per million) for one hour per day.

Nutrients in OTEC discharge are expected to be greater than those found in the receiving warm seawater environment. If we treat the nutrients as a conservative property, a worst-case scenario, we find that during ebb current conditions, without influences from other currents, the concentration of nitrogen could be relatively high and could act to increase the rates of biofouling. Although the nutrient concentrations found at the warm seawater intake, resulting from OC OTEC discharge, would be less than values calculated with our computer model, due to consumption, it would be prudent to investigate cause and effect relationships occurring as a result of discharge at this tidal current condition before discounting the potential impacts on the warm seawater intake.

Furthermore, changes in water quality resulting from degassing OC OTEC water would additionally increase the concentration of available nutrients and organic carbon in the discharge above that previously calculated -- due to lysing (disintegration of bacteria, plankton, etc.). This could result in a significant change in water chemistry, i.e., decrease in dissolved oxygen.

In general, as long as there is either a northward or southward current, as normally occurs, discharge "via canal" is acceptable for existing OTEC research projects at NELH. The discharge should not influence the water quality at the warm seawater intake. However, under an ebb tide condition, with no external currents, it is recommended that disposal of OC OTEC water occur in another manner until more detailed investigations provide additional information.

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I. INTRODUCTION

The Natural Energy Laboratory of Hawaii (NELH) is located at Keahole Point on the most western point of the island of Hawaii, illustrated in Figure I-1. It provides an excellent environment for conducting ocean-related research such as Ocean Energy Thermal Conversion (OTEC) and aquaculture.

Under the existing National Pollutant Discharge Elimination System (NPDES), Permit No. HI 0020893, discharges from OTEC research of up to 1500 gpm are acceptable. Currently, NELH discharges approximately 1000 gpm of mixed warm seawater, pumped from approximately 303 feet offshore at a depth of 45 feet, and cold deep seawater, pumped from approximately 2100 feet deep. The mixtures range from 1:1 to 1:6 depending on the demand from the experiments.

In anticipation of increased open-cycle (OC) OTEC research, discharge is expected to increase to 16,000 gpm with approximately 6,500 gpm deep-cold and 9,500 surface-warm seawater.

Oceanit Laboratories, Inc. (hereinafter "OLI") was contacted to investigate increasing the discharge "via canal" from 1000 gpm to 16,000 gpm. Results and findings are to be included in a supplemental environmental impact statement (EIS).

The specific considerations addressed in our study include the following:

1) Describe the effect on water quality from OC OTEC research on the warm seawater intake.

2) Provide a general computer model to simulate discharge of OTEC water at the shore -- "via canal".

3) Assess the influence on NELH's warm seawater intake from a potential 165 kw OC OTEC facility, discharging approximately 16,000 gpm "via canal".

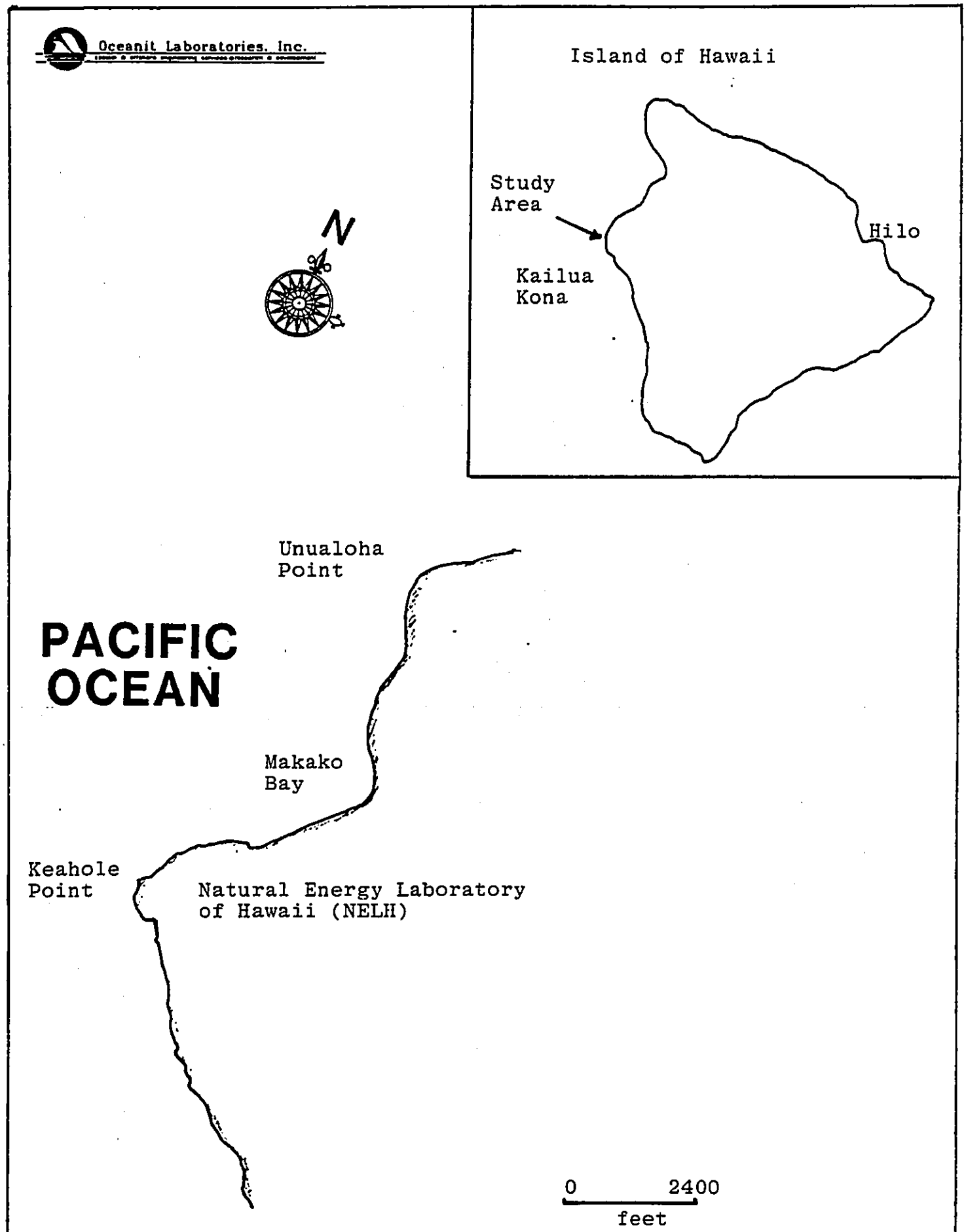


Fig. I-1 Location of study site, Keahole Point, Hawaii.

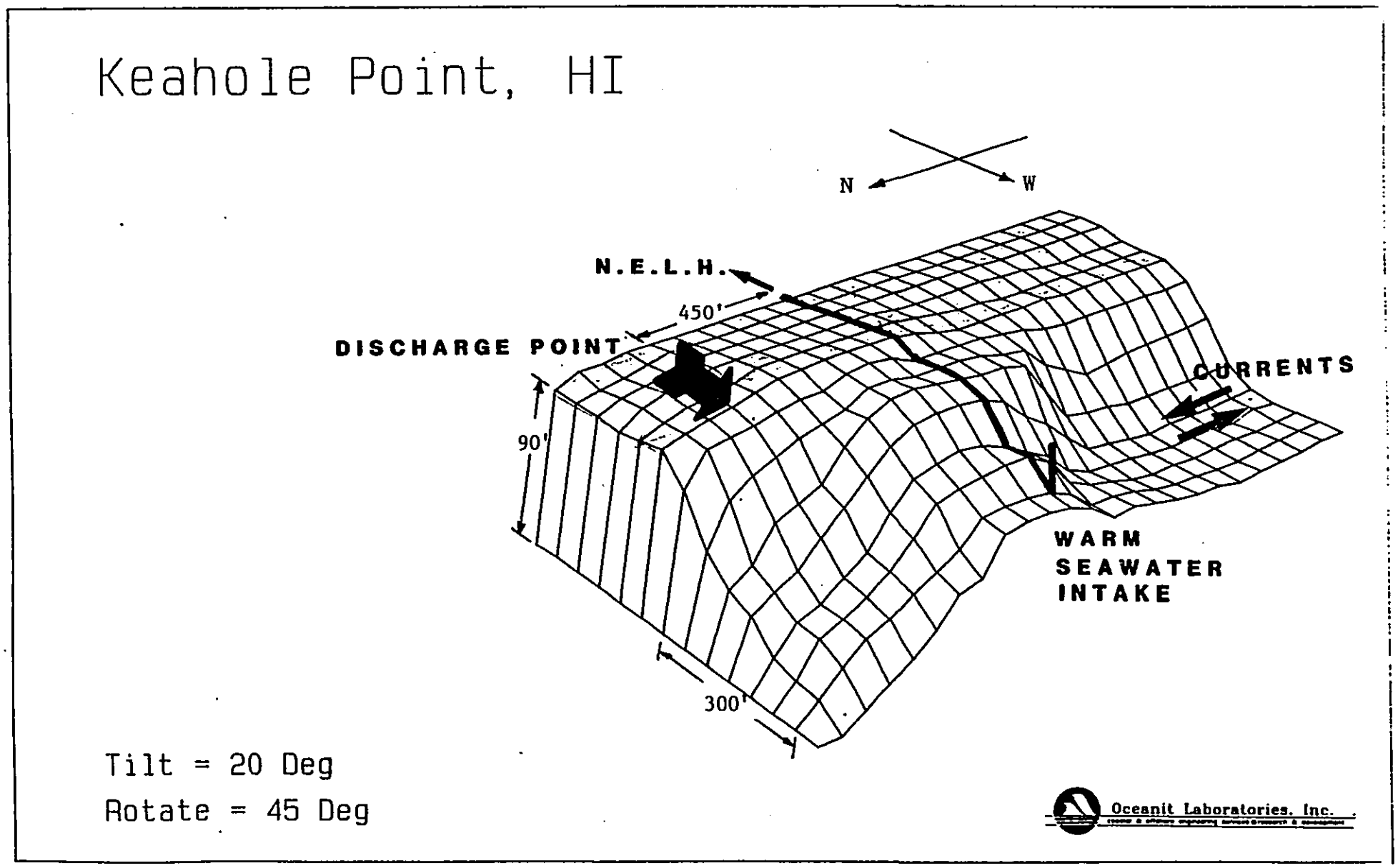


Fig. I-2 3-D representation of Keahole Point, Hawaii.

II. TECHNICAL CONSIDERATIONS

A. OPEN-CYCLE OTEC RESEARCH

The OTEC concept is believed to have started in the late 1800's with a French physicist named D'Arsonval who suggested the possibility of extracting heat energy from the ocean. The first working demonstration of the OTEC concept, open-cycle (OC) OTEC, occurred in the late 1930's with George Claude off the coast of Cuba [1].

OC OTEC power is generated by a large low pressure turbine driven by water vapor produced from the evaporation of warm surface seawater. The evaporated seawater, working fluid, is later condensed to a liquid by cold deep seawater. If condenser tubes are used, fresh water can be produced; otherwise the condensate is discharged with the cold seawater. To increase the efficiency of the evaporator and condenser, dissolved gases, primarily oxygen and nitrogen, will be removed from the warm seawater before it reaches the evaporator. The degassification process changes the available form of organic carbon and other nutrients due to the low pressure environment via lysing. An operational OC OTEC facility does not require heat exchanger tubes, either

for the evaporator or the condenser, except to produce fresh water. Therefore, most of the corrosion and biofouling problems associated from closed-cycle OTEC are eliminated.

The Department of Energy has identified the development of ocean energy technology as one of its long-range missions. Areas related to OTEC that are identified for future research include the following [2]:

- Research and Analysis on Thermodynamics
  * OC OTEC heat and mass transfer process feasibility (includes gas sorption, evaporation and condensation)
  * Advanced OC cycle turbine rotor research
  * Advanced theory for OTEC systems integration
  * Alternate OTEC power cycle

- Experimental Verification and Testing
  * Direct-contact heat and mass transfer performance validation
  * OC OTEC concept feasibility investigations
  * Heat exchanger performance improvement
  * Advanced technology for heat exchanger fabrication
  * STF (Seacoast Test Facility) upgrades
  * Small-scale cold water pipe (CWP) experiments
  * Modular-scale CWP experiments
  * Alternative ocean energy systems research and analysis (e.g., wave energy)

- Materials and Structural Research
  * Heat exchanger materials research
  * CWP design methods and installation procedures
  * Remote CWP inspection maintenance and repair technology

- Oceanographic, Environmental and Geotechnical Research
  * Oceanography
  * Environmental and legal compliance
  * Seabed and geotechnical studies

Various experiments have been planned to investigate OC OTEC concepts. Figures II-1 and II-2 illustrate experimental research that is currently either ongoing or under consideration.

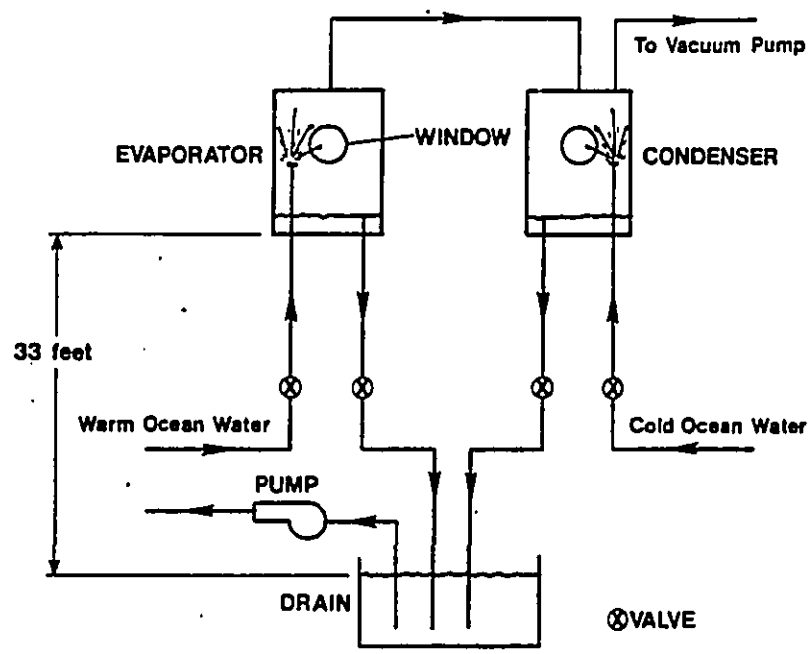


Fig. II-1 OC OTEC Evaporator Experiment (5).

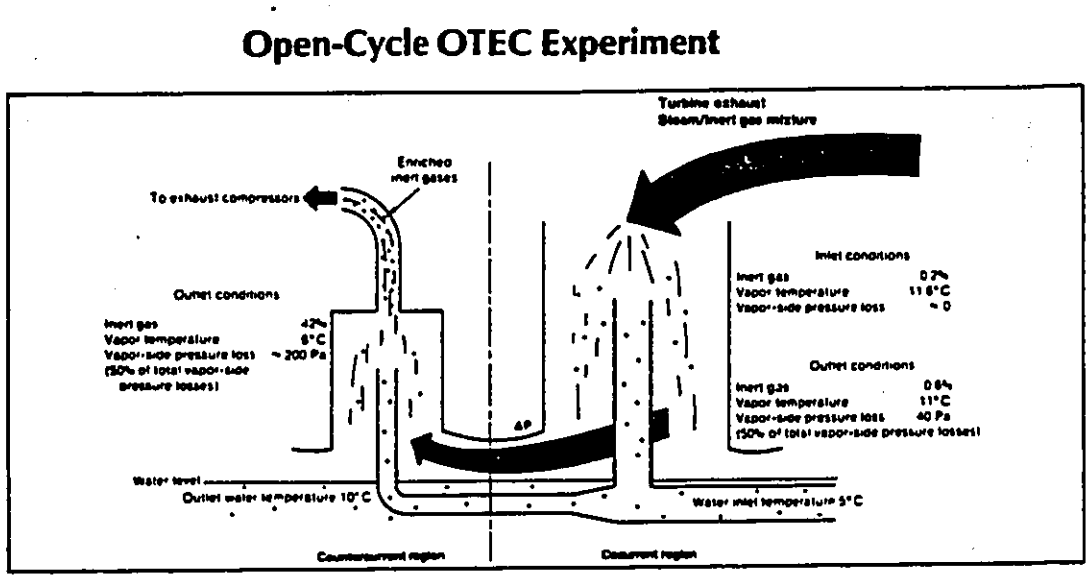


Fig. II-2 Example two state direct contact condenser (3).

The experiment by Solar Energy Research Institute (SERI), a Department of Energy core group, will be carried out in two phases [3] (see Figure II-3). In the first phase, evaporator and condenser modules will be in the form of three, 8-foot diameter pressure vessels. Heat and mass transfer experiments will be conducted with full scale geometries. In the second phase, additional heat transfer modules and a turbine will be added to permit completion of a cycle feasibility assessment. Figure II-3 gives more detailed specifications regarding the SERI's OC OTEC experiment [3].

The Pacific International Center for High Technology Research (PICTR) has identified certain areas of OC OTEC research as high priority areas, including in the following [4]:

- Implement component and system performance models for analyzing OC OTEC experiments; evaluate designs and scaling requirements for tests of the Claude cycle (simplest OC OTEC cycle that boils warm seawater and drives a turbine with low density steam).
- Test Claude OC OTEC components including direct contact condenser using seawater.
- Develop designs for turbines for OC OTEC applications.
- Perform systems-levels tests of Claude OC OTEC power system to investigate heat and mass transfer, and to determine systems performance characteristics.
- Develop conceptual designs for alternate commercial scale OC OTEC plants between 1 to 10 MW size.
- Perform preliminary design optimization analysis.
- Evaluate alternative cold water pipe design and installation techniques to accommodate Pacific Island conditions.

- Analyze the economics of alternative OTEC concepts for various Pacific Island communities.

OC OTEC research proposed for NELH is more concerned with segassification than with materials selection. It is perhaps the most important open-cycle research problem because it directly affects the technical and economic feasibility of OC OTEC.

Current OC OTEC experiments at NELH are investigating the following [5,6]:

- Problems of foaming and the release of non-condensable gases
- Evaporator/condenser efficiency as a function of spout size, length, configuration and fluid velocity
- Operational experience
- Effects of evaporator and condenser configurations
- Gas desorption from the seawater

Large scale OC OTEC operation could have adverse impacts on the environment for a variety of reasons [7]. The discharge of large volumes of degassed seawater could lead to environmental impacts on the marine biota. If the gases are redissolved in the discharge stream, the receiving waters could be impacted from seawater that is significantly different in character. In addition, infrared-absorbing gases that escape to the atmosphere could result in global atmospheric changes as well as global heat budget changes. However, when considering the small scale of the

proposed 165 kw research facility, these concerns are not appropriate. Moreover, the research provided at the proto-type facility could help to decrease the uncertainty in speculative environmental impacts of a larger scale OTEC facility.

It is important to maintain the warm seawater quality so that current closed-cycle OTEC research, concerned with materials selection and biofouling control methods, can continue [8]. Therefore, OC OTEC discharge must not significantly influence the warm seawater quality at the warm water intake.

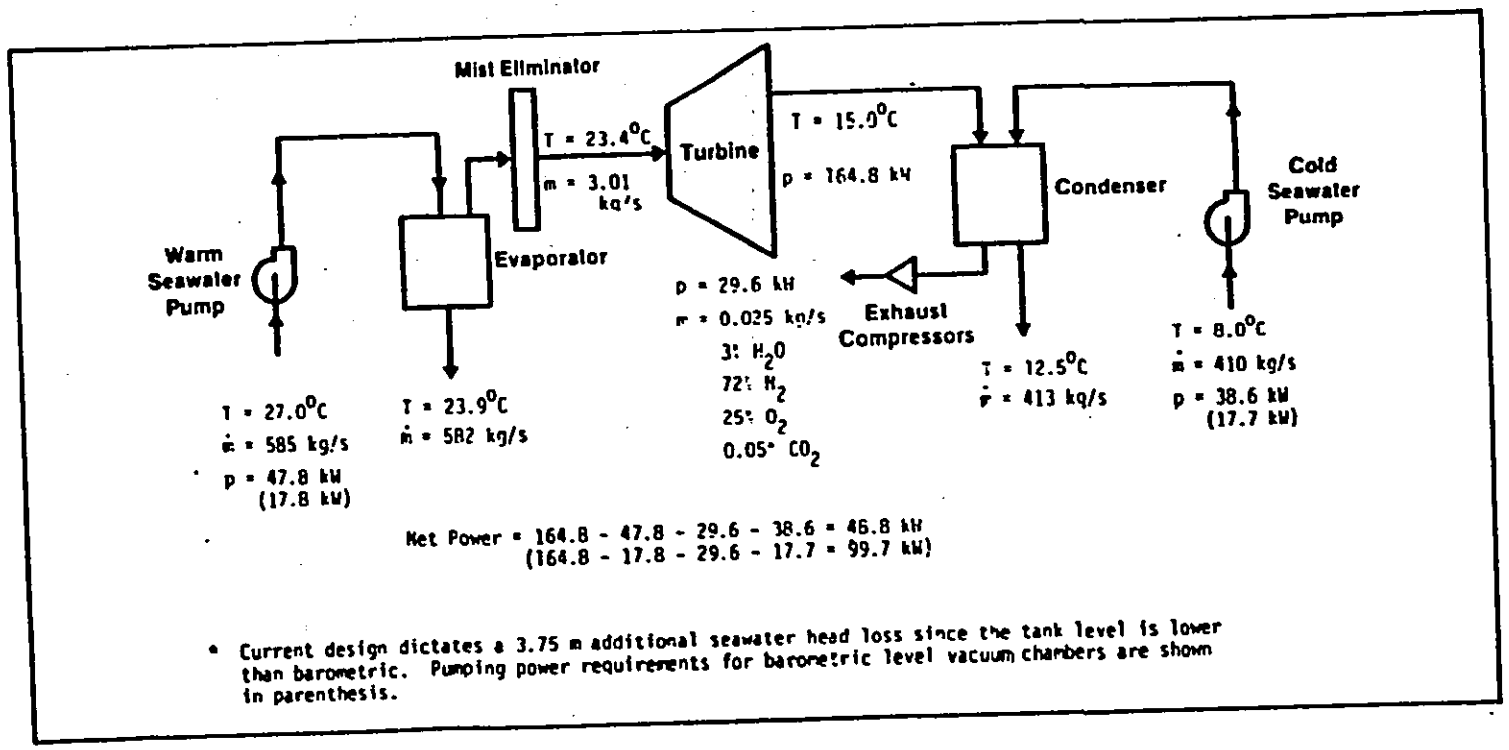


Fig. II-3 OC OTEC experimental flow diagram (3).

ENVIRONMENTAL CONCERNS

Major environmental concerns regarding large scale OC OTEC focus on potential effects of discharging substantial quantities of deoxygenated seawater as well as substantial quantities of carbon dioxide and other gases suspected of promoting a greenhouse effect. However, problems associated with a small scale prototype facility, such as the 165 kw OC OTEC facility planned for NELH, are considerably smaller, and include the discharge of deoxygenated and nutrient-rich seawater.

Currently, the 1000 gpm of seawater discharged at Keahole Point does not produce a nutrient-rich plume or any measureable adverse environmental impact, resulting from the mixture of 1:1 to 1:6 cold to warm seawater. This is because the inter-tidal ponding area transforms the nutrients into algae and seaweed [34]. However, before the same type of ponding area can be used for larger discharge volumes, additional investigations are required to determine the physical characteristics that cause the pond to act as a "reactor vessel" that adds oxygen, removes nutrients and increases the discharge water temperature to approximately that of the ambient seawater.

From an OTEC systems viewpoint, there are two considerations regarding the discharge of degassified seawater; the first is environmental, the second is related to the efficiency of the system. Due to the parasitic power losses that result from removing gases and pumping them to atmospheric pressure for disposal, there is interest in reinjecting the gases back into the seawater prior to disposal. This would have a two-fold benefit; it would discharge much more environmentally-acceptable seawater and would decrease parasitic power losses associated with pumping the gases. An illustration of this type of arrangement is given in Figure II-4 [33].

After discussing the problem of degassification and regassification with various investigators involved with OC OTEC, i.e., from the University of Hawaii, the University of Pennsylvania, the Solar Energy Research Institute, the Argonne National Laboratory and the Department of Energy, it became clear that regassification of the discharge plume was of interest and concern to all parties interviewed and will be addressed in one form or another in their respective research efforts. A brief summary resulting from conversations with people from each of these organizations is included in the following:

> Dr. Hans Krock of the University of Hawaii indicated that although reoxygenation of the discharge plume is possible by processing the seawater through turbulent motion, e.g., a small fountain, it is more useful to reinject the gases originally removed during degassification so that parasitic power losses can be minimized.

Dr. Terry Penny of the Solar Energy Research Institute indicated that degassification and reinjection of gas es (primarily O_2, N_2, CO_2) will be addressed in his research effort.

Dr. Noam Lior of the University of Pennsylvania indicated research planned for NELH is directed at producing an operational OC OTEC facility. Questions concerning the reaeration of OTEC discharge will not be directly addressed because of limited resources. However, problems associated with the efficiency of the OC OTEC facility, i.e., noncondensible gases in the condenser, will be addressed.

Dr. C. B. Panchal of the Argonne National Laboratory indicated that predearation is an important factor in making the condensers and evaporators operate efficiently. Research at NELH will address the problems associated with dissolved gas (O_2, N_2, CO_2) reinjection as well as removal. However, much more work is required before anything can be included as part of an OC OTEC system.

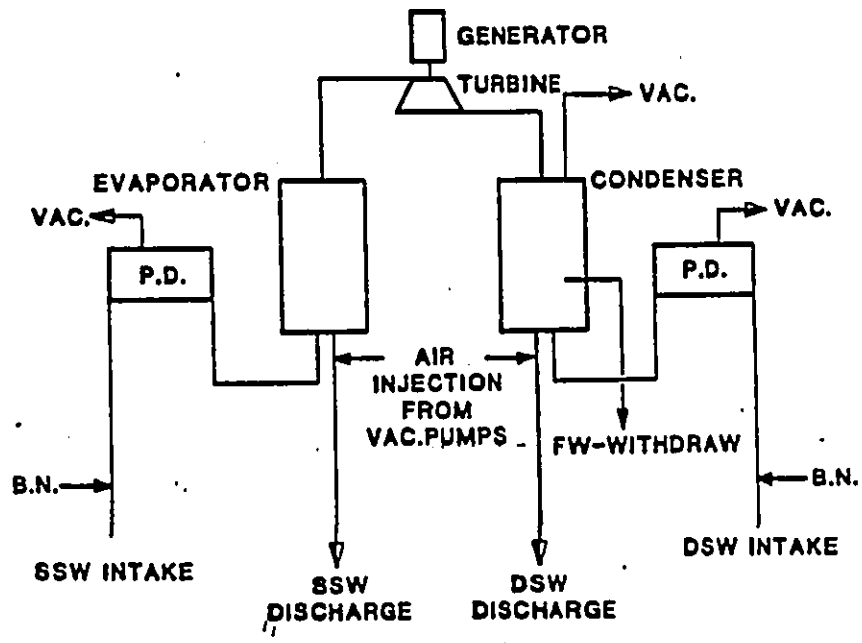
Dr. David Johnson of the Solar Energy Research Institute indicated that the Department of Energy is not looking at reaeration of OC OTEC discharge as a separate task. However, reaeration will automatically be included as part of their proposed research because of the possibility of reducing parasitic power losses in addition to reducing possible environmental impacts associated with discharging oxygen-poor seawater.

Dr. Carmine Castellano of the Department of Energy indicated that regassification of OC OTEC discharge is of concern because of a need to minimize environmental impacts. He indicated that reaeration could be accomplished using a spout-type arrangement. Another way to reaerate would be to use a hydraulic pump that would recombine the gases previously removed from the warm and cold seawater. However, problems associated with aeration are not yet resolved and require more research.

Dr. Lloyd Lewis of the Department of Energy indicated that the feasibility of reinjection is not yet known. However, if sucessful, it could be used to reduce parasitic power losses in the OC OTEC process.

In addition to concerns regarding the discharge of low oxygen and nutrient-rich seawater, there is a concern regarding impact from

the resort developments that are occurring along the Kona Coast or the adjacent coastal areas on the western part of the Big Island. The situation at Keahole Point is different from that found in other areas such as the northwestern shore of Oahu, around Kahuku, where Marine Culture Enterprises (MCE) is operating an aquaculture facility. At MCE some of the water entering the nearshore coastal environment from the shrimp operation gets trapped in the "nearshore coastal regime" that exists along the north shore. This coastal regime results from reversing tides as well as the north equatorial current impinging upon the island of Oahu so that waters hug the coastline all the way down to the western tip of Oahu. However, at Keahole Point, the westernmost point on the Big Island, currents are dominated by large eddies (approximately 100 km in diameter) that reverse from time-to-time [35]. These eddies have a tendency to take nearshore water away from, rather than along, the coastline. Therefore, there is no nearshore coastal regime like the one found on the northwestern shore of Oahu. In general, waters entering the nearshore marine environment around Keahole Point are not expected to remain in the nearshore area for very long.



Schematic Design of Open Cycle OTEC Process
P.D. = Predeaeration
SSW = Surface Sea Water
DWS = Deep Sea Water
FW = Fresh Water
Vac = Vacuum
B.N. = Bubble Nucleation

Fig. II-4 Example of OC OTEC system that would use gas reinjection (32).

B. DISCHARGE WATER DESCRIPTION

OC OTEC discharge water will be composed of warm seawater after it has been degassed and exposed to a low pressure environment, and cold seawater after it has been used for condensing water vapor. The cold water will be degassed if used as a direct contact heat exchanger.

LYSING OC OTEC WATER CONSTITUENTS

Due to the pressure decrease in the evaporator, lysing (disintegration or dissolution of tissues or microoganisms) of plants and animals in the OC OTEC water will occur because of the internal boiling due to the drop in pressure. This will change the available form of nutrients in the water into perhaps a more easily assimilated form. Table II-1 illustrates the percent weight composition of the most prevalent elements found in microoganisms [16]. If we assume that the organic content of warm seawater at NELH is approximately 100 ug/liter and that most of these materials are from living animals and plants, we can estimate the increase in available nutrients in the mixed discharge water. For example, 14 percent of 100 ug/liter will provide 14 ug/liter additional nitrogen or approximately 0.014

ppm. In the case where we have 1,000 ug/liter of organic matter we would find an increase of 0.14 ppm in the discharge plume -- an increase in nitrogen by up to 50 percent above that calculated using a 1:1.5 mixture of warm and cold seawater. However, the total nitrogen content would not change if the total nitrogen includes all constituents in the seawater, i.e., nonfiltered seawater. Lysing only changes the molecular state of the available nitrogen not the total nitrogen. Similarly, available phosphorus could increase by 0.003 to 0.03 ppm -- an increase of 5 to 60 percent--although the total phosphorus would remain constant.

Table II-2 illustrates the elemental compositions of plants, animals and seawater, deep and surface, with respect to the numbers of atoms of nitrogen (N), phosphorus (P), carbon (C), calcium (Ca) and silicon (Si). It is important to note that the the ratio of available atoms of N and P in plant and animal tissue is the same as that found in deep seawater. However, caution should be employed when interpreting these numbers because they do not provide a distinction between the molecular state of the atoms of interest. For example, nitrogen could be in the form of nitrate, nitrite, ammonia or N_2 gas. Moreover, when nutrients are introduced from lysing, the N and P will be introduced in the same atomic proportions that currently exist in deep seawater.

TABLE II-1

Elemental cell composition [16].

Element	Percent Dry Weight
Carbon	50
Oxygen	20
Nitrogen	14
Hydrogen	8
Phosphorus	3
Sulfur	1
Potassium	1
Sodium	1
Calcium	0.5
Magnesium	0.5
Chlorine	0.5
Iron	0.2
All Others	0.3

TABLE II-2

Atomic composition ratios found in plant/animal tissue and seawater [17].

	P	N	C	Ca	Si
Soft Tissue	1	15	105	0	0
Hard Parts	0	0	26	26	50
Composite	1	15	131	26	50
Deep Seawater	1	15	1000	5000	50
Warm Surface Seawater	0	0	869	4974	0

DISSOLVED GASES REMOVED DURING OC OTEC

Degassing OC OTEC water, prior to evaporation, removes dissolved oxygen, nitrogen, carbon dioxide, and trace gases such as Ar, He, and Xe from seawater. Initial results at NELH indicate that about half of the nitrogen and oxygen normally found in cold deep seawater is removed under conditions that simulate OC OTEC degassification [7]. However, later research done at NELH with warm and cold seawater indicates that up to 95 percent of the dissolved gases can be removed under OC OTEC conditions [18, 32]. The majority of the gases removed will be oxygen and nitrogen. Because most usable nitrogen in the seawater is in the form of nitrate, nitrite, ammonia and kjeldal nitrogen, the nitrogen gas removed during degassification can be considered inert for most biological purposes and is not expected to result in a significant impact. Removal of dissolved oxygen will change the dissolved oxygen levels of the discharge water to values significantly below those found in the ambient warm seawater; the discharge plume will be oxygen poor compared to surrounding waters. Organisms exposed to the plume may be oxygen-starved [9]. This situation could be addressed with reoxygenation through a process of aeration.

TRACE METALS

Trace metals released in seawater from corrosion and erosion of metallic members within an OTEC facility will increase metallic ion concentrations in nearby and receiving waters. However, this is expected to have no significant impact on the nearby marine environment.

Heat exchangers are not required for OC OTEC, except for the production of fresh water. Of the heat exchanger candidate materials, aluminum is of the most interest. Aluminum concentrations below 10 mg/l have been found to have no effect on marine fish and shrimp; concentrations less than 0.2 mg/l did not significantly inhibit marine algae [9]. Calculations of metallic ion concentrations from aluminum heat exchanger corrosion for warm seawater corrosion (worst-case), indicate that resulting metallic ion concentrations would be less than concentrations found in the ambient seawater (see Appendix A). Therefore, no significant impact would result from any heat exchanger configuration of a 165 kw size.

CHLORINATION DURING OTEC OPERATION

Very little chlorine will be used in an OC OTEC operation because there are no warm seawater heat exchangers in the evaporator and, depending on the specific OC OTEC design, there may be no cold seawater heat exchangers in the condenser. In the event that heat exchangers are employed in the condenser, very little chlorine, if any, will be used to control biofouling because of the very low rate of biofouling found in cold seawater.

Chlorine is commonly used for waste treatment in water because of its ability to oxidize and disinfect [10]. In closed-cycle OTEC research it is produced electrochemically and insitu as sodium hypochlorite or bleach (NaOCl) immediately upstream of the section of heat exchanger tubing to be cleaned.

Recent closed-cycle OTEC research performed in warm seawater at NELH indicates that chlorination levels of only 0.1 ppm for 1 hour per day are required to prevent film formation and keep heat transfer fouling resistance from rising above the maximum tolerated values [11]. In addition, results from cold water research indicate that biofouling in the cold water heat exchanger is very low.

Based on results from closed-cycle OTEC research and the low levels expected for OC OTEC, chlorination of a 165 kw OC OTEC facility should have no significant impact on the marine environment. A more detailed discussion on chlorination is given in appendix C.

NUTRIENTS FROM MIXING WARM AND COLD WATER

Nutrient levels in the discharge plume will change as a function of the cold:warm seawater ratio in the mixture. Under the condition where 1.5 parts is warm and 1.0 is cold, the following nutrients are expected in the effluent:

TABLE II-3

Nutrient mixing in the OTEC effluent

	Cold Seawater	Warm Seawater	1:1.5 mix	State Std GeoMean	NTE_1 10%	NTE_2 02%
D.O. (ppm)	1.0	6.0	4.0	*	*	*
NO2+NO3 (ug/L)	554.0	2.4	223.0	3.5	10.0	20.0
PO4 (ug/L)	930.0	4.7	374.8	5.0	9.0	13.0
pH	7.6	8.3	7.9	**	**	**
Temp (C)	8.3	26.1	19.0	----	----	----
TN (ug/L)	590.0	57.6	270.6	115.5	195.0	279.0
TP (ug/L)	93.0	10.0	43.2	16.0	30.0	45.0
Si (ug/L)	2180.0	97.0	930.2	----	----	----

D.O.=dissolved oxygen, NO2+NO3=nitrate+nitrite, PO4=orthophosphate, TN=total nitrogen, TP=total phosphorus, Si=silicon, * = not less than 75% saturation, ** = 8.1 +/- 0.5 pH units, state standards as per "Public Health Regulations, Chapter 37-A, Water Quality Standards" for a dry open coastline [31].
NTE_1=Not To Exceed less than 10 percent
NTE_2=Not To Exceed greater than 2 percent

Results indicate that a 1:1.5 mixture would exceed the state of Hawaii water quality criteria for nitrate plus nitrite, orthophosphate, total nitrogen and total phosphorus. However, neglecting variations in ambient current velocities, the concentrations in the discharged water would decrease to approximately 5 percent of the initial value within 100 feet of the discharge point. If water is discharged into a ponding area, similar to the one existing at NELH, concentrations would decrease. Theoretically, if the physical parameters that cause the ponding area to act as a reactor vessel could be scaled-up to accommodate the increase in discharge volume, concentrations could approach ambient seawater conditions.

III. DISCUSSION AND RECOMMENDATIONS

Concentrations at the warm seawater intake were found to be sufficiently diluted during most tidal and current conditions so that the water quality at the warm seawater intake is not influenced from the discharge. However, during an ebb tide, without external currents, i.e., resulting from large cyclonic/anticyclonic gyres, tradewinds, etc., constituent concentrations of the discharged water will be diluted by approximately one part in two-hundred at the warm seawater intake.

A 1:1.5 mixture of cold and warm seawater coupled with a dilution of one part in two hundred results in levels of dissolved oxygen slightly below the ambient and total nitrogen levels slightly above the ambient. In this simple case, values are within the statistical variations that naturally occur. However, because the natural marine environment is more complex, further research is recommended, including measurements of the sensitivity of biofouling to nutrient and oxygen levels and an evaluation of the effect of an oxygen-starved and nutrient-rich plume on its nearby marine environment.

Under the worst conditions of current, results indicate that metallic ion concentrations from heat exchanger corrosion from a 165 kw closed-cycle OTEC facility (a worst-case compared to a 165 kw OC OTEC facility) are lower than concentrations found in the ambient seawater. Therefore, metallic ion contamination is not a consideration.

Chlorination is not expected to be an enviromnental concern with OC OTEC because heat exchangers are not expected to be used, except for the production of fresh water. In addition, the low biofouling levels found in cold seawater require very little chlorine, if any, to control biofouling. However, if the concentration of chlorine is kept to the present level used in the warm seawater closed-cycle OTEC experiments, (approximately 0.1 ppm for one hour per day), no adverse effects on existing experiments are anticipated.

Based on our findings, specific recommendations can be made regarding discharging water from a 165 kw OC OTEC facility:

1) In order to better determine conditions that provide the best and the worst transport and mixing of discharged water, it is recommended that low cost micro current monitoring be initiated. Results of a micro current study could then be correlated with existing historical data of currents and meterological conditions.

2) If chlorination becomes a concern, it is recommended that a dechlorination system be investigated, e.g., one that uses sodium bisulfate. Furthermore, to reduce future concern about large scale OTEC chlorination, an engineering research program to design an OTEC dechlorinator would be beneficial.

3) Nutrient levels of the discharged water could be decreased with processing prior to discharge. For example, algal mats could be employed to remove the relatively large concentration of nutrients [33]. Aeration could be used to increase dissolved oxygen levels.

4) A qualitative analysis of existing water quality data using statistical methods [27,28] would provide a better interpretation of existing water quality conditions and changes that normally occur. These results could then be used to determine acceptable levels of nutrients in the ambient seawater.

5) Further improvements could be achieved in the predictive capabilities of the computer model if more conditions of current, velocity and duration, including dispersion and micro currents, were investigated.

6) It is recommended that close contact be maintained with the various private and federal research interests that are involved in research at NELH. This list includes, but is not limited to, the following: the Solar Energy Research Institute (SERI), Argonne National Laboratories (ANL), ALCAN Aluminum Co., ALCOA Aluminum Co., the University of Hawaii, the University of California at Berkeley, Cyanotech Corporation and Monterey Abalone Farms. The resulting information exchange could help maintain the quality of water at the warm water intake, maintain the nearshore marine ecosystem and allow further testing and development of new technologies at NELH.

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APPENDIX A

HEAT EXCHANGER CORROSION

If we exclude copper-nickel alloys, because of their lack of compatibility with candidate working fluids for closed-cycle OTEC, and discount titanium and stainless steel, because of their relative immunity to corrosion in seawater under OTEC conditions [19], we are left with aluminum alloys. Due to the relatively low cost of aluminum in a commercial scale OTEC facility, it is an attractive candidate heat exchanger material. In general, research conducted at NELH [20,21,22] indicates that localized attack (site selective corrosion, e.g., pitting, crevice corrosion) does not occur in the warm water heat exchangers. However, under certain conditions the cold water heat exchangers still show signs of localized attack.

Results from localized attack found in cold seawater corrosion of aluminum are reported as average uniform surface corrosion for purposes of comparison and simplicity, even though the modes of corrosion are different. If we use the mathematics available for warm seawater corrosion of aluminum, assuming uniform attack, we

can calculate metallic ion concentrations as a function of time and then relate our findings to cold seawater corrosion of aluminum, based on empirical data. Aluminum corrodes according to a parabolic oxidation rate law in warm seawater, found by Sullivan and Liebert [22,19]; we can predict the corrosion weight loss resulting from uniform corrosion of aluminum heat exchanger tubing by using equation A-1 [23].

Eqn.A-1

$$W = k * SQRT(t) + C$$

where W = grams/area weight loss
k = parabolic rate constant
C = constant

The candidate aluminum heat exchanger materials that are under consideration are composed of greater than 90 percent aluminum with the balances made of the following materials:

Alclad 3003 (uses anodic cladding of Al7072)
Al 3003 1.2%Mn, 0.12%Cu
Al 3004 1.2%Mn, 1.0%Mg
Al 5052 2.5%Mg, 0.25%Cr
Al 7072 (cladding only) 1.0%Zn

The initial corrosion of aluminum alloys in warm seawater has been found to have a rate of approximately 3400 um/yr after 30 minutes of exposure [22]. Eventually corrosion rates decrease to approximately 3 um/yr [21]. In cold seawater the corrosion rates appear to be less than that found for warm seawater; however, due to localized attack, the long term corrosion rates are of special concern.

Results from our calculations will be compared to concentrations that are normally found in seawater as given in Table A-1.

TABLE A-1

General concentrations of metallic ions in seawater [24]

ion	Concentration ppm
Al	0.5
Zn	0.005
Mg	1272
Cr	less than $1X10^{-10}$
Cu	0.001-0.01
Mn	0.001-0.01

TABLE A-2

Deep and surface seawater concentrations of metallic ions in seawater [25]

ion	Concentration (deep) ppm	Concentration (surface) ppm
Al	.001	.0006
Zn	.0000065	.00044
Mg	1284	---
Cr	.00027	.00030
Cu	.000034	.00013
Mn	.000034	.000038

Although OC OTEC does not employ heat exchangers, except for the production of fresh water, we investigated possible metallic ion contamination that could result from the use of cold water heat exchangers. Due to the wealth of information regarding warm water heat exchanger corrosion, we calculated metallic ion concentration levels with warm seawater. We then extrapolated our findings to estimate production of metallic ion contaminants via cold seawater corrosion.

As a worst-case scenario we considered warm water corrosion in 200 meters of one-inch aluminum alloy heat exchanger tubing. A water velocity inside the tubing of about 6 feet/sec was used and calculations were made for a total of 8,000 gpm.

In a 165 kw OTEC plant we would expect to have approximately 8,000 gpm of warm and cold seawater each to give a total discharge of approximately 16,000 gpm. However, in a OC OTEC facility the warm water heat exchangers would not be used and the cold seawater heat exchangers would be used only to produce fresh water. In this case there would be 8,000 gpm of cold seawater running through heat exchangers. Under these circumstances we estimated that corrosion rates will be less than the corrosion rates found in the warm seawater, e.g., 33-75 percent. However, because we have data describing warm seawater corrosion, metallic ion concentrations for warm seawater corrosion were calculated.

Based on these results we can estimate cold seawater corrosion-induced metallic ion discharge.

The corrosion kinetics of aluminum follow the parabolic rate law as given by Equation A-1: rates decrease quickly with time. Consequently, metallic ion contaminants from heat exchanger corrosion are only of interest at times immediately following the start-up of a heat exchanger system. Results from our calculations are given in Figure A-1 and Table A-1.

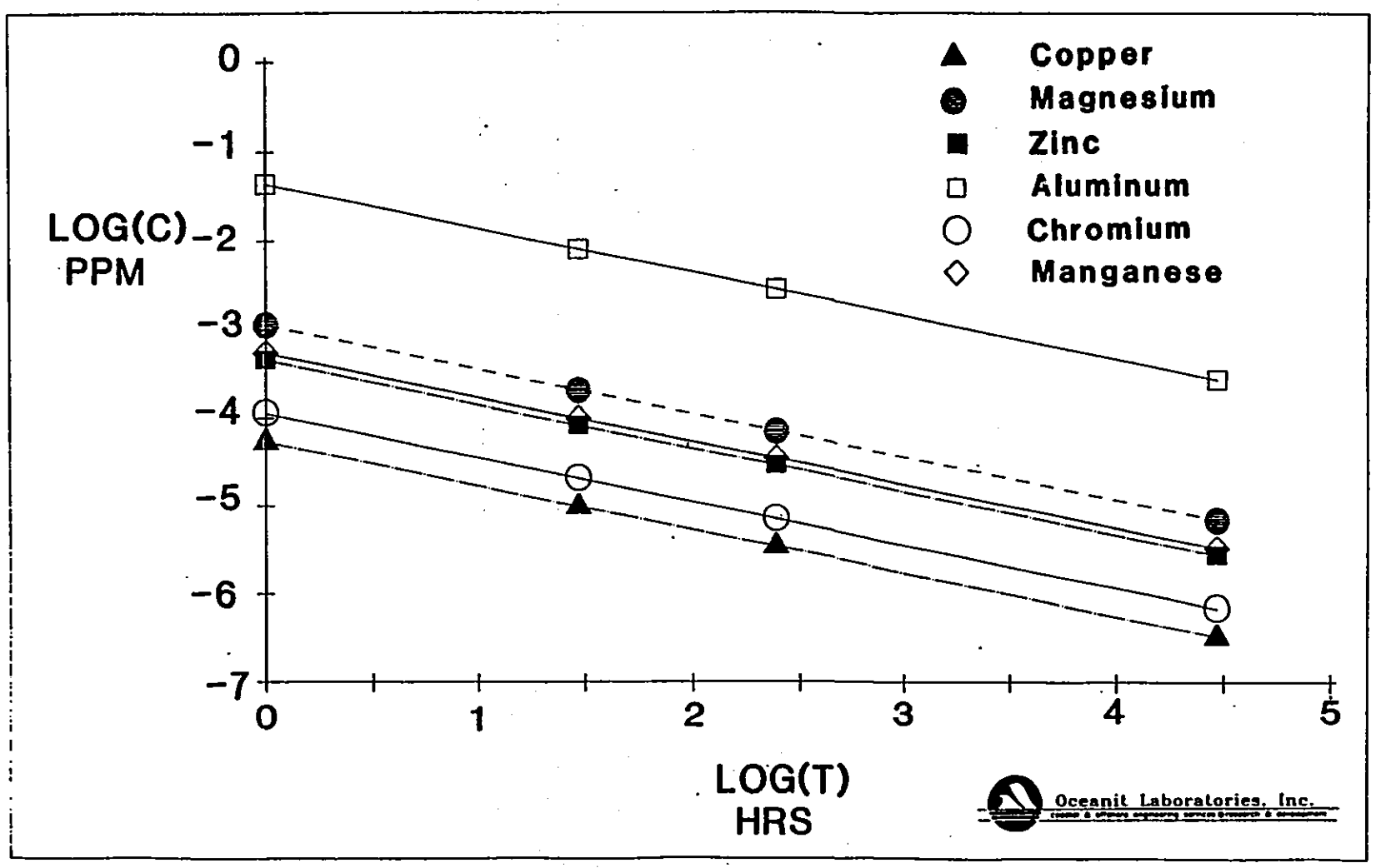

Fig. A-1 Metallic ion concentrations versus time for 200 meters of one-inch aluminum heat exchanger tubing. Calculations were made for warm seawater corrosion, assuming uniform attack, at flow rates of 8,000 gpm.

TABLE A-1

Calculated metallic ion concentrations in OTEC effluent from the corrosion of aluminum alloys 5052, 3003 and 7072

Time (min)	ppm Zn	ppm Al	ppm Mg	ppm Cr	ppm Mn	ppm Cu
1	.0004440	.0433835	.0011101	.0001110	.0005329	.0000533
5	.0001987	.0194108	.0004967	.0000497	.0002384	.0000238
10	.0001405	.0137303	.0003513	.0000351	.0001686	.0000169
15	.0001148	.0112137	.0002869	.0000287	.0001377	.0000138
22	.0000948	.0092623	.0002370	.0000237	.0001138	.0000114
30	.0000812	.0079341	.0002030	.0000203	.0000975	.0000097
60	.0000575	.0056150	.0001437	.0000144	.0000690	.0000069
90	.0000470	.0045877	.0001174	.0000117	.0000563	.0000056
180	.0000333	.0032488	.0000831	.0000083	.0000399	.0000040
250	.0000282	.0027592	.0000706	.0000071	.0000339	.0000034
500	.0000200	.0019558	.0000500	.0000050	.0000240	.0000024
1000	.0000142	.0013878	.0000355	.0000036	.0000170	.0000017
5000	.0000064	.0006297	.0000161	.0000016	.0000077	.0000008
10000	.0000046	.0004500	.0000115	.0000012	.0000055	.0000006
20000	.0000033	.0003230	.0000083	.0000008	.0000040	.0000004
30000	.0000027	.0002668	.0000068	.0000007	.0000033	.0000003

APPENDIX B

NUMERICAL MODELING OF DISCHARGE

After discharged water is introduced into a coastal area dispersion is governed by two processes: diffusion and advection. If the discharge were introduced into a stagnant water body, only diffusion due to concentration gradients would occur. In the case where we have motion and transport due to a current, we also have advection.

The advection process in a coastal area is controlled by longshore currents that are produced from wave action, ocean currents, wind stresses, etc.. The resulting currents change their magnitude and direction as a result of prevelent controlling factors. Thus, they are very difficult to predict. The only way to estimate their variability is to study a long series of data taken in the area. The second type of currents is due to the tides. Usually the flood and ebb tides are in opposite directions. Their strength can be estimated more accurately from short periods of measurement.

NEARFIELD PLUME

Immediately after the discharge is introduced into the ocean, mixing processes start to occur. The water is discharged with a particular injection velocity that ultimately dies down due to the mixing entrainment. The region where this velocity is depreciated to about 10 percent of the injection velocity is called the nearfield or the region of initial mixing. The nearfield plume depends on the density difference between the discharge and receiving waters as well as the velocities of discharge and receiving water, and the characteristics of the diffuser and its alignment.

FARFIELD PLUME

After the initial mixing, the particles are moved mainly by random motions due to turbulent diffusion and advection. The turbulent diffusion occurs in such a way that the standard deviation of the concentration of any discharge patch increases with the square root of the time. The relation is given by equation B-1.

$$o = SQR(2 * D * t) \qquad \text{Eqn. B-1}$$

where: o = standard deviation
D = turbulent diffusion coefficient
t = time

In advective diffusion the process is governed by the partial differential equation given by equation B-2.

$$\frac{dC}{dt} + \frac{d(u * C)}{dx} = D * \frac{d^2C}{dx^2} \qquad \text{Eqn. B-2}$$

where: C = concentration (ppm)

In the model used for our work the process of advection and diffusion were handled separately. Advection of the slugs of discharge were simulated by using estimated velocities for the location. Displacements of slugs were simulated as discrete processes. The onshore-offshore currents were simulated using a random number generator with zero mean and standard deviation corresponding to that of a noise assumed for the location.

Diffusion was calculated after the final positions of slugs were determined at the end of the time-stepping. Contributions to adjacent grid locations were calculated using a normal distribution with a mean at the grid location and standard deviation calculated as a function of the eddy diffusion coefficient and age of the slug.

The relationship proposed by Krock [18] was used to calculate the diffusion in nearshore waters as given by Equation B-3.

$$D = A * L^B \qquad \text{Eqn. B-3}$$

where: L = length scale
B = power factor = 1 for nearshore waters
A = Coef. = 0.003 for nearshore waters

ASSUMPTIONS

In order to simulate advection it is necessary to have real time data. In the absence of real time data, estimates of the longshore currents and tidal currents have to be used, as in the case of this study.

The longshore mean current was estimated at 0.33 feet/sec and the amplitude of the semidiurnal tidal currents was 0.44 feet/sec [25]. Results from work done by Noda [26] indicate that the currents at Keahole Point generally flow in the northern or southern direction.

The model was run for the following test cases:

1) sinusoidal tidal current with period 12.5 hours and amplitude 0.44 feet/sec superimposed on a longshore current of 0.33 feet/sec flowing away from the intake

2) similar combination as in case #1 except with the longshore current moving towards the intake

3) sinusoidal tidal current in the absence of any longshore current

Results indicate that the concentrations under conditions 1 and 2 are extremely low, on the order of $1X10^{-10}$ times the concentration of the water from the discharge. However, in the absence of a longshore current, the discharged plume crosses directly over the intake. (Illustrated in Figure B-1.) Concentration variations at the intake, assuming complete mixing over the total water column, were calculated; the results are given in Table B-1. Time was measured from the beginning of the ebb tide. The ebb tide current direction flows toward the intake from the discharge.

TABLE B-1

Concentrations at the warm water intake at NELH during an ebb tide without other currents.

Time (hrs)	Concentrations (ppm)
0	0
3	$1X10^{-15}$
6	$3.2X10^{-5}$
9	$4.9X10^{-3}$
12	$1X10^{-13}$
oo	$6.29X10^{-3}$

If these conditions prevail over several tidal cycles, the final concentration at the intake will reach a value of 6.29×10^{-3} times the discharge concentration. However, it is very unlikely that this unusual condition would occur for more than one or two tidal cycles.

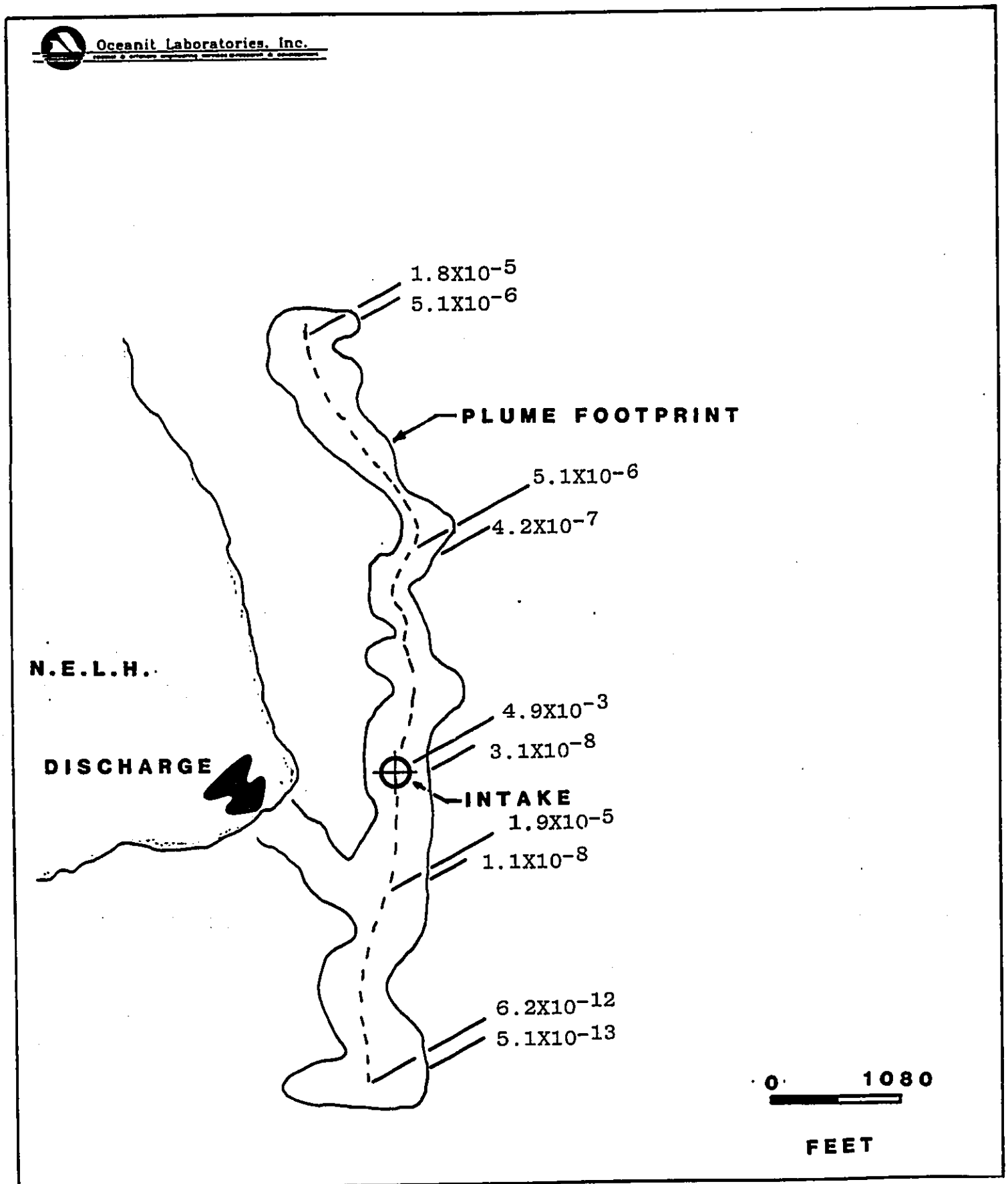

Fig. B-1 Plume footprint and concentration factors 9 hours after the beginning of an ebb tidal cycle, assuming a single point discharge of 16,000 gpm.

APPENDIX C

SEAWATER CHLORINATION

Reaction kinetics of chlorine in water are related to the organic carbon content of the water, .i.e, waters of high organic content produce more halocarbons than waters of lower organic content. Research at NELH has shown that 250,000 ppm in a closed experimental system will produce approximately 550 ppm bromoforms [12].

When chlorine oxidizes material in seawater many different compounds may result, e.g., $CHCl_3$ (chloroform), CHI_3, $CHCl_2Br$, $CHClBr_2$. When chlorine oxidizes ammonia it produces ammonia compounds, including [12]:

Monochloramine	NH_2Cl
Dichloramine	$NHCl_2$
Trichloramine (nitrogen trichloride)	NCl_3

There are also a variety of end products produced from ammonia oxidation by chlorine, including [10]:

Hydrazine	N_2H_4
Hydroxylamine	NH_2OH
Nitrogen	N_2
Nitrous Oxide	N_2O
Nitrite	NO_2
Nitrogen Tetroxide	N_2O_4
Nitrate	NO_3

Chlorination of marine waters can result in the production of halogenated organics. Some of these compounds show mutagenic, carcinogenic, and/or cytotoxic properties [13]. Chlorine used for controlling biofouling may adversely affect the local marine environment since chlorinated compounds are highly toxic, even at low concentrations. In addition, once chlorine is released to the environment, its toxic by-products could impact non-target organisms [9]. Experiments by Sansone [14] measured the disappearance rates of two classes of chlorine-produced oxidants (CPO's) that have also been studied using coastal waters from the continental United States. The first class is "free available oxidants" (FAO), the most toxic of the oxidants produced from seawater chlorination; they also provide the best anti-biofouling activity. In continental coastal seawater they disappear in seconds to minutes. These compounds include hypohalous acids and hypohalites. The second category includes "combined residual oxidants" (CRO) that are halogenated compounds produced from the decomposition of FAO's, found to display

long-term toxic effects on marine organisms. In the continental United States, CRO's disappear over the course of several thousand minutes.

Results indicate that because of the relatively low levels of biofouling found in an OTEC environment, i.e., found at NELH, lower levels of chlorine are required to maintain acceptable biofouling levels with respect to coastal continental waters. However, low biofouling levels also cause the reactive free oxidants to persist much longer in OTEC waters.

Past research indicated that the addition of 250 ppb of chlorine resulted in 0.081 ppb and 0.0021 ppb halocarbons in the warm surface and deep cold seawater, respectively. The low values were attributed to the very low organic carbon content of these waters with respect to coastal continental waters [14].

Based on work by Sansone [14] the halocarbon production from OTEC chlorination is unlikely to cause major environmental effects, particularly because of the rapid dilution of the discharge waters. The low levels of acetonitrile that would be produced through OTEC chlorination were not judged to be a serious environmental threat [15]. In addition, the formation of methyl halamines from OTEC chlorination are not expected to pose a significant environmental problem.

In order to give additional perspective to the issue of clorination, it should be pointed out that the maximum chloride concentration allowable in U.S. drinking water is 250 ppm [29]. An example of chloride concentration that may be familiar to those who have sampled the tap water in Orange County California (Water Factory 21) water is 120 ppm. Furthermore, the amount of residual chlorine typically found in sewage after treatment is approximately 1 ppm, providing a 98-99 percent reduction in bacterial populations [30]. These levels of chlorination are provided to give perspective to the 0.07 ppm (70 ppb) introduced insitu at NELH to control biofouling. The total chlorine residuals that are eventually discharged to the ocean are expected to be substantially less, e.g., 5 percent of initial chlorine level.

The effects of chlorination on aquatic biota are not necessarily the same as the effects of chlorination on people from use as a disinfectant in drinking water. Therefore, inferences on the effects of relatively small amounts of chlorine on the marine environment should not be easily rendered. Moreover, these numbers are provided so that general comparisons can be made.

APPENDIX B

IMPACTS OF OC OTEC AND MARICULTURE DISCHARGES FROM THE NATURAL ENERGY LABORATORY OF HAWAII ON THE NEARBY MARINE ENVIRONMENT

GK & ASSOCIATES

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GK & ASSOCIATES

October 13, 1986

SUMMARY

In comparison to ambient waters, open cycle (OC) OTEC discharges would be altered in some physicochemical parameters and would contain elevated concentrations of inorganic nutrients. The temperature of the discharged water would be between 19°C and 19.4°C (66.2-67°F). Dissolved oxygen concentrations could be significantly lower than ambient, and near zero if degassing is employed. Nitrogen concentrations would be significantly higher than ambient offshore concentrations due to the contribution of the deep water to the mixed discharge and to lysing of cells in the OC OTEC process. These concentrations would, however, be on the order of one half of the nitrate concentrations in groundwaters presently seeping into coastal waters. Any consequent impacts would not result from the concentrations themselves, but from the volume of discharged water which would elevate the total nitrogen flux to coastal waters. OC OTEC will not introduce supplemental concentrations of heavy metals, and chlorine additions are unlikely. Pretreatment requirements necessary to protect the marine environment appear to include only reaeration of degassed waters prior to discharge.

Of the optional methods and locations for disposal of the OTEC discharges, the most environmentally benign is deep injection, but co-disposal with mariculture effluents appears to be acceptable and less costly. Subsurface disposal would allow sedimentation, filtration, chemical precipitation, adsorption, decomposition and, with adequate residence time, natural die-off of any entrained pathogens. Discharges via either canal or very nearshore shallow trench have the greatest potential to elevate nearshore nutrient concentrations and thus have the most potential to stimulate the algal turf at the shoreline. Inhibition of grazers in the surge zone would tend to allow an accumulation of macroalgal biomass. This may be aesthetically undesirable. Trench discharges at greater distances from the shoreline will allow greater plume spreading prior to entry into the sea and therefore less concentrated nutrient supplements and a less obvious biostimulatory response from the primary producers. Canal disposal would allow warming, disinfection by UV light, decomposition and nutrient uptake.

Potential mariculture organisms for use at NELH include microalgae, macroalgae, mollusks, crustaceans, and finfish. Constituents of discharges from these operations may include inorganic nutrients, dissolved organics, particulate matter, and chemical additives

including selective toxicants, disinfectants, antibiotics/anti-parasitics and oxidants. Mariculture discharges would be disposed of into a trench some distance behind the shoreline. This trench would likely be filled with crushed lava to increase the available surface area for nitrifying bacteria and other in situ treatment processes. Trench disposal will serve to remove solids, precipitate some of the phosphorus and metals, allow decomposition to break down some of the organic material, and provide a matrix for bacterial action. Adsorption in a trench or in the substratum would be poor because of the lack of clays and organic soils in the area. Pretreatment requirements may include reaeration and possibly nutrient and process chemical removal. Mariculture at NELH will likely continue to focus on production technology, as mariculture designed for waste treatment is inefficient in terms of land use and may not be required as a mitigating measure. Culture of certain high-value algae may provide some economical nutrient stripping, but culture of higher organisms cannot be expected to provide a net improvement in discharge water quality.

PURPOSE AND SCOPE

The "Final Environmental Impact Statement for the Development Plan for the Hawaii Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaii" (HTDC, 1985) was based in part on the assumption that waters to be used in forthcoming OTEC experiments at NELH would be disposed of via a deep-ocean outfall to be funded by the U.S. Department of Energy. Federal budget cuts necessitated major revisions to this plan including elimination of the deep-ocean outfall in favor of less-costly, shore-based disposal options.

The action evaluated includes pumping as much as 60 mgd (42,000 gpm) of warm and cold ocean waters to shore for use in OC OTEC experimentation and mariculture research and demonstration. The maximum volumes of water to be disposed of are as follows:

- o OTEC--23 mgd (16,100 gpm--6,500 gpm cold, 9,600 gpm warm);
- o mariculture uses--37 mgd (25,900 gpm). For comparison, the maximum projected waste water volume anticipated from the adjacent HOST Park is about 100,000 gpm, of which it is estimated that about 80% would be warm water (HTDC, 1985).

Both NELH and HOST Park would gradually increase water usage over a period of years. Initial flow volumes would be on the order of 1,000 gpm for NELH (existing flow) and 6,000 to 6,800 gpm for the HOST Park.

The scenarios considered for disposal of NELH discharges include the following:

- o disposal of mariculture discharges into the ground via a shallow trench located along the NELH access road (this is the only option being considered for disposal of this fraction of the NELH discharge);

- co-disposal of mariculture and OTEC discharges into the ground via a shallow trench located along the NELH access road;
- disposal of OTEC discharges directly at the shoreline via a shallow, surface "canal" similar to that presently being used for NELH discharges;
- disposal of OTEC discharges into the ground via a shallow trench similar in design to the mariculture trench, but located seaward of the OC OTEC facility;
- disposal of OTEC discharges into the ground via deep injection wells located seaward of the present NELH facility.

The purposes of this report are as follows:

- supplement the marine biological impact assessment provided in the original EIS to include land-based disposal of OTEC discharges;
- describe and analyze the impacts of process chemicals which might be used in NELH mariculture operations;
- provide a conceptual description of potential pretreatment options available for use prior to disposal of mariculture discharges;
- update the previous cumulative impacts assessment in light of the large number of resort development projects being planned for nearby coastal areas.

SITE DESCRIPTION

The marine biological environment offshore of NELH/HOST Park was described for the original EIS (GK & Associates, 1985). Since then additional surveys in the area have been completed for neighboring projects.

Dollar (1986) carried out a qualitative marine biological reconnaissance survey of the area fronting the proposed O'oma II resort development immediately adjacent to and bounded on two sides by the HOST Park. His description of the area conforms with those previously summarized. The wave-washed intertidal platform has numerous tide pools where the seaweeds Ahnfeltia concinna and Ulva fasciata, encrusting red algae, sea urchins and juvenile fish are the most visible biota.

He identifies three offshore zones on the basis of substratum type, depth, physical conditions, and dominant coral species. A shallow, basaltic terrace extending from the shoreline to about 25 m offshore receives maximal wave energy. Pocillopora meandrina, a sturdy coral able to rapidly colonize new surfaces, is dominant. Seaward of the terrace is flat basaltic pavement, interspersed with lava extrusions and sand channels. The dominant coral is Porites lobata, found primarily as thick-lobed colonies. This zone extends offshore about

55 m into waters about 10 m deep, and is the zone of most active reef-building. Beyond this is an abrupt increase in slope where the substratum is dominated by unconsolidated rubble and sand. Here the dominant "finger coral," Porites compressa, forms dense thickets.

In addition to the corals, sea urchins and sea cucumbers are common on the reefs. Frondose benthic algae are notably rare, and those present, Turbinarea ornata, Padina spp., and varieties of encrusting red coralline algae for example, are hardy in structure.

Six categories of reef fish were found, including juveniles, planktivorous damselfishes, herbivores, rubble-dwelling fishes, swarming tetrodonts, and surge-zone fishes. The deep zone of finger coral harbored a high concentration of juvenile fishes. "Food fishes" were not abundant, but included parrotfishes, goatfishes, taape (Lutjanus kasmira - an introduced snapper), jacks and groupers. Butterfly fishes were relatively scarce, and Dollar attributes this to harvesting by aquarium fish collectors.

OPEN CYCLE OTEC WASTE DISCHARGE CONSIDERATIONS

The present action includes disposal of up to 16,100 gpm of water used in OC OTEC experiments. About 6,500 gpm of cold water would be mixed with about 9,600 gpm of warm water for disposal. The mixed water would be below ambient surface seawater levels of temperature, dissolved oxygen and pH, but contain higher concentrations of major plant nutrients. Using worst case data from the NELH water quality monitoring program, assuming the above proportions of warm and cold water, and assuming all parameters behave conservatively yields the following values: temperature -- 17.8°C (64°F); dissolved oxygen (in the absence of degassing) -- 3.98 ppm; pH -- 7.79 units; nitrate plus nitrite -- 17.1 µg-at/l; phosphate -- 1.48 µg-at/l; and, silicate --41.2 µg-at/l. Discharge concentrations would be modified by the OC OTEC process. Some warming will occur in the process. Noda (1985) estimates discharge temperatures of 19.0-19.4°C (66.2-67°F). Dissolved oxygen could be substantially lowered if one or both of the source water streams are degassed prior to use. Lysing of cells in the evaporator will increase the concentrations of dissolved nutrients over those given above.

The OC OTEC process selected for experimental work at NELH does not produce dissolved metal ions and would very likely not utilize chlorination because direct contact heat exchangers would be used (L. Lewis, DOE, pers. comm., Sep. 3, 1986).

MARICULTURE WASTE DISCHARGE CONSIDERATIONS

Potential components of discharges from OTEC-associated mariculture are summarized below using examples from representative species which have been identified as having some potential for mariculture at NELH. The major types of crops considered are microalgae, macroalgae, mollusks, crustaceans, and finfish.

Discharges from mariculture can be characterized by examination of solute levels resulting from continuous operation and from periodic manipulations to the system such as harvesting, cleaning or feeding which typically result in brief, low-volume, but concentrated, pulses of waste material. For example, Sparrow (1979) found that up to 25% of the wastes from typical salmonid hatcheries were generated in cleaning the tanks. Waste products of mariculture can be characterized as: organic wastes from crop metabolism and unused feeds, inorganic fertilizers, antibiotics and other disease treatments, chemicals used for maintenance of water quality or facility disinfection, and larvae or other propagules.

POTENTIAL SPECIES

MICROALGAE

Microalgae are grown in continuous or batch cultures. In many cases, water is recycled to preserve the chemical constituents of the medium. If so, the only discharge is from washing culture containers and equipment. Occasional, minor losses to the environment would also be expected from the harvest operation or periodic draindown of the raceways due to culture crashes or repairs. Such events may result in large volume discharges. If algae are grown as food for shellfish, they are generally transferred to the shellfish culture system from where effluents can be recycled or discharged.

Any water discharged from phytoplankton cultures would contain algal and bacterial cells, residual trace elements from the enrichment medium and elevated concentrations of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON), which are extracellular metabolites found in any dense algal culture.

Enrichment media are used primarily to maintain stock cultures of phytoplankton in the laboratory. The ingredients are expensive and generally other nutrient sources such as commercial fertilizers are used for large-scale cultures. The composition of enrichment media varies somewhat with species to be grown and the preferences of the grower. Two recipes of popular enrichment media for diatoms, naked flagellates and other eukaryotes such as Chaetoceras, Dunaliella, Tetraselmis and Pheodactylum are presented in Table 1. Spirulina and other blue-green algae are generally cultured in a slightly different medium, as presented in Table 2. During normal operation, cultures are maintained in light-limited conditions, making all of the constituents of the enrichment present in some concentration. However, the concentrations of ambient nutrient salts are maintained at very low levels in order to reduce contamination of cultures by competing species.

Small containers may be disinfected with chlorine, however, the amounts derived from algal cultures are not likely to be a significant fraction of the total chlorine usage of a mariculture facility.

Table 1. The compositions of F/2 (R.L. Guillard, 1959) and Laws' media (E.A. Laws, pers. comm. to D. Robichaux, 1986)

F/2 Medium

$NaNO_3$	0.88 mM	Na_4-EDTA	11.7 uM
NaH_2HPO_4	36.3 uM	$FeSO_4.7H_2O$	11.7 uM
$NaSiO_4$	0.1 mM	$CuSO_4$	0.04 uM
B12	0.5 ug/l	$ZnSO_4$	0.08 uM
Biotin	0.5 ug/l	$MnCl_2$	0.9 uM
Thiamine	100.0 ug/l	$NaMoO_4$	0.03 uM

Laws Medium

NH_3SO_4	0.1 g/l	F/2 trace metals
$(NH_3)^2PO_4$	0.2 g/l	
B12	0.5 ug/l	
Biotin	0.5 ug/l	
Thiamine	5.0 ug/l	
$NaHCO_3$	0.14 g/l	

Table 2. The composition of Zarrouk's medium for Spirulina.

$NaHCO_3$	16.8 g/l	H_3BO_3	3.0 mg/l
K_2HPO_4	0.5 g/l	$MnCl_2$	1.8 mg/l
$NaNO_3$	2.5 g/l	$ZnSO_4$	0.2 mg/l
$MgSO_4$	0.2 g/l	$CuSO_4$	0.08 mg/l
K_2SO_4	1.0 g/l	MoO_3	0.015 mg/l
NaCl	1.0 g/l	NH_4VO_3	0.023 mg/l
$CaCl_2$	0.04 g/l	K_2CrO_4	0.096 mg/l
$FeSO_4$	0.01 g/l	$NiSO_4$	0.048 mg/l
EDTA	0.08 g/l	$Ti(SO_4)_3$	0.04 mg/l
		$Co(NO_3)_2$	0.044 mg/l

MACROALGAE

Macroalgae are grown in continuous cultures which discharge water in proportion to the size of the tank or pond. In many cases, the discharge is regulated primarily to maintain the proper temperature rather than to limit discharge concentrations of nutrients.

Macroalgal culture media are generally less complex and less expensive than microalgal culture media because large quantities are required to fertilize continuous cultures.

Several species of macroalgae are currently produced at NELH. They are: Macrocystis pyrifera (giant kelp), Porphyra tenera (nori) and a mixture of species used for stripping inorganic ions from the present discharge. The precise methods for cultivation of Macrocystis are proprietary, and additives are unknown. The cultivation of nori requires no additional enrichment at the growout stage, and has some potential for use as a mitigating measure for discharge of inorganic

TABLE 3: Waste characterization of an oyster growout facility on Oahu (From Rothwell and Losordo, 1979).

Parameter	Influent[1]	Draindown[1]	Normal Effluent[2]		Cleaning and Harvesting Effluent[3]	
			Average	Range	Average	Range
Temperature (° C)	27.0	25.5	27.8	25.0-31.0	26.0	25.3-26.3
Salinity (‰)	31.2	25.8	30.7	29.5-32.0	27.4	25.1-31.5
Alkalinity*	145	--	141	130-152	137	133-141
pH	7.7	7.6	7.97	7.82-8.10	7.54	7.10-7.80
Dissolved oxygen**	3.1	6.6	7.0	6.6-7.4	6.0	4.3-7.2
Fecal coliform***	0.0	0.0	2.8	0.0-7.7	5.7	0.0-9.7
Total COD	3.5	20.0	7.5	4.1-16.0	29.1	24.0-32.9
Soluble COD	3.5	15.3	8.1	4.1-16.0	14.0	10.3-18.5
BOD_5	1 <	--	1 <	0-1.0	--	6.5
Suspended solids	3.4	14.0	1.1	0.7-2.3	70	15-130
Settleable solids (%)	n.a.	36	n.a.	n.a.	82.5	79-86
Volatile suspended solids (%)	n.a.	n.a.	n.a.	n.a.	24	21-28
Total Kjeldahl nitrogen	0.18	0.62	--	0.44	1.5	0.96-1.96
NH_4 - N	0.129	0.067	0.204	0.127-0.282	0.077	0.040-0.142
NO_2 - N	0.001	0.030	0.039	0.027-0.059	0.029	0.022-0.036
NO_3 - N	0.032	0.780	0.666	0.226-1.320	0.877	0.586-1.320
PO_4 - P	0.010	0.013	0.043	0.030-0.056	0.076	0.055-0.131
Chlorophyll a (mg/m^3)	--	0.68	--	0.03	2.26	0.84-3.68
Phaeopigments (mg/m^3)	--	1.28	--	0.05	3.22	1.31-5.13
Duration (hours)	continuous	0.33	--	continuous	4	4-6
Volume (liters)	545,000 ℓ/day	12,000	--	545,000/day	26,000	22,000-34,000

Notes:

* mg/ℓ as $CaCO_3$

** All values presented as mg/liter except where specified

*** Colonies/100 ml

1 Single sample

2 Four samples

3 Three samples

nitrogen and phosphorus, if such a measure were desirable. Research is ongoing to determine depth, flow and harvest manipulations necessary for optimization of nutrient stripping in shallow channels. Nutrient stripping rates of up to 1.2 g-N/m^2/day and up to 0.67 g-P/m^2/day are reported from initial data at NELH (Robichaux, unpublished). Other species of macroalgae with potential for growth in OTEC effluents could provide a net improvement to water quality by increasing dissolved oxygen, and reducing inorganic nitrogen, phosphorus, and trace metals concentrations.

Occasionally, macroalgal culture tanks or raceways would be emptied and scrubbed with chlorine to disinfect them. This would result in discharges of chlorine and chlorine produced oxidants to the waste stream. Recommended concentrations for short term disinfection are 1000-2000 ppm, but in normal washdown operations these would be diluted greatly prior to release into the disposal system.

MOLLUSKS

Marine mollusks which are, or have been, cultured in OTEC discharges at NELH are abalone (Haliotis sp.), oysters (Crassostrea, Ostrea), clams (Tapes, Mercinaria, Tridacna), and opihi (Celana sp.). Bivalve mollusks are filter feeders and as such effective at removing suspended particulate material such as phytoplankton, detritus and inorganic carbonate precipitates. Much of the material filtered is redeposited as feces or pseudofeces which would be flushed into the effluent stream periodically. Wastewater from an existing oyster growout facility was characterized by Rothwell and Losordo (1979). Data from this facility are presented in Table 3.

Potential chemical additives to mollusk cultures include antibacterial and antifungal agents, especially at the hatchery stage. These would generally be added only as necessary, and in relatively small quantities. Copper sulfate or one of the latter generation copper compounds may be used as selective toxicants to fouling filamentous algae in oyster tanks. These compounds would not be added to other cultures of mollusks as filter feeders would concentrate the copper adsorbed on particulate matter, and grazing mollusks such as abalone and opihi utilize filamentous algae as feed. Isopods and other parasites have been reported to infest oysters grown in dense cultures and natural waters. We are not aware of any effective chemical for treatment of these endoparasites; however, if there is a chemical treatment the nature of the chemical should be investigated prior to its introduction into the discharge system, as it may significantly impact the resident epifauna in the discharge trench.

CRUSTACEANS

Potential species of crustaceans for cultivation at NELH are shrimp (Penaeus) lobster (Homarus, Panulirus) and brine shrimp (Artemia). Of these species, Artemia is the only filter feeder. Artemia cultures would utilize phytoplankton or other particulate organic feeds which would subsequently be discharged intact or as wastes. Artemia also

produce extremely durable cysts under some circumstances, but their escape would only provide food for resident fish species.

Both shrimp and lobster are omnivorous and require high protein feeds for adequate nutrition in cultivation. Their metabolic wastes, uneaten feeds and residuals of various chemical treatments would appear in the discharge stream. The identities of all potential chemicals which might be used in crustacean cultures at NELH are not known; however, the waste stream from an existing shrimp culture enterprise was characterized by AECOS, Inc. (1982) (Table 4). The discharge in that case is an order of magnitude lower in nutrients than that of a typical Oahu secondary sewage treatment plant discharge. With filtration, the shrimp discharge would be comparable to that of a tertiary STP.

In addition to the parameters shown in Table 4, the discharge permit for this operation includes provisions for regular additions of formalin and a chelated copper compound which act as in situ antibacterial and antifouling agents, respectively. Formalin was expected to appear in the effluent at a concentration of 7.1 ppm for approximately 50 hours per week. Similarly, the copper compound (Cutrine-plus) was reportedly used at concentrations of 4-6 ppm in tanks; resulting in effluent concentrations of 0.3 ppm for periods of 10 hrs per day. Additional chemical wastes may be generated in cleaning tanks with chlorine or other disinfectants.

FINFISH

Potential species of finfish for cultivation at NELH are primarily carnivorous or omnivorous. Techniques which have been developed at NELH (Katase, et al. 1985) for coho salmon, steelhead trout, and rainbow trout utilized flow-through culture systems with regulated feeding of formulated feeds. Discharges from these tanks could be expected to have elevated levels of ammonia, nitrate and phosphate, and reduced levels of dissolved oxygen. Tanks were periodically drained and cleaned with chlorine. Larger scale finfish culture may utilize in situ antifouling techniques such as additions of copper sulfate, or chelated copper in order to reduce labor costs in manually cleaning these tanks.

Ectoparasites have been reported in many fish culture operations. Most fish culturists rely on antiparasitic agents which are added at intervals designed to prevent the target species from completing its life cycle.

CHEMICAL ADDITIVES

The following is a partial list of chemicals in popular use among mariculturists. It is by no means comprehensive; however, many of the chemicals not found in the following list are similar or identical to those presented below. The microalgal culture media described above are not reproduced here.

TABLE 4 - A SUMMARY OF WATER QUALITY INFORMATION RELEVANT TO THE PROPOSED SHRIMP OPERATION

	Nitrate-Nitrite	Ammonium	Total Nitrogen	Ortho-Phospate	Total Phosphorous	Chl a	Turbidity	Non-filterable Residues	BOD
	(----------ug/l					----------)	(--NTU--)	(-------mg/l	----------
State Water Quality Standards Open Coastal Waters (geometric means)									
wet period	5.0	3.5	150	7.0	20.0	0.30	0.50	20.0	
dry period	3.5	2.0	110	5.0	16.0	0.15	0.20	10.0	
Geometric means of site survey dry season	3.4	3.2	220*	1.9	7.4	0.03	0.75*	1.6	
Combined Effluent Characteristics of proposed shrimp operation (arithmetic means)	388	1278	2646	148	395		14.9	11.9	5.5
Primary STP (1,2)			24,000		8,000		6.6	86	67
Secondary STP (2,3)			17,000		7,000		5.4	37	20
Tertiary STP (4)			100-1,000		2,000		0.5	1	1

1. Pearl City Primary Treatment Plant (Young and Chau, 1970).
2. Average of 8 STP's on Oahu (Young and Chau, 1970).
3. Gakstatter, et al., 1978.
4. Eckenfelder, 1970.

* greater than not to exceed value more than 10% of the time - State Water Quality Standards

Aquatic Herbicides/Selective Toxicants

Aquathol-K (oxabicycloheptane-dicarboxylic acid): A contact weed killer for use on submerged aquatic vegetation along pond margins, also toxic to phytoplankton. Used in concentrations around 100 ppm. Limited potential application at NELH.

Copper Control/Cutrine-Plus (Copper-triethanolamine-diethanolamine complex): Control of filamentous and planktonic algae. Chelated copper used in concentrations of up to 1.0 ppm. Periodicity ranges from several times per year in stagnant ponds to daily in high intensity raceways. Average concentration in current high-tech shrimp culture is slightly over 1 ppm on an annual basis. Potential use in crustacean and finfish culture at NELH.

Copper sulfate: Traditionally used as an algecide in fresh water and to a limited extent in marine waters in concentrations up to 10 ppm. Limited application at NELH.

Diquat (1,1-ethylene-2,2-bipyridylium dibromide cation): A commonly used herbicide lethal to most vascular aquatic plants such as duckweed, hydrilla and water hyacinth. Limited application at NELH.

Fintrol (Antimycin A): Toxic to fish in concentrations of 5-20 ppb. Is used for nonselective irradication of fish from ponds and lakes. Limited application at NELH, except perhaps as part of an anchialine pond restoration program.

Rotenone: Toxic to fish at concentrations of 0.2-20 ppm. Is used for nonselective irradication of fish from ponds and lakes. Limited application at NELH, except perhaps as part of an anchialine pond restoration program.

Disinfectants

Argentyne (Polyvinylpyrrolidone-iodine, 10%): Time release iodine for disinfection of eggs suspended in hatchery tanks. Used as a 100 ppm solution for short periods during hatchery operations. Total amounts depend on hatchery size and frequency of the hatchery cycles.

Benzalkonium Chloride (N-alkyl quaternary amines): Disinfectant for tanks and other hard surfaces. Used as a 1-2% solution as necessary for cleaning equipment.

Chlorine (Sodium or calcium hypochlorite): The most widely used disinfectant for hard surfaces, equipment and tanks. Used as 200-1000 ppm solutions as necessary.

Antibiotics/Antiparasitics

Antibiotics: Many of the traditional antibiotics (Erythromycin, Neomycin, Penicillin, Sulfamerazine) are used to reduce bacterial contamination in phytoplankton stock cultures or as treatment for

culture animals. Due to the expense, these chemicals are not generally used in large quantities. One popular antibiotic, Chloramphenicol, has been restricted, and is no longer sold over the counter in the United States.

Chloramine-T (Sodium para-toluene-sulfonchloramide): Chlorine-based treatment for bacterial gill disease in salmonids and other finfish. Concentrations of 6-10 ppm not more than 1/day.

Formaldehyde: The universal bacteriocide. Used for in situ disinfection of fish and shrimp, and preservation of specimens. Concentrations of 5-50 ppm are used for short intervals in culture water. Average additions for operational shrimp culture facilities are 2 ppm in the effluent stream on an annual basis.

Malachite Green: Traditionally used in conjunction with formalin as antiparasitic, antibacterial, and antifungal agent. Concentrations of 0.05-0.1 ppm are effective. Regulations restrict its use in the the United States due to its resistance to natural degradation.

Potassium Permanganate: Used in concentrations of 1-5 ppm to relieve oxygen shortage, rotenone detoxification, removal of organic contaminants, and bacterial/parasitic control.

Prefuran/Furance/P 7138 (Nifurpirinol) A general treatment for bacterial, fungal and parasitic infections. Used either as treatment of known infections (1-2 ppm), or as a prophylactic (0.05-0.1 ppm).

Trichlorfon/Masoten/Dylox/Dipterex/Chlorofos/Metrifonate/Neguvon (Dimethyl-trichloro-hydroxyethyl) phosphonate: Used commonly for treatment of ectoparasites such as anchorworm, flukes or isopods. Concentration is roughly 0.25 ppm; treatment no more frequently than once per week.

New chemicals will undoubtedly be added to this list in the future. Each of these chemicals is toxic to some organisms at some concentrations, and each mariculture operation should be required to demonstrate that its chemical additives and patterns of usage would not detrimentally effect other mariculturists, the OTEC experiments, the treatment system, the anchialine ponds or offshore ecosystems. Surveilance and monitoring are recommended.

MARICULTURE AND TRADITIONAL METHODS FOR EFFLUENT PRETREATMENT

The use of aquaculture systems for waste water treatment has received increasing attention in recent years. The level of technology studied has varied from essentially unmanaged, natural wetlands to highly managed raceways. Numerous plant and animal species have been examined in this context, although the bulk of the work to date has been with freshwater systems.

Both natural and constructed wetland systems have been used to further treat secondary sewage effluents, with removal percentages for BOD_5, suspended solids, nitrogen and phosphorus up to about 90% (Reed, et

al., 1979). These systems, however, do not provide the opportunity for process control and require relatively large land areas, i.e., on the order of 20-60 acres per million gallons of waste water applied.

Basic waste water treatment pond technology has been modified for use with free-floating aquatic plants, particularly water hyacinth and duckweed. Again, treatment efficiencies can be high, but land requirements are also high, i.e., on the order of 5-15 acres per million gallons of wastewater applied, depending on the treatment goal. These systems have been found to be generally uneconomical because of the necessity to harvest and dispose of up to 50 dry tons of plant biomass per acre per year (Reed, et al., 1979).

Aquaculture of plants and animals, principally fish, has been combined with traditional waste water technology in successful sewage treatment systems, although systems using higher forms of animals are reported to be less efficient, require more land, and are more difficult to manage than those using plants only. Additionally, these systems cannot generally be optimized for both treatment efficiency and protein production.

A pilot-scale marine polyculture system for removal of nitrogen from secondary effluents was tested at Woods Hole (Ryther, 1975). Effluents were diluted with seawater and sequentially passed through phytoplankton ponds, shellfish raceways, and macroalgal production units. The overall nitrogen removal efficiency was 89%, but the shellfish production unit was not successful and it appeared that comparable treatment could be accomplished with only the macroalgal unit.

Kawasaki, et al. (1982), created laboratory-scale artificial food chains to recycle dissolved nutrients in secondarily treated domestic waste waters. Sequential monocultures of a unicellular green algae, an herbivorous cladoceran crustacean, an herbivorous or carnivorous teleost fish, and a filamentous green algae were employed. Virtually all nutrient removal was found to occur in the first stage.

To devise a treatment system for NELH effluents it is first necessary to define the goals of treatment in terms of what "pollutants" are to be removed. Table 5 summarizes the primary contaminants of concern in the NELH effluents.

Table 5. Contaminants of concern in NELH effluents

Contaminant	Reason for Concern
Suspended solids	May lead to clogging of the disposal trench or injection wells. Offshore disposal via canal may adversely affect corals by sedimentation and algae by increased turbidity.
Biodegradable organics	Consist principally of proteins, carbohydrates, and fats. Measured as BOD or COD. In very high concentrations, oxidation in the environment may deplete natural oxygen resources.
Pathogens	Bacteria and viruses may affect resident species.
Nutrients	Carbon, nitrogen, phosphorus, and trace elements are essential for growth. High concentrations may cause biostimulation. Very high concentrations may be toxic.
Heavy metals	May be toxic in relatively low concentrations, may accumulate biologically and on adsorptive surfaces.
Aquaculture additives	Those most likely to be used at NELH include copper-based selective toxicants, iodine and chlorine-based disinfectants, antibiotics, and formaldehyde.
Refractory organics	May be toxic in relatively low concentrations, may accumulate in the environment, biologically and on adsorptive surfaces, and may decay slowly. Examples include surfactants, phenols and pesticides.

(After Tchobanoglous, et al. (1979))

Mariculture-based treatments could provide mitigating influences on suspended solids, heavy metals and nutrients, but except for the possibility of culturing certain high-value algae, appear uneconomical.

OTHER TREATMENT TECHNOLOGIES

PHYSICAL

Sedimentation--Removes settleable solids, some colloidal solids and incidentially reduces BOD, nutrients, heavy metals, refractory organics, and pathogens. Will occur naturally in trenches and injection wells.

Filtration--Mechanical removal of particulates. Will occur in trenches and injection wells. Often the filter medium provides a substrate for bacterial growth and associated biological treatment. Lava slag (1-2 mm diameter) has been used successfully as a percolating filter to treat aquaculture discharges prior to reuse in fish culture (Naegel, 1979). Filling the disposal trench with crushed lava would increase mechanical and biological filtration.

Air Stripping--This physicochemical process works best at a pH above 10. Ammonium ions are converted to gaseous ammonia and vented to the atmosphere.

Adsorption--Colloidal solids removed by interparticle attractive force (van der Waals force). Will occur in trench and in injection wells, but is a reversible process unless particles are removed.

Others--Dilution, distillation, heating, freezing, UV irradiation. Dilution will be particularly important for NELH discharges.

CHEMICAL

Precipitation--Effective removal of phosphorus and heavy metals by formation of or co-precipitation with insoluble compounds. Phosphorus precipitation is most efficient at high pH ($>$ 10), but will occur to some extent in disposal trench and injection wells.

Adsorption--Effective removal of phosphorus and heavy metals, less effective removal of refractory organics by attachment to substrate or plant surfaces. For tertiary treatment of municipal waste water, adsorption onto activated carbon is most commonly used. Contact times of 25-35 minutes are optimal for fixed-bed adsorption of biological and chemical secondary effluents, respectively (Chow and David, 1978). Activated carbon treatment can remove chlorine and chloramines, but efficacy in seawater matrix is problematic.

Ion Exchange--Numerous resins are available for energy-efficient, large-scale separation processes, however, their use in a seawater matrix may result in rapid breakthrough times.

Zeolitic Molecular Sieves--These porous, crystalline aluminosilicates are widely used for adsorption separation processes. More than thirty natural zeolites and over 100 synthetic varieties are used to selectively exchange cations. Clinoptilotite, a natural mineral, is widely used for ammonia removal. Many others exhibit selectivities for

various nonferrous metal cations, including copper, nickel, cadmium and zinc (Sherman, 1978). Potential uses at NELH would include ammonia and heavy metals stripping, but aluminum would not be taken up and for most zeolites, major ions in seawater would be selectively taken up before ammonium. Seawater or a salt solution is used to recharge zeolites.

Ozonisation--Treatment with the powerful oxidant, ozone, splits even refractory organic compounds. Acts to sterilize a fluid, but residual ozone is highly toxic, and its production is not energy-efficient.

Decomposition--Primary effects on refractory organics and pathogens. Chemical decomposition or alteration of less stable compounds by phenomena such as UV irradiation, oxidation, and reduction. Will occur in trench and in injection wells.

Disinfection/Sterilization--Chlorine compounds are most commonly used. Oxidants such as iodine and bromine compounds, hydrogen peroxide and potassium permanganate are sometimes employed. Surface active chemicals are also used.

Others--Dialysis, reverse osmosis, solvent extraction, coagulation.

BIOLOGICAL

Bacterial Metabolism--Effective treatment of colloidal solids, BOD, nitrogen, and refractory organics. Will occur in trench and in injection wells. Heterotrophic bacteria can enzymatically deaminate food remnants, urine and feces into ammonium. Autotrophic bacteria (nitrifiers) convert ammonium into nitrate using oxygen and carbon dioxide. Under anaerobic conditions, denitrification, production of gaseous nitrogen from nitrite and nitrate, proceeds with utilization of organic carbon sources (Naegel, 1979). Activated sludge treatment employs, in sequence, a highly aerated nitrification basin, a settling basin, and a denitrification basin. Immersion elements, also called rotating biological contactors (RBCs), provide greatly enhanced surface area for nitrification. To maintain highly aerobic conditions, liquid oxygen is sometimes injected.

Plant Metabolism--Dissolved organics may be taken up by plants. Some extracellular metabolites may be toxic to pathogens.

Plant Absorption--Nutrients, metals and organics are taken up.

Natural Die-Off--Sufficient time in an unfavorable environment will destroy pathogens. Will occur where residence time in the ground is sufficient, such as in the mariculture disposal trench or the injection wells.

Many of these treatments will naturally occur in the disposal systems being evaluated. Canal disposal of OTEC discharges would include treatment by plant metabolism and absorption, decomposition and disinfection by UV light. Disposal into the ground would result in

sedimentation, filtration, chemical reactions, decomposition and natural die-off of pathogens.

FATE OF DISCHARGES TO A CANAL, TRENCH OR INJECTION WELL

In the event a canal is chosen for disposal of OTEC waters, uptake of solutes by aquatic vegetation would provide some waste treatment. Approximately five species of marine algae dominate discharge streams now existing at Keahole Point. These communities are capable of removing inorganic nitrogen and phosphorus at rates of 1.2 $g/m^2/day$ and 0.67 $g/m^2/day$ respectively (Robichaux unpublished). Roughly 20% of the inorganic material absorbed is transformed into dissolved organic nitrogen and phosphorus which is released back into the discharge stream.

In addition, algae in the canal remove CO_2 at rates of over 26 $g/m^2/day$. Trace metals such as iron, copper and zinc are absorbed at rates in the range of 1-10 $micrograms/m^2/day$, when concentrations are non-toxic.

Commercially valuable algae such as nori, (Porphyra sp.) or ogo (Gracilaria sp.) could be produced in the discharge for the dual purpose of treating waste and reclaiming some of the expense of waste treatment. Strong recommendations for further investigation of this potential have come from researchers and commercial seaweed growers who are familiar with the NELH facility, but the trade-off between land area and efficiency of nutrient stripping needs more research and economic evaluation.

Disposal of OTEC waters through a nearshore trench would create a subsurface plume, 67% of which would discharge over a distance of 600 feet along the shoreline at an average rate of 26,000 gpd/foot (Dames and Moore, 1986). The Dames and Moore model assumed that this plume would intersect the bottom at depths between 0 and -50 feet. Discharge rates would average 26 gpd/ft^2 with a maximum of 72 gpd/ft^2. Minimum residence times would be less than a day.

Disposal of mariculture waters into a trench set back 750 feet or more from the shoreline would create a plume extending from 0 to -200 feet. Eighty-five percent of this discharge would occur along 4,300 feet of the shoreline, with flows averaging 7,300 gpd/foot. Flux through the bottom would average 1.9 gpd/ft^2, with maximum values of about 4.2 gpd/ft^2. The residence time would be 1-2 months.

If OTEC discharges are co-disposed of in the mariculture trench, 77% of the discharge would occur over 3,800 feet of shoreline (12,200 gpd/foot). If the flow remained between 0 and -200 feet, flux through the bottom would average 3.2 gpd/ft^2, with maximum values of about 5.9 gpd/ft^2. Residence times would decrease to between 18 and 38 days.

Using the uptake data from the canal, an uncovered, unfilled disposal trench 10' X 100' (93 m^2) would remove 111 g-nitrogen and 62 g-phosphorus daily, with 20% being re-released. With this design, less

than 5% of the inorganic nutrient load would be removed under the best conditions. Nutrient removal by algae in a disposal trench will not be an efficient treatment strategy. More treatment would result from filling a trench with crushed lava and allowing bacterial decomposition, sedimentation and filtration to occur.

Adsorption of chemical solutes in a trench at NELH will be poor due to the lack of clays or organic soils. Tasato and Dugan (1980) report limited adsorption of nitrogen and phosphate compounds in volcanic cinder and carbonate sand. Their study used volcanic soils of the Tantalus series which are much older and more oxidized than those at Keahole Point. Without further study it must be assumed that the adsorption of chemical solutes will be insignificant in the proposed trench.

The natural groundwater lens beneath Keahole Point occurs as an unconsolidated lens of brackish (5ppt) water roughly 125 feet thick and has a flow rate averaging 2-5 mgd/mile. The volume of water disposed of in the trench will be either 37 mgd or, if OTEC wastewaters are disposed of there, 60 mgd. In either case, dilution of the discharge by groundwater will be insignificant. The aquifer surrounding Keahole Point is expected to experience reduced temperatures, increased salinity, and increased solute concentrations. The natural quality of the aquifer renders it unsuitable for municipal or agriculture uses. Impacts resulting from these changes include potential alteration of the anchialine ponds in the area if the plumes reach them, and potential offshore impacts.

After entering the aquifer, the rate of adsorption and oxidation of organic chemicals and metabolites is considerably slowed. Inorganic ions in the discharge, including ammonia, will pass through the ground relatively unaffected due to the short residence time (less than 62 days) and lack of soils or clays in the Keahole Point region.

Ishizaki, Burbank, and Lau, (1967) studied the fate of soluble organics in sewage flowing through thin cracks in basaltic lavas. They found that the primary effect was clogging of the cracks by bacteria and their extracellular metabolic products. Little or no treatment was observed on biochemical oxygen demand (BOD), organic carbon, ammonium, or other standard parameters of waste treatment. The poor waste treatment capacity of the lavas is due in part to their low surface area, and suggests that clogging of the disposal trench (or injection wells) is possible. If the trench were filled with crushed lava, its waste treatment capacity would increase and it could be excavated and refilled if clogging occurred. Organic material entering the disposal trench system will be remineralized to end products which depend largely on the amount of available oxygen. Under aerobic conditions, carbohydrates and proteins are oxidized to CO_2, H_2O, NO_3, SO_4, and microbial cell tissue. In the absence of oxygen, the same inputs become reduced end products such as methane, hydrogen, ammonium, hydrogen sulfide, and a variety of intermediate products such as organic acids, alcohols, amines and mercaptans. It is likely that the proposed disposal trench will be predominantly aerobic; however,

pockets of particulate accumulation may provide reducing environments which allow denitrification of nitrates and nitrites to ammonia, nitrogen gas or nitrous oxide.

Of the metals which may be present in the mariculture discharge, copper is the element which requires closest monitoring. At levels in the range of 1-10 ppb copper is an essential plant nutrient; however, in concentrations of 0.5 ppm and over it becomes extremely toxic (Table 5), and is commonly used as an herbicide. Management of the disposal system to provide treatment of mariculture effluents requires that copper concentrations in the effluent be maintained below toxic levels. Data from an operational shrimp farm on Oahu show copper concentrations appearing in the effluent average 0.016 - 0.02 ppm inside the effluent ditch, with maximum reported values of 0.03 ppm. Short exposure to concentrations in this range should not be detrimental to algae or bacteria.

Table 5. Lethal concentrations of copper as copper-triethanolamine (Cutrine-plus)

Blue-Green algae	0.2 ppm	Argent (1986)
Phytoplankton	0.2-0.5 ppm	"
Filamentous algae	0.5-1.0 ppm	"
Ulva, Gracilaria	1.0 ppm	"
Small fish	0.2 ppm	Skea & Simonin, 1979

Precipitation of various chemicals is promoted in the presence of multivalent cations such as calcium, barium, strontium, magnesium, iron, aluminum, cadmium, zinc, manganese, and chromium and other metals which can form insoluble precipitates with carbonates, sulfates, phosphates, florides and hydroxides. Deep sea water is supersaturated with respect to calcium carbonate and other dissolved minerals. Addition of cations and warming of the effluent favors precipitation of these minerals which may contribute to clogging of a trench or injection well. These reactions occur slowly under natural conditions; however, high flow and changes in temperature may result in accumulation of inorganic precipitates in quantities sufficient to slow the rate of infiltration.

Disposal of OTEC waters by deep (300 feet) injection wells would create a subsurface plume confined to depths between -300 and -400 feet. Eighty-five percent of this discharge would occur over a distance of 30,000 feet, averaging 660 gpd/foot. The average discharge rate would be 1.2 gpd/ft^2, and the maximum rate would be 2.9 gpd/ft^2. A minimum residence time of about three months was calculated (Dames and Moore, 1986). An injection well system would provide the least amount of in situ treatment of the disposal options under consideration. Active mechanisms would include filtration and precipitation. Clogging is distinctly possible, and has occurred in smaller, shallower wells used by HAF. Adsorption and oxidation would not provide significant in situ treatment.

Dames and Moore, Inc. noted the probable occurrence of lava tubes and other zones of high permeability in the subsurface geology. If lava tubes are present in close proximity to the disposal trench or to the injection well, discharges may have a hydrologic residence time considerably less than expected, and discharges passing into the receiving waters will be more concentrated than expected. If no direct channels are encountered, the lava structure is expected to provide a matrix for accumulation of bacterial biomass which would allow limited biological treatment.

FATE OF MARICULTURE WASTES IN SEAWATER

Chlorine

Chlorine is the most widely used disinfectant and cleaning agent currently in use in aquaculture. The product is marketed as liquid or dry sodium or potassium hypochlorite.

Chlorine additions to the waste stream are expected to be periodic at any specific location, however, as the disposal trench is designed to service multiple facilities, it is conceivable that some chlorine will enter the stream on a nearly constant basis. Data reported by Epply, et al. (1976) indicate free chlorine and chlorine produced residuals are toxic to marine phytoplankton in the range of 0.01-0.1 ppm in seawater. Figure 1 shows the depression of photosynthesis as a function of chlorine concentration.

When added to seawater, chlorine reacts with ammonium, other nitrogen forms, halogens, and dissolved or particulate organic material, collectively referred to as the chlorine demand of a water mass. These precursors are oxidized to form chloramine, bromamine, bromoform, and a wide variety of halocarbons, some of which have been identified as dangerous in drinking water. The disappearance of reactive chlorine has been examined at NELH by Sansone and Kearney (1985). Due to the paucity of dissolved organic carbon (DOC) in oligotrophic waters, the rate of chlorine disappearance, as measured by the accumulation of halocarbon residuals, is considerably reduced.

In estuarine waters, Crane, et al. (1980) reported the deactivation of chlorine concentrations of 5 mg/l to be complete within 30 min. of its release, while in both surface and deep waters from Keahole Point this reaction was not complete after 30,000 to 40,000 min. (21-28 days) (Figure 2).

The chlorine demand of tropical seawater is considerably lower than would be expected for mariculture discharges which presumably have high organic loads. If the free oxidants are dissipated within the tanks and supply trenches, there seems to be little cause for restriction of their disposal; however, if the addition of chlorine exceeds the demand of the receiving waters in the trench, the existing literature suggests that the natural waters surrounding Keahole point will provide little in situ treatment capacity. Rough calculation of the chlorine demand of particular discharges can prevent excessive discharge of free

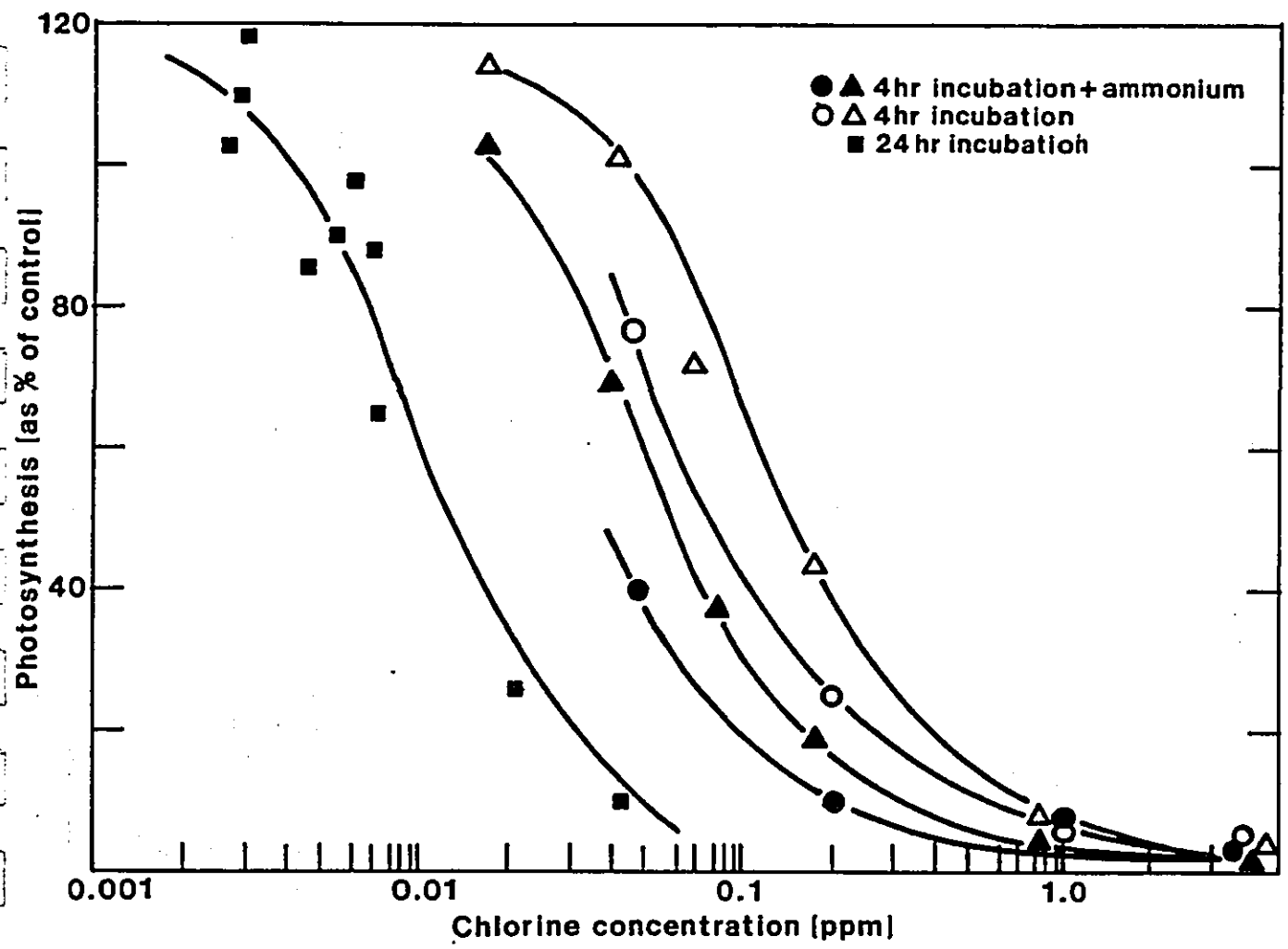


Figure 1. Inhibition by chlorine of photosynthetic carbon assimilation by natural assemblages of marine phytoplankton. Data from several experiments on different days.

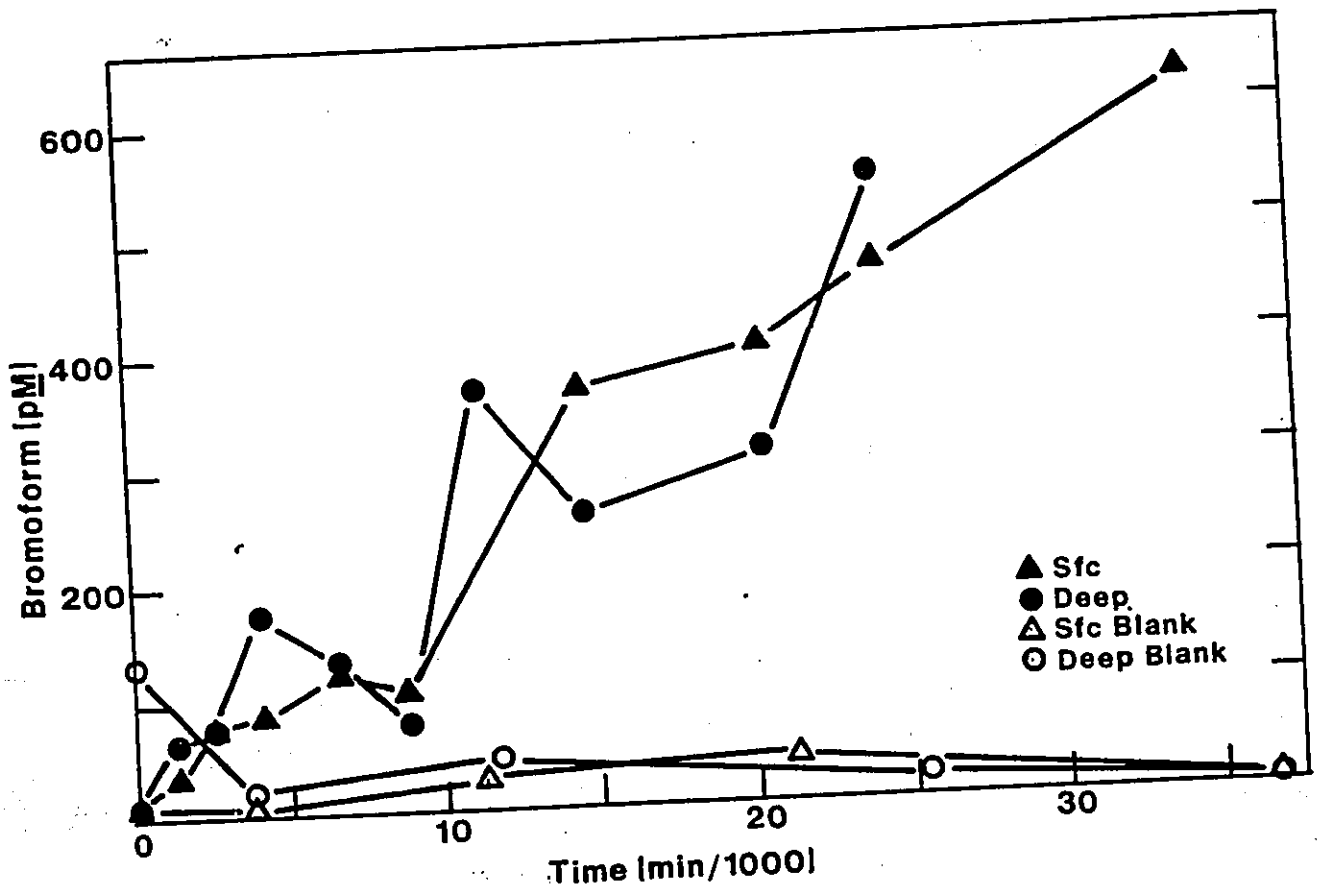


Figure 2. Time variation of bromoform in chlorinated and nonchlorinated [Blank] surface [Sfc] and deep NELH seawater.

oxidants and save money in operating expenses. Periodic monitoring of chlorine residuals at various points in the system is recommended.

Formaldehyde

When used as an antibiotic alone or in conjunction with other theraputic agents, formalin (dilute formaldehyde) has been shown to be effective at reducing bacterial, fungal and parasitic infections at concentrations of up to 250 ppm (Hinton and Eversole, 1980). Thresholds for inhibition of cell division in microalgae, bacteria, and protozoans are in the range of 0.4-25 ppm. LD50 concentrations for rainbow trout eggs and fingerlings are roughly 500 ppm and 100 ppm respectively.

Biological degradation of formalin occurs with or without oxygen to end products of CO_2 and H_2O. This breakdown, measured as standard BOD, shows only 40% activity after 5 days. Residence in the substratum should be sufficiently long to insure its complete oxidation prior to reentering the source waters. Wastewater treatment methods for formalin include adsorption on activated charcoal (adsorbability: 0.018 g/g-Carbon, 9.2% reduction at 1 g/l influent concentration); absorption in trickling filters (up to 3.45 lbs/cubic yd.) or in activated sludge filters (See Attachment 1). The probable concentrations of formalin appearing in effluent from mariculture operations will be absorbed by bacteria and algae in the supply and disposal trenches. Assuming the average residence time in the ground is greater than 30 days, it is doubtful that any formalin will reach the receiving waters. Preliminary treatment in the disposal trench is dependent on the standing crop of bacteria (and algae, if present), which is susceptible to poisoning by infrequent pulses of formalin above concentrations of 20 ppm in the discharge. It is recommended that any formalin used as a disinfectant be diluted out into the discharge stream as necessary to prevent high concentrations from appearing in the disposal trench.

Copper sulfate, chelated copper compounds

The use of copper sulfate is a traditional method for reducing phytoplankton populations in ponds or biofouling in tanks. Its use is more effective in fresh waters than in marine or other "hard" waters, due to its tendency to precipitate as copper carbonate. This is also true of other trace metals which may be residual nutrients from algal cultures. These carbonate salts are relatively insoluble and are expected to be removed in the disposal trench.

Cutrine-plus and copper control are more effective in marine systems because of the chelating agent triethanolamine which oxidizes very slowly. After 20 day BOD tests only 6.2% of the theoretical oxygen demand was met. As a result, the copper triethanolamine complex is likely to remain active through all of the treatment processes described above. Both copper and triethanolamine can be removed by activated charcoal (0.067 g/g-carbon). Triethanolamine is toxic to algae and bacteria in concentrations in the range of 2-60 ppm (Attachment 1), but the copper complex would not be expected to appear

in the discharge in concentrations higher than 1 ppm. Federal regulations restrict the discharge of copper from power plants and other point sources to concentrations less than 1 ppm.

Dimethyl-(trichloro-hydroxyethyl) phosphonate

This chemical is sold under a variety of trade names listed in a previous section. LD50 values for algae and fish are high (ca. 100 ppm) while toxicity in crustaceans and insects appears at concentrations of 0.2-20 ppb. No data were obtained for rates of environmental degradation.

Malachite Green

This has been used until recently in conjunction with formalin as a theraputic drug in fish culture. However, federal regulations have severely restricted its use in natural waters due, in part, to its resistance to oxidation and biological degradation. No significant reduction in activity after 3 weeks in freshwater was reported by Bills, et al. (1977). Many aquaculturists use chemicals from overseas suppliers to reduce expenses. Malachite green may represent a serious threat to OTEC source waters if used at the proposed site, and it is recommended that its use there be prohibited.

IMPACTS AND MITIGATION

OTEC EFFLUENTS

OC OTEC effluents will be characterized by relatively low dissolved oxygen concentrations, low temperatures, high nutrient concentrations and possibly a very small amount of chlorine, but no additional heavy metals. Of potential concern to the nearshore ecosystem are the altered oxygen and nutrient concentrations and lowered temperatures of the OTEC discharges. The dissolved oxygen concentration in the mixed discharge could be as low as 4 ppm (worst case without degassing) although typically concentrations of about 5.5 ppm would be expected. Canal discharge would have the effect of aerating the discharge stream, probably to values near saturation. Photosynthesis in the canal would add oxygen during daylight hours, but respiration would decrease oxygen during the night. The resulting balance of these processes will require empirical testing, and pre-dawn measurements of oxygen at the seaward end of the canal are recommended. Discharges containing reduced concentrations of oxygen will tend to depress metabolic activity of the coastal community, but rapid mixing and dilution in the surge zone and advection will minimize the areal extent of this impact. If a canal is used to dispose of OTEC effluents and if evidence is found of reduced nearshore oxygen concentrations, then further monitoring of benthic community metabolism would be warranted.

If degassing of the OTEC waters takes place, then a reaeration pretreatment will be necessary prior to discharge to avoid severe metabolic stress to communities resident in the canal and nearshore. Krock (Pers. comm., G. Krasnick, July 31, 1986) has stated that

reaeration of degassed OTEC waters is a more economical process (in terms of either energy or dollars) than venting the removed gases to the environment, so this requirement should be readily accommodated in process design.

OTEC waters disposed of into a trench at NELH would not benefit from the turbulence and photosynthesis which would characterize passage through the canal. Oxygen concentrations would likely further decrease somewhat due to bacterial activity in the trench. Again, actual equilibrium values would have to be empirically determined. Trench disposal would considerably diffuse entry of these waters to the sea, and rapid mixing at entry would tend to mitigate impacts. Seepage from the trench would range between 26 and 72 gpd/ft^2 along a relatively narrow band directly offshore of the trench location. Recommended mitigation measures are reaeration of degassed waters and offshore monitoring.

Oxygen concentrations in OTEC waters disposed of into injection wells would experience none of the alterations discussed above for a canal or trench, and will remain at much the same oxygen concentration through the substratum. The potential impacts would be much as those for trench disposal, but the flux of discharged water through the bottom would be much lower per unit area (1.2-2.9 gpd/ft^2).

The temperature of discharged OTEC water will be below ambient for all discharge options. Considering that some warming will occur as the waters flow through the OTEC system, the worst case discharge temperature is 19-19.4^{o}C (66.2-67°F). Canal discharge will provide further warming and impacts would be expected to be very minimal. If reduced temperatures are experienced at the point of entry to the sea, this would provide a small benefit in terms of slowing metabolic rates and thereby reducing oxygen requirements making it easier for resident species to accommodate any reduction in oxygen concentrations.

Trench disposal of OTEC waters will afford some warming, but not as much as canal discharge. The major difference would be that the former will greatly diffuse the flux and allow much greater initial dilution in the receiving waters. It does not appear that the magnitude of the potential temperature depression would cause mortalities in the benthic community, but again monitoring of community metabolism would be needed to provide quantitative estimates of impact.

OTEC waters disposed of via injection wells would receive the least amount of warming in disposal, but would receive the greatest dilution prior to entry into receiving waters and would enter waters of lowest ambient temperatures. At -300 to -400 feet ambient temperatures vary between about 20 and 25°C (68-77°F) depending on depth and season. Impacts would be very slight.

Nutrient concentrations in OTEC discharges will be elevated over those of receiving waters. If we assume that nitrogen is the limiting macronutrient and the OTEC mixed discharge of 16,100 gpm contains 17.1 ug-at N/l, then a "canal" area about 433 feet on a side would be

necessary for complete nitrogen removal. About 920 pounds dry weight of algae would be produced daily. In reality, the nitrogen in the OTEC discharge would be higher than this due to lysing of entrained cells. OLI (1986) estimated this additional nitrogen to be on the order of 20%, and a corresponding increase in treatment area would be necessary. On the other hand, complete nitrogen removal is certainly not necessary. The offshore ecosystem is adapted to a constant influx of nutrient-rich brackish groundwater. Walsh (1984) found an inverse relationship between nitrogen and salinity in nearshore surface seawater samples which indicates that groundwater of about 8 ppt would be expected to have a nitrogen concentration very similar to that of the mixed OTEC discharge. Measurements of the nitrate concentration in groundwaters at Waikoloa indicate values in the range of 40-50 ug-at/l, slightly above the concentrations in undiluted deep ocean waters (R. Brock, Pers. comm. to G. Krasnick, Oct 11, 1986). Thus nutrient concentrations in the OTEC discharge should not of themselves be a concern, although discharge of these waters at a point source (end of the canal) would be qualitatively different than seepage through the bottom, and quantities disposed of would eventually exceed normal seepage volumes. The impact of canal discharge would likely be more diffuse. As it appears that this water would be similar in nutrient content to existing algae from the benthos will adequately mitigate impacts. Some localized increase in fish population sizes could be expected.

Disposal of OTEC waters via injection well would result in the highest nutrient concentrations at discharge because of the lack of opportunities for biological treatment within the disposal system. As for oxygen and temperature, however, the flux from injection wells would be most diffuse at entry to the receiving waters. According to modeling done by Noda & Associates (1985) for the deep ocean outfall concept, the density of the plume would match ambient densities of -250 feet in summer and -380 feet in winter. The former is at the lower limit of the mixed layer, but above the top of the nutricline. Some stimulation of phytoplankton production is likely but mixing and advection would likely obscure these impacts. Entrainment of these waters in an eddy system could have the indirect impact of raising the bottom of the photic zone and the nutricline depth range, but these would not be significant impacts.

APPLICABILITY OF MARICULTURE TO TREAT NELH WASTES

In any aquaculture process a very large number of interrelated factors, some uncontrollable, act to determine overall system efficiency and productivity. Klontz, et al. (1978) list more than 40, of which about eight are primary. It is not possible to simultaneously manage an aquaculture system for maximum productivity and maximum waste treatment. Therefore, commercial aquaculturists may not be interested in implementing a system for waste water treatment unless a subsidy is provided. A mariculture system for treatment of wastes at NELH would like be the responsibility of NELH itself, as facilities manager. The primary purpose of such a facility would be to reduce the nutrient content of the effluents. To significantly reduce nutrient loading

would require a large land area. This is not to say that some treatment would not occur incidental to mariculture operations at NELH. Algae culture would serve to reduce nutrient loading; but culture of higher organisms would increase loading.

A more fundamental question that whether mariculture waste treatment is appropriate is whether nutrient removal is necessary. As described in the previous NELH/HOST Park EIS, the offshore benthic algal community is maintained at a very low standing crop by grazing and physical stresses. Nutrient subsidies would not be expected to greatly increase macroalgal biomass, except in the case of discharge at the shore via canal and for a portion of the trench seepage because grazing is inhibited in the surge zone. Phytoplankton growth responses would lag nutrient uptake by a day or more, during which time advection would carry the cells away from the area and mixing would dilute cell concentrations.

The only potential reasons for reducing nutrient content in the discharge would be if canal or trench disposal is selected and stimulation of the nearshore algal turf is aesthetically unacceptable. In this case, treatment with RBC technology would be much more efficient than with mariculture. Either method would require disposal of biomass generated in the process. If a commercially valuable seaweed could be utilized in a canal system and sufficient land area would be made available, then this might be technically and economically viable.

APPLICABILITY OF OTHER PRETREATMENT OPTIONS

In addition to inorganic nutrients, mariculture wastes may contain dissolved and particulate organics, antibiotics, disinfectants including chlorine, iodine and formaldehyde, toxicants including copper-based compounds and perhaps various life stages of non-native species. Trench-disposal of these discharges will filter out particulates, and organics will be acted upon by bacteria in the pores of the substrate. Chlorine and copper-based derivatives are not expected to appear in the combined waste waters in toxic concentrations but, if removal of these compounds is necessary, then an activated carbon pretreatment system is recommended.

RELEASE OF EXOTIC SPECIES

Importation of exotic species to Hawaii is controlled by a multi-tiered review and permit system administered by the Plant Quarantine Branch of the Hawaii Department of Agriculture. All potential imports and the facilities for holding them must undergo a thorough review prior to approval. Disposal of mariculture effluents into a trench will effectively preclude escape of these species under normal operating conditions. Catastrophic occurrences could result in discharge of exotic species to coastal waters. However, temperate-water species such as have been the focus of much of the prior research at the facility would not be expected to survive in the warm surface waters off Keahole.

CUMULATIVE IMPACTS OF PLANNED DEVELOPMENTS

The recent surge of resort development planning for West Hawaii has implications for NELH. Adjacent to and south of the HOST Park site are the proposed O'oma II and Kohanaiki developments, respectively. Each is anticipated to include golf courses and substantial other landscaped areas. Domestic wastes are projected to be disposed of into or onto the ground. Coastal waters nearby may receive nutrient subsidies as well as rations of various pesticides and other pollutants typical of urban runoff. If this occurs, it may well be that the usefulness of the NELH facility will be compromised. Impacts to the warm water intake may occur. It may be that in coming years, the purpose and use of the NELH facility may change to depend less on the pristine quality of the coastal waters for such things as materials testing.

WATER QUALITY MONITORING PROGRAM

Purpose

A water quality monitoring program is proposed to document the effects or lack of effects resulting from construction and operation of new facilities at the Natural Energy Laboratory of Hawaii (NELH) and the Hawaii Ocean Science and Technology Park (HOST Park) at Keahole Point, North Kona, Hawaii. Reasons for implementation of a water quality monitoring program are as follows:

- o to protect the source waters used for experimental and production purposes at both facilities;
- o to protect the natural ecosystems present in offshore coastal waters and in the nearshore anchialine ponds;
- o to comply with the requirements of the Conservation District Use Permit (CDUP) and the National Pollutant Discharge Elimination System (NPDES) permit for the NELH;
- o to determine whether or not the State of Hawaii water quality standards (Administrative Rules, Title 11, Chapter 54) are being met;
- o to furnish data to the DOE in support of biofouling and corrosion studies; and
- o to assist in implementation of mitigation measures recommended in the HOST Park EIS (HTDC, 1985).

POTENTIAL CAUSES OF WATER QUALITY DEGRADATION

Water quality reductions may result from construction and operation of the NELH or HOST Park facilities. Construction of pipelines and installation of subsurface pump stations would cause transient increases in turbidity and disrupt benthic communities along the line.

Discharges associated with operations of the facilities could potentially cause long-term degradation of water quality.

Discharges of the NELH and HOST Park are characterized elsewhere in this EIS and in the Host Park EIS. Expansion of the NELH will provide the capacity for testing of open cycle (OC) OTEC components and processes and allow additional mariculture experimentation. Components and characteristics of the NELH OC OTEC discharges which are of concern to maintenance of water quality and ecosystem integrity are:

- o reduced temperatures;
- o reduced concentrations of dissolved oxygen; and
- o increased concentrations of plant nutrients.

Other factors have been suggested as potentially having the capacity to produce negative impacts on nearby ecosystems. These include reduced pH and buffering capacity, dissolved metals concentrations, and chlorine residuals. While the latter two factors are not expected to be associated with the OC OTEC discharges, they may result from ongoing heat exchanger experiments.

Mariculture experimentation at the NELH will result in discharges with the following components and characteristics of most concern:

- o elevated concentrations of inorganic plant nutrients;
- o increased concentrations of dissolved and particulate organic matter; and
- o pulses of chemicals used to clean facilities or maintain water quality in culture containers (especially chlorine and copper compounds).

HOST Park discharges will reflect the mixture of park uses as it develops. Mariculture will be a major activity at the park, and resulting discharges will be similar to, but larger in volume than, the NELH mariculture discharges. Potentially, large volumes of domestic wastes could also be generated.

NELH presently employs four septic tanks for disposal of domestic wastes. At full development, the volume of domestic waste from the NELH is projected to fall in the range 19,000-27,300 gpd. The HOST Park development plan proposes additional septic tanks as well as leaching fields to dispose of, for development scenarios A, B and C, respectively, 60,000-80,000 gpd, 104,000-142,000 gpd and 159,500-223,300 gpd.

LOCATIONS OF POTENTIAL IMPACTS

Discharges from the expanded NELH facility may be disposed of in several ways, as described elsewhere in this EIS. Plumes resulting from these discharges were modeled mathmatically, and the results are summarized below.

Disposal of NELH OTEC waters through a canal similar to the one presently in use would create an offshore plume which would be rapidly mixed by waves and advected by prevailing currents. OLI (1986) estimates that at equilibrium the concentration of discharged OTEC water at the warm water intake would be 0.006 of the concentration at the discharge outlet.

Disposal of OTEC waters through a nearshore trench would create a subsurface plume, 80% of which would discharge over a distance of 4,100 feet along the shoreline at an average rate of 4,500 gpd/foot (Dames and Moore, November 4, 1986, addendum). The Dames and Moore model assumed that this plume would intersect the bottom at depths between 0 and -50 feet. Discharge rates would average 4.5 gpd/ft^2 with a maximum of 6.6 gpd/ft^2. Minimum residence times would be one to two days.

Disposal of mariculture waters into a trench set back 750 feet or more from the shoreline would create a plume extending from 0 to -200 feet. Eighty-five percent of this discharge would occur along 4,300 feet of the shoreline, with flows averaging 7,300 gpd/foot. Flux through the bottom would average 1.9 gpd/ft^2, with maximum values of about 4.2 gpd/ft^2. The residence time would be 1-2 months.

If OTEC discharges are co-disposed of in the mariculture trench, 77% of the discharge would occur over 3,800 feet of shoreline (12,200 gpd/foot). If the flow remained between 0 and -200 feet, flux through the bottom would average 3.2 gpd/ft^2, with maximum values of about 5.9 gpd/ft^2. Residence times would decrease to between 18 and 38 days.

Disposal of OTEC waters by deep (300 feet) injection wells would create a subsurface plume confined to depths between -300 and -400 feet. Eighty-five percent of this discharge would occur over a distance of 30,000 feet, averaging 660 gpd/foot. The average discharge rate would be 1.2 gpd/ft^2, and the maximum rate would be 2.9 gpd/ft^2. A minimum residence time of about three months was calculated (Dames and Moore, 1986).

Disposal of HOST Park discharges into a trench approximately 2000 feet inland, at the initial flow increment of 20 mgd (13,900 gpm) would create an underground plume 2.7 miles wide at the shoreline and reach 0.9 miles inland. It would require between 187 days and 3.6 years before the disposed ocean water re-emerged at the shoreline. At total development, 144 mgd (100,000 gpm), the plume would be 22.4 miles wide at the shoreline and would reach 2.4 miles inland. The residence time would be between 26 and 144 days.

Disposal of HOST Park discharges into large-diameter, deep injection wells would require 3 wells for the initial flow (20 mgd) and about 15 wells for full development (144 mgd). Significant discharges would occur along about 6,400 feet of the shoreline. Flow thickness would be about 400 feet, and the flux would average about 2.2 gpd/ft^2.

The area of influence of these plumes would be dominated primarily by the HOST Park mariculture plume and secondarily by the NELH mariculture

plume. The combined area influenced would include waters along the coast fronting NELH, HOST Park and adjacent properties from the shoreline out to bottom depths of at least -200 feet. Concentrations of discharge waters would be highest directly offshore of the respective disposal trenches and less at increasing distances. Concentrations of plume tracer parameters could be expected to exhibit a relative low offshore between the two mariculture plumes.

Disposal of OTEC waters by canal would create a comparatively concentrated plume off Keahole Point, whereas co-disposal with NELH mariculture waters would provide a much greater degree of dispersion prior to entry to the sea.

Injection well disposal methods would substantially alter the offshore areas most directly affected by the discharges. For the NELH OTEC waters the affected area would encompass about six miles along the coast, but the discharge would emerge at depths of about -300 to -400 feet. HOST Park injection wells would also displace the principal area of impact offshore to include areas at least 400 feet deep. Neither of the injection well options are preferred due to economic and technical (potential clogging) considerations. The water quality monitoring stations identified below are not therefore based on anticipation of use of these options. If injection is later utilized, monitoring stations may have to be relocated.

AFFECTED ENVIRONMENTS

From the above descriptions, it may be concluded that the primary geographic area of concern will be a band offshore of the two facilities out to water depths of at least -200 feet. The offshore bathymetry of this area indicates that the -200 feet contour lies at only about 600-800 feet offshore. Beyond this, the bottom slopes more gently to depths of -400 feet at about 2,000 feet offshore. The benthic community out to depths of approximately -200 feet is dominated by several species of coral, encrusting algae and sea urchins. Beyond this the rocky slope grades into a sandy plain harboring large aggregations of taape (Lutjanus kasmira).

In the water column above the benthos are populations of phytoplankton, zooplankton (including fish eggs and larvae), micronekton and nekton. Marine mammals and threatened or endangered species may also pass through these waters.

Onshore, the anchialine ponds will be affected by the displacement of groundwater around the NELH by the discharge plumes.

POTENTIAL IMPACTS

Degradation of water quality parameters is a negative impact to the extent that biota are affected or that human use and enjoyment of the environment is compromised. A water quality monitoring program should therefore be designed to provide insights to an understanding of these impacts. Baseline data regarding water quality, biota, human use, etc,

are required, as is an appreciation of how water quality perturbations may influence biota and/or human use. Present plans for both facilities include a gradual increase in volumes of water to be used. This will allow the monitoring program to provide early detection of any impacts. In addition, the potential impacts are reversible. That is, if discharges are halted, the affected ecosystems could be expected to revert to baseline conditions. Key characteristics or components of the discharge streams and the nature of their potential impacts are discussed below.

Reduced water temperatures. Discharge water temperatures from either facility would not be below 19 C, and lethal impacts are not expected on any affected populations. Sublethal impacts could include reduced metabolic rates, especially of corals. This could retard reef growth and in the long-term alter community structure by changing the competitive balance among species. It could lead to avoidance by some motile species, and primary productivity could be lowered.

Reduced dissolved oxygen concentrations. Reaeration of OTEC discharges is strongly recommended to avoid potentially severe toxic effects. Aquaculture discharges could also be depleted in oxygen, especially in the pre-dawn hours. Rapid dilution at entry to the ocean would tend to mitigate against negative impacts regardless of the disposal option adopted, but some sub-lethal reductions of metabolic rates could occur.

Increased nutrient concentrations. Nutrient subsidies could increase algal uptake rates, growth and standing crops. Fleshy macroalgae are notably sparse off the coast except in the surge zone where grazing is inhibited, so impacts of stimulation of the benthic algal community beyond the surge zone might be expressed as increased population sizes of herbivores and higher trophic levels rather than elevated algal standing crops. Offshore phytoplankton densities are very low in these clear, oceanic waters. Nutrient subsidies may increase uptake and growth rates, but the time lag between uptake and growth responses (on the order of a day), advection by offshore currents and grazing by herbivorous zooplankton would all act to minimize elevations of phytoplankton concentrations.

Mariculture additives. Biocides, by definition, are toxic to some species in some concentrations. Of concern from mariculture operations are chlorine and its derivitives and copper compounds.

MONITORING PLAN

Locations

To be able to determine causal relationships between discharges and impacts, a comprehensive network of monitoring locations is required. Water quality, biological and operational data must be collected. Recommended monitoring locations are grouped and numbered for later reference below.

NELH Stations:

1. Cold water intake
2. Warm water intake
3. Existing and future OTEC discharge facilities, e.g. trench. (If canal is used, add at least one additional station near entry to ocean)
4. Each mariculture facility discharge.

HOST Park Stations:

5. Cold water supply
6. Warm water intake
7. Each tenant waste stream (or disposal trench)

Groundwater stations:

8. Monitoring wells
9. Anchialine ponds at NELH
10. Wawaloli spring

Offshore stations:

11. One-half mile north of NELH in water depth -100 feet. Discrete samples at depths of 1, 10, 25, 50 and 75 feet.
12.-14. Off Keahole Point in water depths of -100, -200 and -400 feet. Sampling depths as above, but adding 150 feet sample at station 13 and 150 and 300 feet samples at station 14.
15. Off Kalihi Point, as at station 11.
16.-18. Off HOST Park, as off Keahole Point.
19. One-half mile south of HOST Park, as at station 11.

Biological monitoring locations will include the anchialine ponds (station 9) and inshore from stations 11, 12, 15, 16 and 19. The offshore station locations are shown on Figure 3.

Parameters

Parameters to be monitored at any of the above stations are listed below and numbered for reference in the monitoring plan matrix below. Analytical methods to be used are those appropriate to the character of the water to be tested and the expected concentration of the parameter to be measured.

1. Temperature
2. Salinity
3. pH
4. Turbidity
5. Light extinction
6. Nitrate + nitrite nitrogen
7. Ammonia nitrogen
8. Total dissolved nitrogen
9. Total particulate nitrogen

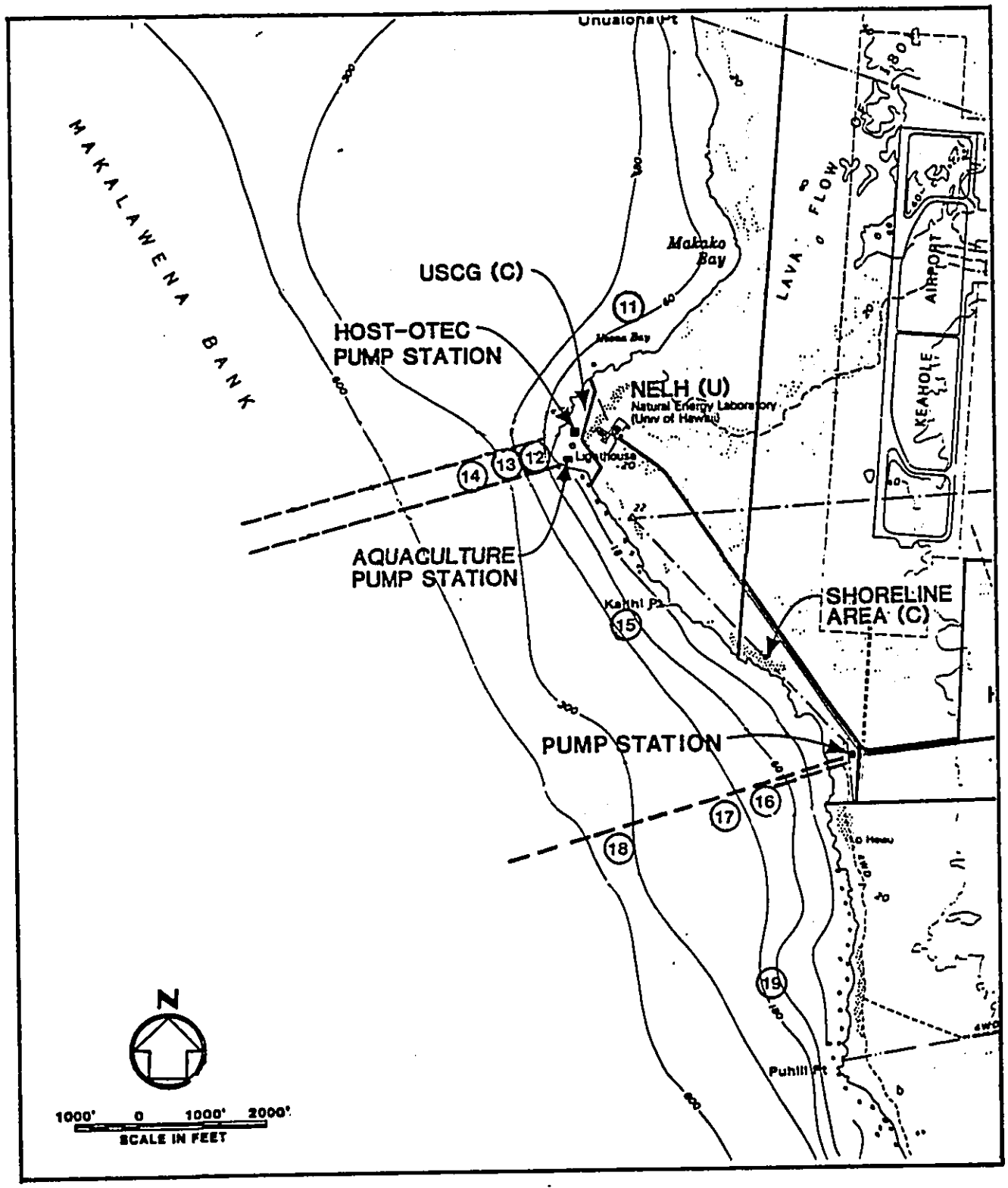


Figure 3. Locations of offshore monitoring stations for the combined NELH/HOST Park water quality program.

10. Total nitrogen
11. Orthophosphate
12. Total dissolved phosphorous
13. Total phosphorous
14. Total organic carbon
15. Total particulate carbon
16. Particulate inorganic carbon
17. Silicate
18. Dissolved oxygen
19. BOD
20. Total suspended solids
21. Total residual oxidant in discharge stream
22. Discharge flow rates
23. Total dissolved gas
24. Fecal bacteria
25. Climatology
26. Offshore Currents
27. Ciguatera algae
28. Copper
29. Chlorophyll a
30. Biota
31. Human use

The biota monitoring should result in detailed species lists of the plants and animals within the given ecosystem. Data should include, as appropriate, population sizes, biomass estimates, density, distribution and/or frequency of occurance. All major species groups should be included. Sampling methods would vary with the requirements of the various stations.

Human use monitoring is included to generate data on recreational fishing catch and effort.

Frequency

The frequency of monitoring should be designed to allow early detection of the potential effect anticipated. Frequency should be greatest during construction and start-up and later be reduced when consistent patterns are established with confidence. The monitoring plan should be frequently reevaluated to provide for modifications based on new results as they become available. Stations should be added as new sources come on line. The entire network should be reviewed annually. A logical vehicle for this would be an annual report which should comprehensively evaluate the data collected during the previous year, compare them with baseline conditions and discuss relationships between discharges and any observed changes from baseline conditions. Interim data reports should be made available quarterly. Reports should be circulated among the major agencies with interests in the results, especially the State Department of Health, the Fish and Wildlife Service, the National Marine Fisheries Service and the Army Corps of Engineers.

The following frequency codes are used in the monitoring matrix below.

1. Continuous
2. Daily
3. Weekly
4. Monthly
5. Quarterly
6. Semi-annually
7. Annually

Monitoring Matrix

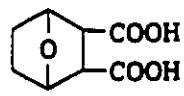
The matrix below summarizes the frequency with which each parameter should be monitored at each station.

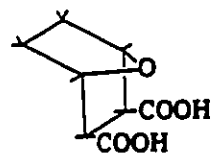
PARAMETER	STATION NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	4
2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
3	-	-	2	2	-	-	2	3	3	3	4	4	4	4	4	4	4	4	4
4	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
5	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
6	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
7	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
8	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
9	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
10	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
11	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
12	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
13	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
14	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
15	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
16	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
17	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
18	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	4
19	-	-	-	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
20	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
21	-	-	2	2	-	-	2	3	3	3	4	4	4	4	4	4	4	4	4
22	-	-	1	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
23	2	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	3	3	3	-	-	-	-	-	-	-	-	-
25	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-
28	3	3	-	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
29	3	3	-	3	3	3	3	-	3	-	4	4	4	4	4	4	4	4	4
30	5	5	-	5	5	5	5	5	5	-	5	5	-	-	5	5	-	-	5
31	3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes
* One station will suffice.
Monitoring for ciguatera-causing algae only following pipe installation.
Daily monitoring times should be varied to document diurnal cycles.
OTEC discharge monitoring should be coordinated with timing of experimental runs.
Only initial lmonitoring frequencies are shown.

Attachment 1: The following material represents a compilation of the known evironmental data on relevant chemicals which have been identified in this report. The information is reprinted from Verschueren (1983), and the format and abbreviations are from the same source.

aquathol K (7-oxabicyclo(2,2,1)heptane-2,3-dicarboxylic acid; 1,2-dicarboxy-3,6-endoxocyclohexane; 3,6-endoxohexahydrophthalic acid; endothall; accelerate; des-i-cate; hydout; hydrothol; ripenthol, triendothal)





Use: herbicide, defoliant, desiccant, growth regulator

A. PROPERTIES: mp. 144°C, solub. 100 g/kg at 20°C

D. BIOLOGICAL EFFECTS:

–Algae:

		ppb		
Chlorococcum sp.	Technical acid	1×10^5	50 percent decrease in O_2 evolution	*f*
Chlorococcum sp.	Technical acid	5×10^4	50 percent decrease in growth	Measured as ABS (525 mu) after 10 days
Dunaliella tertiolecta	Technical acid	4.25×10^5	50 percent decrease in O_2 evolution	*f*
Dunaliella tertiolecta	Technical acid	5×10^4	50 percent decrease in growth	Measured as ABS (525 mu) after 10 days
Isochrysis galbana	Technical acid	6×10^4	50 percent decrease in O_2 evolution	*f*
Isochrysis galbana	Technical acid	2.5×10^4	50 percent decrease in growth	Measured as ABS (525 mu) after 10 days
Phaeodactylum tricornutum	Technical acid	7.5×10^4	50 percent decrease in O_2 evolution	*f*

–Crustacean: *Gammarus lacustris*: no effect at 100,000 µl/96 hr (dipotassium salt)

–Insects: lowest observed avoidance conc., mayfly nymphs (*Ephemerella walkeri*) >10 mg/l (dipotassium salt)

–Fish:

rainbow trout (*Salmo gairdneri*), lowest observed avoidance conc.: >10 mg/l (dipotassium salt)

Pimephales promelas: 320,000 µg/l LC_{50}, 96 hr (dipotassium salt)

Lepomis macrochirus: 160,000 µg/l LC_{50}, 96 hr (dipotassium salt)

Pimephales notatus: 110,000 µg/l LC_{50}, 96 hr (disodium salt)

Lepomis macrochirus: 125,000 µg/l LC_{50}, 96 hr (disodium salt)

Micropterus salmoides: 120,000 µg/l LC_{50}, 96 hr (disodium salt)

Notropis umbratilus: 95,000 µg/l LC_{50}, 96 hr (disocium salt)

Micropterus salmoides: 200,000 µg/l LC_{50}, 96 hr (disodium salt)

Oncorhynchus tschawtscha: 136,000 µg/l LC_{50}, 96 hr (disodium salt)

–Mammals:

acute oral LD_{50} (rats): 51 mg/kg (acid)
182–197 mg/kg (sodium salt)

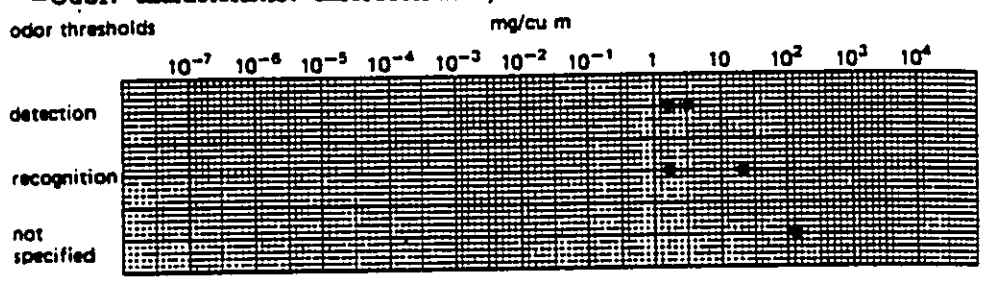
in diet: endothall-Na, fed for 2 years to rats at 1000 ppm caused no ill effects

bromoform (tribromomethane)
$CHBr_3$

Users and formulation: pharmaceutical mfgs.; ingredient in fire-resistant chms.; gage fluid; heavy liquid in solid separations based on differences in specific gravity, geological assaying, solvent for waxes, greases and oils. (347)

A. PROPERTIES: colorless liquid; m.w. 252.77; m.p. 6/7°C; b.p. 149°C; v.p. 5.6 mm at 25°C; v.d. 8.7; sp.gr. 2.89 at 20/4°C; solub. 3,190 mg/l at 30°C

B. AIR POLLUTION FACTORS: 1 ppm = 10,34 mg/cu m, 1 mg/cu m = 0.0966
—Odor: characteristic: chloroformlike, sweetish (211)



(610; 671; 777; 795)

C. WATER POLLUTION FACTORS:
—Odor threshold: detection: 0.3 mg/kg (894)
—Water quality: in N.W. England tap waters (1974): <0.01–2.5 ppb (933)
—Water treatment: experimental water reclamation plant:

	sample 1	sample 2	
sand filter effluent	211 ng/l	154 ng/l	
after chlorination	1723 ng/l	3711 ng/l	
final water after A.C.	175 ng/l	135 ng/l	(928)

D. BIOLOGICAL EFFECTS:
—Larvae of eastern oyster (*Crassostrea virginica*): LD_{50}, 48 hr: 1 mg/l, initial conc., static test (after 48 hr only approx. 30% of original conc. was still present) (1545)

chloramphenicol (chloromycetin; *d*-(−)-threo-2,2-dichloro-N-[β-hydroxy-α-(hydroxymethyl-*p*-nitrophenethyl] acetamide)
$Cl_2CHCONHCH(CH_2OH)CH(OH)C_6H_4NO_2$

Use: an antibiotic derived from *Streptomyces venezuelae* or by organic synthesis; antifungal agent

A. PROPERTIES: m.w. 323.13; m.p. 148–150°C
C. WATER POLLUTION FACTORS:
—Biodegradation rates: adapted A.S. at 20°C—product is sole carbon sourc 86.2% COD removal at 3.3 mg COD/g dry inoculum/hr
D. BIOLOGICAL EFFECTS:
—Carcinogenicity: ?
—Mutagenicity in the *Salmonella test*: ?
<4.5 revertant colonies/nmol
<70 revertant colonies at 5 μg/plate

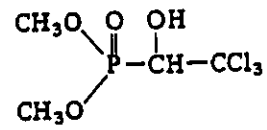
cutrine

Use: algicide
Composition: copper-triethanolamine complexes

D. BIOLOGICAL EFFECTS:
decapod: *Penaeus californiensis*: 96 hr LC_{50}—FT: 1000 mg/l
harlequin fish (*Rasbora heteromorpha*):

mg/l	24 hr	48 hr	96 hr	3 m (extrap.)
LC_{10}(F)	0.7	0.26		
LC_{50}(F)	1.2	0.35	0.24	0.01

dimethyl-(2,2,2-trichloro-1-hydroxyethyl)phosphonate (chlorofos; trichlorphon; dipterex; dylox)



Use: nonsystemic contact and stomach insecticide

A. PROPERTIES: m.p. 81–82°C; solub. 154 g/l at 25°C; v.p. 7.8×10^{-6} mm at 20°C. sp.gr. 1.73 at 20/4°C

D. BIOLOGICAL EFFECTS:

–Algae:

Dunaliella euchlora	50,000 ppb	.54 (O.D. expt/ O.D. cont.)	organisms grown in test media containing pesticide for 10 days optical density measured at 530 mμ	50% soluble powder
Phaeodactylum tricornutum	50,000 ppb	.85 (O.D. expt/ O.D. cont.)		soluble powder
Phaedactylum tricornutum	100,000 ppb	.39 (O.D. expt/ O.D. cont.)		soluble powder
Protococcus sp.	100,000 ppb	.54 (O.D. expt/ O.D. cont.)		soluble powder
Chlorella sp.	50,000 ppb	.70 (O.D. expt/ O.D. cont.)		soluble powder
Chlorella sp.	500,000 ppb	.00 (O.D. expt/ O.D. cont.)		soluble powder
Monochrysis lutheri	50,000 ppb	.55 (O.D. expt/ O.D. cont.)		soluble powder (2347)

–Molluscs:

Crassostrea virginica: american oyster, larvae: 48 hr static lab bioassay, TLm: 1,000 ppb (2324)

–Crustaceans:

Gammarus lacustris: 96 hr LC_{50}: 40 μg/l (2124)
Simocephalus serrulatus: 48 hr LC_{50}: 0.32 μg/l (2126)
Daphnia pulex: 48 hr LC_{50}: 0.18 μg/l (2126)

–Insects:

Pteronarcys californica: 30 day LC_{50}: 9.8 μg/l: 96 hr LC_{50}: 69 μg/l (2117)
Pteronarcys californica: 96 hr LC_{50}: 35 μg/l (2128)
Acroneuria pacifica: 30 day LC_{50}: 8.7 μg/l: 96 hr LC_{50}: 16.5 μg/l (2117)
Pteronarcella badia: 96 hr LC_{50}: 11 μg/l (2128)
Classenia sabulosa: 96 hr LC_{50}: 22 μg/l (2128)

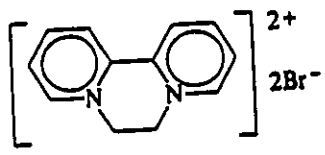
–Fish:

Pimephales promelas: 96 hr LC_{50}: 109000 μg/l (2122)
Lepomis macrochirus: 96 hr LC_{50}: 3800 μg/l (2122)
rainbow trout: 96 hr LC_{50} (S): 4.85 mg/l (1101)

–Mammals:

acute oral LD_{50} (rat): 450–530 mg/kg (1855)
acute dermal LD_{50} (rat): >2,000 mg/kg (1854)
in diet (rat): 1 year at 500 ppm: no ill effect (1855)

diquat (1,1′-ethylene-2,2′-bipyridylium cation; 9,10-dihydro-8a,10a-diazoniaphenanthrene; 6,7-dihydrodipyridol(1,2-a:2′,1′-c)pyrazidinium bromide; reglon; diquat dibromide)
diquat refers to the cation only



A. PROPERTIES: solub. 700 g/l at 20°C
D. BIOLOGICAL EFFECTS:
–Algae:

Chlorococcum sp.	>.5 X 10^6 ppb	50% decrease in O_2 evaluation	*f*
Chlorococcum sp.	2. X 10^5 ppb	50% decrease in growth	Growth measured as ABS. (525 mu) after 10 days
Dunaliella tertiolecta	>5. X 10^6 ppb	50% decrease in O_2 evolution	*f*
Dunaliella tertiolecta	3 X 10^4 ppb	50% decrease in growth	Growth measured as ABS. (525 mu) after 10 days
Isochrysis galbana	>5 X 10^6 ppb	50% decrease in O_2 evolution	*f*
Isochrysis galbana	1.5 X 10^4 ppb	50% decrease in growth	Measured as ABS. (525 mu) after 10 days
Phaeodactylum tricornutum	>5 X 10^6 ppb	50% decrease in O_2 evolution	*f*
Phaeodactylum tricornutum	1.5 X 10^4 ppb	50% decrease in growth	Measured as ABS. (525 mu) after 10 days

(2348)

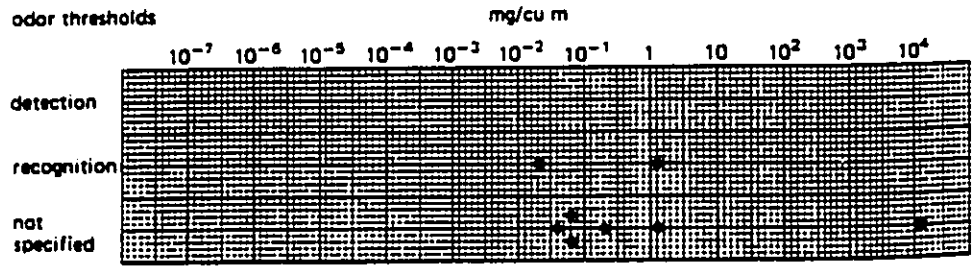
–Crustacean: (2133)
Hyallella azteca: 96 hr, LC_{50}: 48 µg/l
–Insects: (2133)
Callibaetes sp.: 96 hr, LC_{50}: 16400 µg/l (2133)
Limnephilus: 96 hr, LC_{50}: 33000 µg/l (2133)
Tendipedidae: 96 hr, LC_{50}: >100000 µg/l (2133)
Enallagma: 96 hr, LC_{50}: >100000 µg/l (2133)
mayfly nymphs (*Ephemerella walkeri*): 1.0 mg/l (lowest observed avoidance conc.) (1621)
–Fish:
Pimephales promelas: 96 hr, LC_{50}: 14000 µg/l (2131)
Lepomis macrochirus: 96 hr, LC_{50}: 35000 µg/l (2112)
Micropterus salmoides: 96 hr, LC_{50}: 7800 µg/l (2131)

formaldehyde (formalin; oxomethane; methanal)
HCHO

A. PROPERTIES: colorless gas; m.w. 30.0; m.p. −118/−92°C; b.p. −21/−19°C; v.p. −88°C at 10 mm; v.d. 1.03; sp.gr. 0.815 at −20/4°C; THC 134 kcal/mole, LHC 124 kcal/mole; log P_{oct} 0.00 (calculated)

B. AIR POLLUTION FACTORS: 1 mg/cu m = 0.815 ppm, 1 ppm = 1.248 mg/cu m

–Odor: characteristic: quality: hay, strawlike
hedonic tone: pungent



from API #7 gasoline: 14.9 ppm
from API #8 gasoline: 11.3 ppm (1053)
in exhaust of gasoline engine: 59.9–72.9 vol.% of total exhaust aldehydes (394; 395; 396; 397)

–Emission control:
A.C.: retentivity: 3 wt% of adsorbent (83)

–Sampling and analysis:
second derivative spectroscopy: det. lim.: 200 ppb (42)
photometry: min. full scale: 9,500 ppm (53)
PMS: det. lim.: 1–11 ppm (200)
4 f. abs. app.; 60 l air /30 min: VLS: det. lim.:
det. lim.: 15 μg/cu m/30 min; reagent: pararosaniline
150 μg/cu m/30 min; reagent: chromotropic acid (several interferences) (208)

C. WATER POLLUTION FACTORS:

–BOD_5: 60% of ThOD (274)
0.6–1.07 std. dil. at <260 mg/l (27)
0.728 (30)
0.33–1.06 std. dil. sewage (41)
1.06 std. dil. sew. (260)
0.64 std. dil. sew. (282)
0.33 std. dil. sew. at 2.5–10 ppm (269)
0.45 std. dil. sew. at 1.7–20 ppm (263)
1.10 manom 50% sew; at 260 ppm (270)
0.57 manom 5% sew; at 260 ppm (270)
0 Sierp, 10% sew; at 440 ppm (280)
1.00 Warburg, 50% sew; at 130 ppm (281)
1.10 Warburg, 25–50% sew; 250 ppm (281)

–BOD_{20}: 1.228 (30)

–COD: 100% of ThOD (0.05 n $K_2Cr_2O_7$) (274)
1.06 (41, 27)

–$KMnO_4$: 2.84 (30)
94% of ThOD (0.01 n $KMnO_4$) (274)

–ThOD: 1.068 (30)

–Biodegradation:

$$HCHO \xrightarrow{+\frac{1}{2}O_2} HCOOH \longrightarrow CO_2 + H_2O$$
$$HCHO \xrightarrow{+H_2} CH_3OH \longrightarrow CO_2 + H_2O$$ (171)

–Reduction of amenities:
taste and odor caused at 50.0 mg/l (41, 27)
odor threshold: average: 49.9 mg/l
range: 0.8–102 mg/l (97)

–Impact on biodegradation processes:
inhibition of anaerobic sludge digestion: at 100 mg/l
aerobic degradation: 135–175 mg/l
methane fermentation can be acclimated up to 15% formaldehyde (30)

inhibition of degradation of glucose by *Pseudomonas fluorescens*: at 2 mg/l
inhibition of degradation of glucose by *E. coli*: at 1 mg/l (293)

–Waste water treatment:

A.C.: adsorbability: 0.018 g/g C; 9.2% reduction, infl.: 1,000 mg/l, effl.: 908 mg/l (32)

trickling filter:

feed ppm	removal of formaldehyde lb/yd^3	% removal efficiency
110	1.12	23
184	1.25	16
266	1.75	15
300	3.10	23
360	3.45	28 (96)

methods	temp °C	days observed	feed mg/l	days acclim.	
A.S., Resp, BOD	20	1–5	720	<1	nil % theor. oxidation
A.S., W	20	$\frac{1}{3}$	1,500	P	52% theor. oxidation
A.S., BOD	20	$\frac{1}{8}$–5	500	30+	47% removed
A.S., BOD	20	$\frac{1}{3}$–5	333	30+	94% removed (93)

–Sampling and analysis:

VLS; det. lim.: 0.1 mg/l; reagent: pararosaniline
1 mg/l; reagent: chromotropic acid (several interferences) (208)

D. BIOLOGICAL EFFECTS:

–Toxicity threshold (cell multiplication inhibition test) (35% w/w)

bacteria (*Pseudomonas putida*): 14 mg/l (1900)
algae (*Microcystis aeruginosa*): 0.39 mg/l (329)
green algae (*Scenedesmus quadricauda*): 2.5 mg/l (1900)
protozoa (*Entosiphon sulcatum*): 22 mg/l (1900)
protozoa (*Uronema parduczi Chatton-Lwoff*): 6.5 mg/l (1901)

–Bacteria:

E. coli: toxic: 1 mg/l

–Algae:

Scenedesmus: toxic: 0.3–0.5 mg/l

–Arthropoda: *Daphnia*: toxic: 2 mg/l (39)

–Fish: sensitive aquatic organisms: TLm (? hr): >10 mg/l (27)
guppies: TLm (? hr): 50–200 mg/l (30)

species	exposure time	exposure type	effect endpoint	concentration (37% w/w)
rainbow trout (green egg)	96 hr	S	LC_{50}	700 mg/l
rainbow trout (green egg)	96 hr	S	LC_{50}	565 mg/l
rainbow trout (green egg)	96 hr	S	LC_{50}	631 mg/l
rainbow trout (eyed egg)	96 hr	S	LC_{50}	198 mg/l
rainbow trout (eyed egg)	96 hr	S	LC_{50}	338 mg/l
rainbow trout (eyed egg)	96 hr	S	LC_{50}	435 mg/l
rainbow trout (eyed egg)	96 hr	S	LC_{50}	289 mg/l
rainbow trout (sac larvae)	96 hr	S	LC_{50}	96 mg/l

atlantic salmon: 96-hr LC_{50}: 173 µl/l (FT)
lake trout: 96-hr LC_{50}: 100 µl/l (FT)
black bullhead: 96-hr LC_{50}: 62.1 µl/l (FT)
channel catfish: 96-hr LC_{50}: 65.8 µl/l (FT)
green sunfish: 96-hr LC_{50}: 173 µl/l (FT)
bluegill: 96-hr LC_{50}: 100 µl/l (FT)
smallmouth bass (*Micropterus dolomieui*): 96-hr LC_{50}: 136 µl/l (FT)
largemouth bass (*Micropterus salmoides*): 96-hr LC_{50}: 143 µl/l (FT)

–Mammals:

guinea pig: single oral LD_{50}: 0.26 g/kg
rat: single oral LD_{50}: 0.1–0.8 g/kg

roccal (benzalkonium chloride: alkyldimethyl benzylammonium chloride)

Use: microbicide.

D. BIOLOGICAL EFFECTS:

–Mussels:

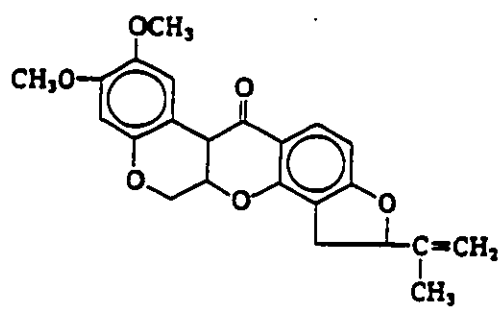
Mercenaria mercenaria (hard clam), egg:
static lab bioassay: 48 hr TLm: 190 ppb

Mercenaria mercenaria (hard clam), larvae:
static lab bioassay: 12 day TLm: 140 ppb

–Fish:

	mg/l	24 hr	48 hr	96 hr	3m (extrap.)
harlequin fish (*Rasbora heteromorpha*)	LC_{10}(F)	1.85	0.59	–	–
	LC_{50}(F)	2.45	1.1	0.62	0.04

rotenone (tubatoxin; noxfish; *see also* dactinol)



Rotenone is the trivial name given to the main insecticidal compound in the roots of certain *Derris* and *Lonchocarpus* spp.

Use: a selective nonsystemic insecticide

A. PROPERTIES: m.w. 394.4; m.p. 178–181°C; b.p. 210–220°/0.5 mm; sp.gr. 1.27 at 20°C; m.p. 163°C; solub. 15 ppm at 100°C

C. WATER POLLUTION FACTORS:

–Odor threshold conc. 0.36 mg/kg

D. BIOLOGICAL EFFECTS:

–Crustaceans:

Gammarus lacustris: 96 hr LC_{50}: 2600 μg/l
Simocephalus serrulatus: 48 hr LC_{50}: 190 μg/l
Daphnia pulex: 48 hr LC_{50}: 100 μg/l

–Insects:

Pteronarcys californica: 96 hr LC_{50}: 380 μg/l

–Fish: exposed to Noxfish (5% rotenone)

bowfin: (*Amia calva*) 96-hr LC_{50}: 30.0 μg/l (S)
Coho salmon: 96-hr LC_{50}: 62.0 μg/l (S)
Chinook salmon: 96-hr LC_{50}: 36.9 μg/l (S)
rainbow trout: 96-hr LC_{50}: 46.0 μg/l (S)
Atlantic salmon: 96-hr LC_{50}: 21.5 μg/l (S)

APPENDIX C

TECHNICAL EVALUATION OF SEAWATER RETURN FLOW DISPOSAL BY DEEP INJECTION WELLS AND SHALLOW TRENCH

DAMES & MOORE

APPENDIX C

DRAFT ENVIRONMENTAL ASSESSMENT AND SUPPLEMENTAL EIS
HYDROLOGICAL SECTION
MODIFICATION OF PROPOSED ACTION TO PERMIT ALTERNATIVE
METHODS OF SEAWATER RETURN FLOW DISPOSAL AT NELH
KEAHOLE, NORTH KONA, HAWAII

Dames & Moore Job No. 03014-119-11
August 15, 1986

GENERAL HYDROLOGY

The climate of the Keahole region is arid in the coastal area but changes gradually to humid in the Hualalai undissected upper slope. The area receives little tradewind rainfall; instead, much of the moisture is accounted for by orographic showers that form within sea breezes which move onshore and upslope. The mean annual rainfall ranges from less than 20/inches along the coast to as much as 75 inches on the lee of Hualalai crater.

Pan evaporation is typically high, in the general range of 0.18/inches per day for the winter and 0.36 inches per day for the summer as measured at Anaehoomalu (Kay et al., 1977). There is no pan evaporation measurement for the Keahole region. Neither perennial nor intermittent streams normally reach the ocean. The sources of groundwater recharge come primarily from the small residual of rainfall after abstraction by evapotranspiration in the upland area and to a lesser extent from the infrequent cyclonic-storm rain affecting the entire area. All groundwater discharges are natural as there is no groundwater development of any kind. These discharges are primarily diffused and not usually visible along the shoreline; only one shoreline spring near Wawaloli Beach, noticeable during low tide, has been observed.

GEOLOGY

The Natural Energy Laboratory of Hawaii (NELH) site in the Keahole Point region consists of primitive basalts of the Hualalai volcanic series, the principal effusive rock of Hualalai volcano (Stearns and MacDonald 1946). The series are composed of heterogeneous, poorly-layered, laterally and vertically restricted units of aa, clinker, and pahoehoe consisting predominantly of basalts and olivine basalts. Individual units extend laterally no more than several hundred feet and vertically less than 100 feet. The average lava flow thickness is about 10 feet. A late trachyte effusion from Puu Waawaa occurs about 15 miles northeast of Keahole.

The lavas for several miles around Keahole Point congealed as flank flows having regional dips of less than 5 degrees; no surficial evidence exists of intrusive rocks, neither dikes nor sills. The

Hualalai volcano, although one of the oldest on the Island of Hawaii, erupted as recently as 1800 to 1801 when the Kaupulehu lava flow reached to within 2,000 feet of Keahole Point. This flow still retains its original appearance because, in the semiarid climate of the coastal sector of western Hawaii, weathering is an extremely slow process. The 1800 to 1801 and previous visible flows have broken, rough surfaces transected by irregular vertical fractures. Lava tubes and other large openings, many of them collapsed, are common.

Except for volumetrically insignificant, spotty accumulations of marine sediments near the coast, all of the exposed rocks are the original, in place basaltic lavas. The depth of weathering is slight, even on the oldest strata, and soil formation is incipient at best. The marine sediments, less than a few feet thick in the most favorable locations, consist of sporadic occurrences of calcareous sand, cemented beach rock, and coral and basaltic gravels driven on shore by stormy seas. These sediments are restricted to a narrow zone along the coast below an elevation of about 10 feet above sea level.

No unusual structural features exist in the region. The nearest rift zone is at least five miles to the north. There is no evidence of faulting or other regional deformation. Indeed, for many miles around Keahole, the geology is that of low dipping flank flows of primitive basalt, a favorable condition for highly permeable aquifers.

GROUNDWATER OCCURRENCE AND AQUIFER CHARACTERISTICS

A thin Ghyben-Herzberg lens underlies the coastal region of western Hawaii from Keahole northward to beyond Kawaihae and southward to beyond Keauhou. In the Keahole vicinity, the lens is brackish, probably less than 125 feet thick and discharges freely along the coast in a narrow band a few feet wide in the intertidal zone. The basal lens water does not meet the U.S. Drinking Water Standards (250 mg/l chlorides, 500 mg/l TDS) even at the top of the lens and at a distance about 3 miles from the shoreline. Chloride, for example, measured to be about 5,000 milligrams per liter (mg/l) to 520 mg/l, and total dissolved solids (TDS) to be about 10,000 to 1,200 mg/l over this distance.

In some places, the lens is visible where the basaltic surface has collapsed and where marine sediments have filled depressions in the original surface near the shore. Maciolek and Brock (1974) describe exposures of the lens (anchialine ponds) along the Kona coast. Small ponds with a surface area of less than 100 square feet exist several hundred yards north of Keahole; however, the nearest ponds of exceptional value are the Kahanaiki Ponds located near Wawahiwaaa Point, 2.25 miles south of Keahole.

The quality of the surge channel water near Wawaloli Beach is influenced by the basal lens discharge to the extent that the coastal water quality standards are exceeded in terms of nitrogen and phosphorus (WRRC, 1980). The principal sources of the nutrients in

the basal lens are, however, believed natural rather than man-made. Likewise, the ocean water also exceeds the same nutrient standards.

Previous investigations by the Water Resources Research Center of the University of Hawaii (Adams et al., 1969) found no unusual groundwater conditions in the Keahole region. The infrared scan of the coastline did not show any evidence of substantial freshwater outflow. The resistivity traverse indicated evidence of only brackish water at elevations below the 300-foot topographic contour, lying about 2 miles inland, and interpretation of the audio-magnetotelluric survey suggested the presence of only a very thin layer of fresh water.

Observations made by the Water Resources Research Center of the University of Hawaii (1980) in conjunction with the geophysical results of previous studies show that an unconfined Ghyben-Herzberg lens containing brackish water underlies the area to at least 5 miles north of Keahole, at least 3 miles to the east, and more than 5 miles to the south. Evidently no structural or lithologic barriers interfere with hydraulic continuity throughout this region. The hydraulics of groundwater flow can therefore be described in terms of a highly permeable basaltic aquifer carrying a continuous thin basal lens of brackish water underlain by salt water.

The brackish water of the lens flows toward the coast along a regional gradient of about 1 foot per mile. The head in well 4360-1 (Kalaoa), 3 miles inland of Wawaloli Beach, was 3.2 feet when drilled, implying an average gradient of 1.1 feet per mile. Kanehiro and Peterson (1977) gave an average gradient of 1 to 2 feet per mile for the reach between Kiholo and Puako, north of Keahole. The brackish water discharges preferentially at indentations in the coast, such as Wawaloli Beach. Groundwater flow lines converge toward these indentations while diverging at head lands. The largest visible discharge of the lens in the Keahole area is near Wawaloli Beach.

The salt water below the lens in the near-shore area is alternatively driven inland and seaward by tidal action so that its dynamics cannot be expressed in terms of a unidirectional, uniform flow field. In hydraulic analysis, however, the salt water is usually treated as being static. This assumption avoids insuperable obstacles to both analytical and numerical solutions of the flow equations. The extrusive basalts of the Hualalai volcanic series are very permeable and, like most flank flows of the major volcanoes of Hawaii Island, constitute aquifers of exceptional hydraulic characteristics. For the area between Kiholo and Puako, 12 to 22 miles north of Keahole but including Hualalai lavas, Kanehiro and Peterson (1977) reported regional hydraulic conductivity of 3,369 feet per day as computed by tidal analysis and of 9,092 feet per day as computed from the flow equation in which the discharge was obtained by hydrologic budgeting. A probable outflow rate, from the lens, of 6.38 mgd/mile was calculated by the budget approach. For the Keahole area, a figure of 2 to 5 mgd/mile is likely based on comparison of drainage area sizes (Keahole vs Kiholo and Puako).

Hydraulic conductivity values of the above order are applicable to the Keahole region. Expressed as a range, hydraulic conductivity is likely to be greater than 2,000 feet per day but less than 10,000 feet per day; the probable regional value is 4,000 to 5,000 feet per day. On a local scale, of about 100 feet or less, the hydraulic conductivity may be very low or extremely high, but for aquifer analysis a regional value of 5,000 feet per day is reasonable. Effective porosity of basalts cannot be conveniently measured; a conservative value of 0.10 is commonly employed.

Hawaiian basalt aquifers are anisotropic with respect to hydraulic conductivity. This anisotropy is a result of layering of sequential lava flows in the seaward direction, and as a result lava tubes oriented in the direction of the flow. The layering tends to orient highly permeable zones such as clinker layers between flows in a seaward direction. Estimates of the ratio of anisotropy have ranged from 5-1 to 200-1, horizontal to vertical. The basalts in the Keahole area are also highly fractured, and in localized areas may transmit water more readily vertically than horizontally. The overall anisotropy would therefore be expected to be at the lower range, approximately 5-1.

The groundwater lens is characterized as an unconfined, thin lens with a typically flat gradient and a flow direction from the mountains toward the ocean. The 1980 University of Hawaii study showed that the coastal part of the lens experiences appreciable ocean tidal influence. At distances of up to 336 feet inland, tidal efficiencies ranges from 69 percent to 100 percent. Further inland at 600 feet, the efficiencies decreased to 43 to 68 percent. There is no simple accurate method for separating the tidal component from the head measurement to reveal the true groundwater head associated with the unidirectional ambient seaward flux. Also, it is not possible to measure the actual basal lens thickness without a drilled hole of sufficient depth. By applying the Ghyben-Herzberg ratio, however, the approximate thickness is calculated to be less than 125 feet within the area of concern.

ON-LAND OCEAN WATER DISPOSAL

It is anticipated that the OTEC activities will generate an ocean water outflow quantity of approximately 16,100 gpm. From additional mariculture operations at NELH, an ocean water outflow quantity of approximately 25,900 gpm is anticipated. Therefore, additional ocean water outflow quantity may eventually approach 42,000 gpm at full development.

Three possible schemes of on-land disposal have been studied to return the anticipated outflow quantity to the ocean. The disposal schemes examined involve possible combinations of shallow trench and deep well disposal. The disposal schemes examined are:

- o Disposal of OTEC discharges by deep wells, and disposal of mariculture discharges in a shallow trench along the existing road towards HOST Park (See Plot Plan, Plate 1).

- o Disposal of OTEC and/or mariculture discharges in a shallow trench along the existing road towards HOST Park.

- o Disposal of OTEC discharges in a shallow trench within the NELH laboratory compound and disposal of mariculture dishcarges in a shallow trench along the existing road towards HOST Park.

The disposal schemes are similar in the basic engineering concept, which is to convert the used ocean water into groundwater flow. The schemes would take advantage of the storage capacity, porosity, and the filtration effect of the lava formation to provide dispersion, diffusion and residence time before the water is discharged to the ocean as underwater seepage flow along the coast. In addition, both the deep well and shallow trench disposal schemes would utilize gravity as the prime moving force and thus conserve energy.

The hydraulic and environmental impacts of the disposal schemes were evaluated by means of analytical computer modeling. The basic hydraulic parameters such as coefficient of storage, coefficient of transmissibility, porosity, hydraulic conductivity and transmissive flux were obtained from published data of the basaltic aquifer in the Keahole region. The detailed assumptions and findings are presented in the Appendix.

EFFECTS OF ON-LAND OCEAN WATER DISPOSAL

Disposal of OTEC Discharges by Deep Wells

The disposal of OTEC discharges (16,100 gpm) by deep wells was modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on offshore bathymetric data. The bathymetric data indicates that the -300 foot bathymetric contour runs approximately north to south at a distance of roughly 800 feet offshore from Keahole Pt. at the closest point. Based on this data, the ocean boundary was modeled using an image well point equidistant from the approximate north to south -300 foot bathymetric contour. Injection below -300 feet was selected based on injecting below the ocean thermocline.

Because of higher density due to lower temperature, and relatively close proximity to the shoreline, the injected OTEC discharges were modeled based on the flow being confined to a zone from elevation -300 to -400 feet. It is anticipated that the discharge would actually not be confined to this zone, but may go deeper due to lower temperatures and consequent higher densities relative to the ambient groundwater. There would also be a tendency for the sea water return to rise because of hydraulic head increases caused by injection. This tendency would, however, be somewhat counteracted by the density

(temperature) gradients and by the constant head condition imposed by the ocean when the seawater return water reaches areas overlain by the ocean. We therefore believe assuming a flow confined to the -300 to -400 foot zone would be appropriate and possibly conservative.

For the above modeling, we calculate that 85% of the discharge would occur over a distance of 30,000 feet along the -300 foot bathymetric contour, an average of 660 gpd/foot. Assuming that the flow was distributed evenly between the -300 to -400 foot contour would result in an average of 1.2 gpd/square foot of ocean bottom in this zone. Discharge would actually be greater in offshore areas in near proximity to the injection point. At these locations, the flow would be approximately 2.9 gpd/square foot between the -300 and -400 bathymetric contours. The distribution of deep well injection discharge is depicted on Plate 2.

A minimum residence time of approximately three months is calculated, using an expanding cylinder model (see Appendix).

Disposal of OTEC Discharges in a Shallow Trench within NELH Laboratory Compound

The disposal of OTEC discharges (16,100 gpm) in a shallow trench within the NELH laboratory compound was modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on shoreline geometry. Keahole point is formed by the confluence of an approximate north-south and an east-west shoreline. Based on this, and because disposal would occur close to the shoreline (within approximately 100 feet of the shoreline at the closest point) the disposal was modeled using three image well points, in accordance with the theory of images, to model the two perpendicular ocean boundaries.

For the above modeling, we calculate that 67% of the discharge would occur over a horizontal distance of 600 feet along the shoreline, an average of 26,000 gpd/foot. Assuming that the flow was distributed evenly between the 0 to -50 bathymetric foot contour would result in an average of 26 gpd/square foot of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 72 gpd/square foot. If the trench were located 300 feet from the shoreline these concentrations would decrease by 50 percent.

Minimum residence times were calculated using an expanding sphere and expanding cylinder model (see Appendix). Because of the proximity of the shoreline, minimum residence times will be less than one day; the minimum residency time would increase to 2 to 3 days for a trench 300 feet from the shoreline.

Disposal in a Shallow Trench Along the Existing Road Towards HOST Park

The disposal of mariculture discharges (25,900 gpm) in a shallow trench was modeled using an analytical computer model based on the Theis non-equilibrium equation. Boundary conditions were set based on shoreline geometry. Keahole point is formed by the confluence of an approximate north-south and an east-west shoreline. Based on this, and because disposal would occur close to the shoreline (within approximately 750 feet of the shoreline at the closest point) the disposal was modeled using three image well points, in accordance with the theory of images, to model the two perpendicular ocean boundaries.

Based on average distance from the shoreline, and assuming an anisotropy of approximately 5 to 1, the flow was modeled for a flow thickness of 200 feet. For the above modeling, we calculate that 85% of the discharge would occur over a distance of 4,300 feet along the shoreline, an average of 7,300 gpd/foot. Assuming that the flow was distributed evenly between the 0 to -200 foot bathymetric contour would result in an average of 1.9 gpd/square foot of ocean bottom in this zone. Discharge would be greater in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 4.2 gpd/square foot.

For disposal of combined mariculture and OTEC discharges (42,000 gpm), the modeling indicates that 77% of the discharge would occur over a shoreline distance of 3800 feet, an average of 12,200 gpd/foot. Assuming that the flow is evenly distributed between the 0 and -200 foot bathymetric contour results in an average of 3.2 gpd/square foot of ocean bottom in this zone. Discharge is greatest in offshore areas closest to the discharge trench. At these locations, the flow would be approximately 5.9 gpd/square foot. Residence times were calculated using an expanding sphere and expanding cylinder model (see Appendix), and are tabulated below:

		Minimum Residence Time
Mariculture Discharge	25,900 gpm	29 to 62 days
Combined Discharge	42,000 gpm	18 to 38 days

Effects of Discharge on Groundwater

The proximity of the proposed discharges to the shoreline and the location on a point (Keahole) limits the effects on the groundwater table. The land configuration results in much less groundwater flow occurring under the site (due to the groundwater divergence caused by the presence of a point of land), and the presence of two ocean boundaries in near proximity to the discharge locations results in relatively rapid migration of discharges to the coastlines.

The deep well injection probably would not have significant effect on the thin lens of brackish water found in the general area. The injected OTEC discharges would be discharged in a zone from elevation -300 to -400 feet. We anticipate that the discharge would not be

confined to this zone, but may go deeper due to lower temperatures and consequent higher densities relative to the ambient groundwater. There would also be a tendency for the sea water return to rise because of hydraulic head increases caused by injection. This tendency would, however, be somewhat counteracted by the density (temperature) gradients and by the constant head condition imposed by the ocean when the seawater return water reaches areas overlain by the ocean. We therefore believe assuming a flow confined to the -300 to -400 foot zone may be appropriate.

The primary effect caused by disposal in shallow trenches would be the disruption and displacement of the existing brackish water lens. The lens is unsuitable for groundwater development, but apparently is the source of water for some stands of kiawe trees located north of Keahole Point. Trees that have deep root systems that reach the groundwater level probably would not survive the displacement of the brackish water lens by the saline ocean water plume.

The disposal by trenches would displace the existing groundwater flow in the immediate vicinity of Keahole Point. The area of displacement varies with the amount of discharge and locations, with the discharge of OTEC discharges within the NELH laboratory compound having the least effect, and the discharge of combined OTEC and mariculture discharges at the road towards HOST park having the largest effect. Flow nets showing flow patterns for the various discharges analyzed are presented on Plates 3 through 5.

The brackish water lens also is the source of water for some anchialine ponds in the vicinity of Wawahiwaa Point approximately 2 miles south of the proposed ocean water disposal area of the NELH site. These ponds are not within the projected disposal plume, for NELH discharge.

The effect of the discharge of the ocean water return into the ocean is being analyzed separately. The rate of discharge per unit area is much greater for the trench discharge than for the deep injection well, particularly for the trench within NELH. However, the the ocean water return would be nearly indistinguishable from the ocean water it is merging with.

DESIGN CONSIDERATIONS

Deep Well Disposal

Large diameter deep disposal wells have been used successfully in Hawaii to dispose of large quantities of treated industrial wastewater. For the OTEC activities, a disposal requirement of 16,100 gpm it is estimated that 4 wells (2 primary and 2 backup) would be needed. The wells would be located immediately makai of the NELH laboratory. The wells would be approximately 2 feet in diameter, 400 feet deep and spaced at least 100 feet apart. The wells would be cased with solid casing from 0 to 300 feet to limit discharge to a

depth below 300 feet and with either open hole or slotted casings from 300 to 400 feet. The wells may need to be deepened if low permeability zones are encountered which reduce capacity. It is estimated that each well could handle about 11.5 mgd (8,000 gpm). Therefore, for a 16,100 gpm operation, only 2 of the 4 wells will be operating. The extra wells are standby capacity for planned maintenance or in case of 1 or more wells becoming inoperative due to clogging. The piping system and well head design would require careful engineering for smooth operation and ease of maintenance.

Alternatively, a forced injection system can be used. However, it would be a complex mechanical installation that would require continuous electrical energy consumption and frequent maintenance. Therefore, a forced injection system is not recommended for NELH.

Shallow Surface Trench Disposal

Proposed locations of shallow surface trench disposal are along the roadway alignment from NELH towards the proposed HOST Park and along the makai boundary of the facility or inland within the NELH compound. We understand that current planning calls for trench excavation, and replacement with a perforated pipe and large boulder backfill. This would not enable maintenance of the trench, but the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required during the phased development of NELH activities.

For the roadway towards the proposed HOST Park, the proposed disposal trench orientation is roughly parallel to and approximately 750 feet from the shoreline. The ground elevation in the area is approximately 10 feet above sea level. For disposal of the anticipated projected quantity of ocean water of 16,100 gpm from the OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 225 feet long. For planning purposes, it would be prudent to allow for twice the theoretical trench length. The extra trench length would provide an allowance for non-homogeneity of the hydrogeologic characteristics of the proposed disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage. The trench should also be designed to allow for extension, if additional capacity is required or to replace clogged areas.

The performance of the disposal trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench can then be incrementally extended to handle more disposal quantity as NELH facilities expand. Theoretically, a 362-foot disposal trench 5 feet wide by 5 feet deep could handle the projected additonal disposal quantity of 25,900 gpm from mariculture operations. Therefore, for the total proposed addtional ocean water outflow of 42,000 gpm, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 587 feet long.

The available length of the disposal area is more than 2,000 feet. The length of the trench, however, can be shortened by digging a deeper trench. A 10-foot wide by 10-foot deep trench would require theoretical trench lengths of 98 feet, 158 feet, and 256 feet, respectively for disposal quantities of 16,100, 25, and 42,000 gpm, respectively, without allowing for any safety factors.

For the trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly parallel to and approximately 100 feet from the shoreline. For disposal of the anticipated projected quantity of ocean water of 16,100 gpm from the OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 144 feet long. A ten foot wide by ten foot deep trench would require a theoretical trench length of 59 feet. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

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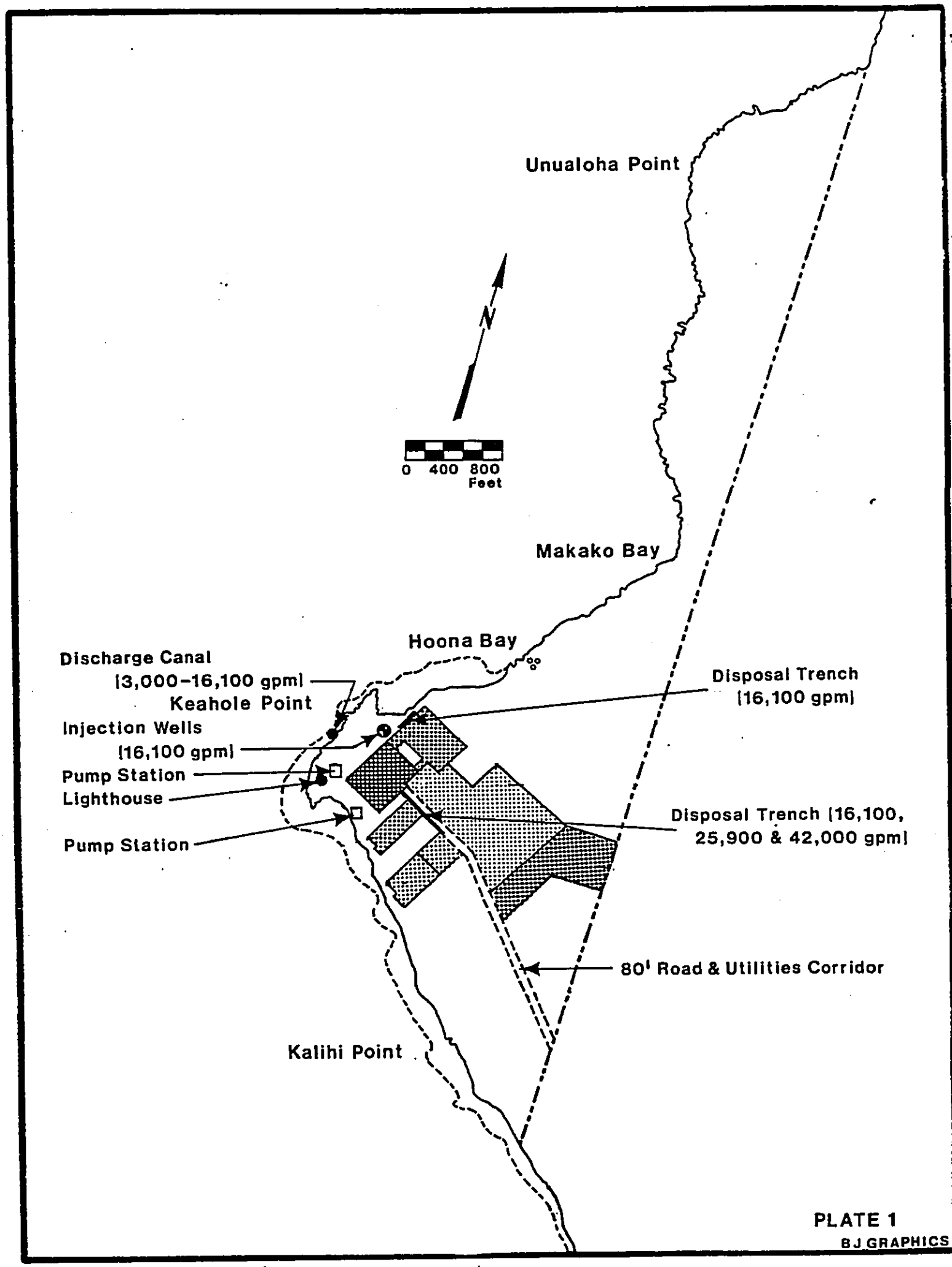
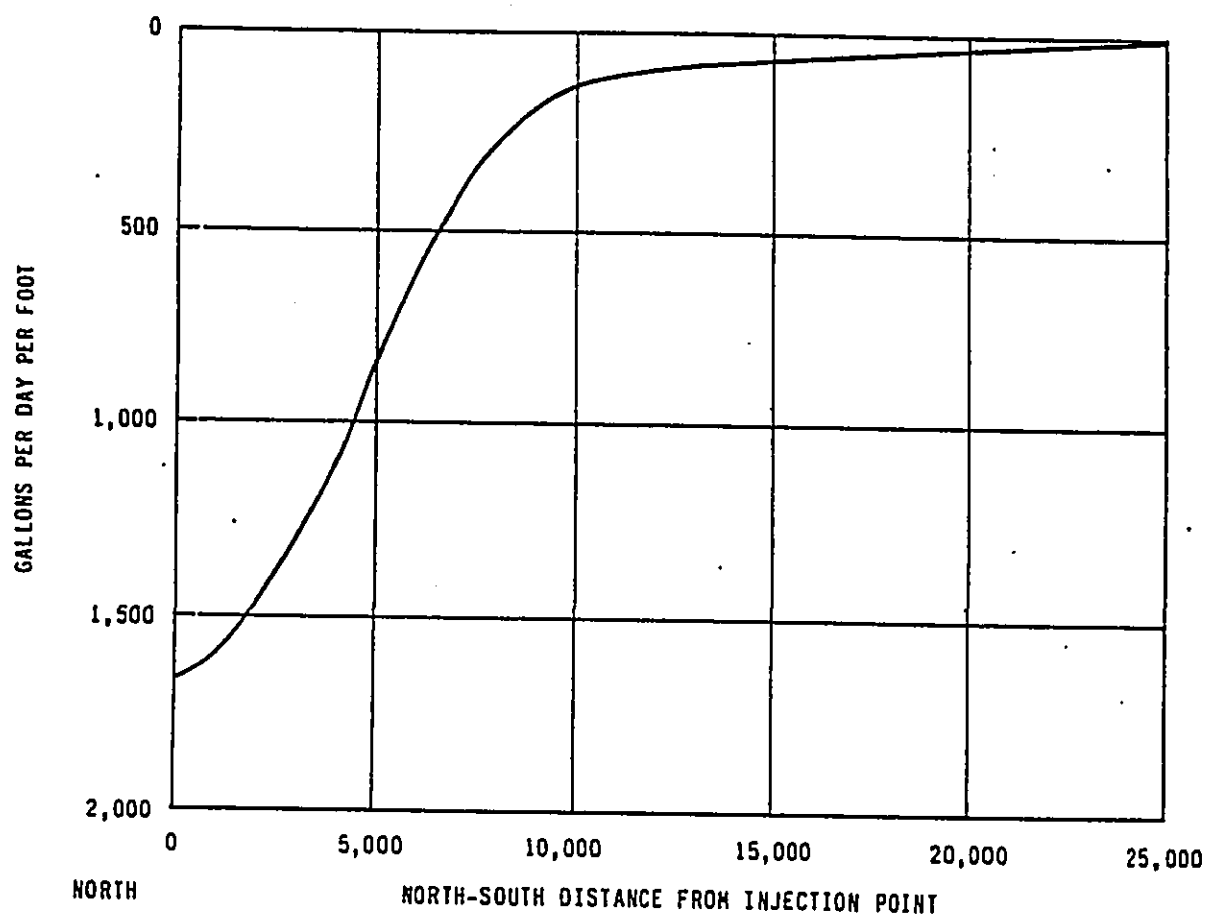
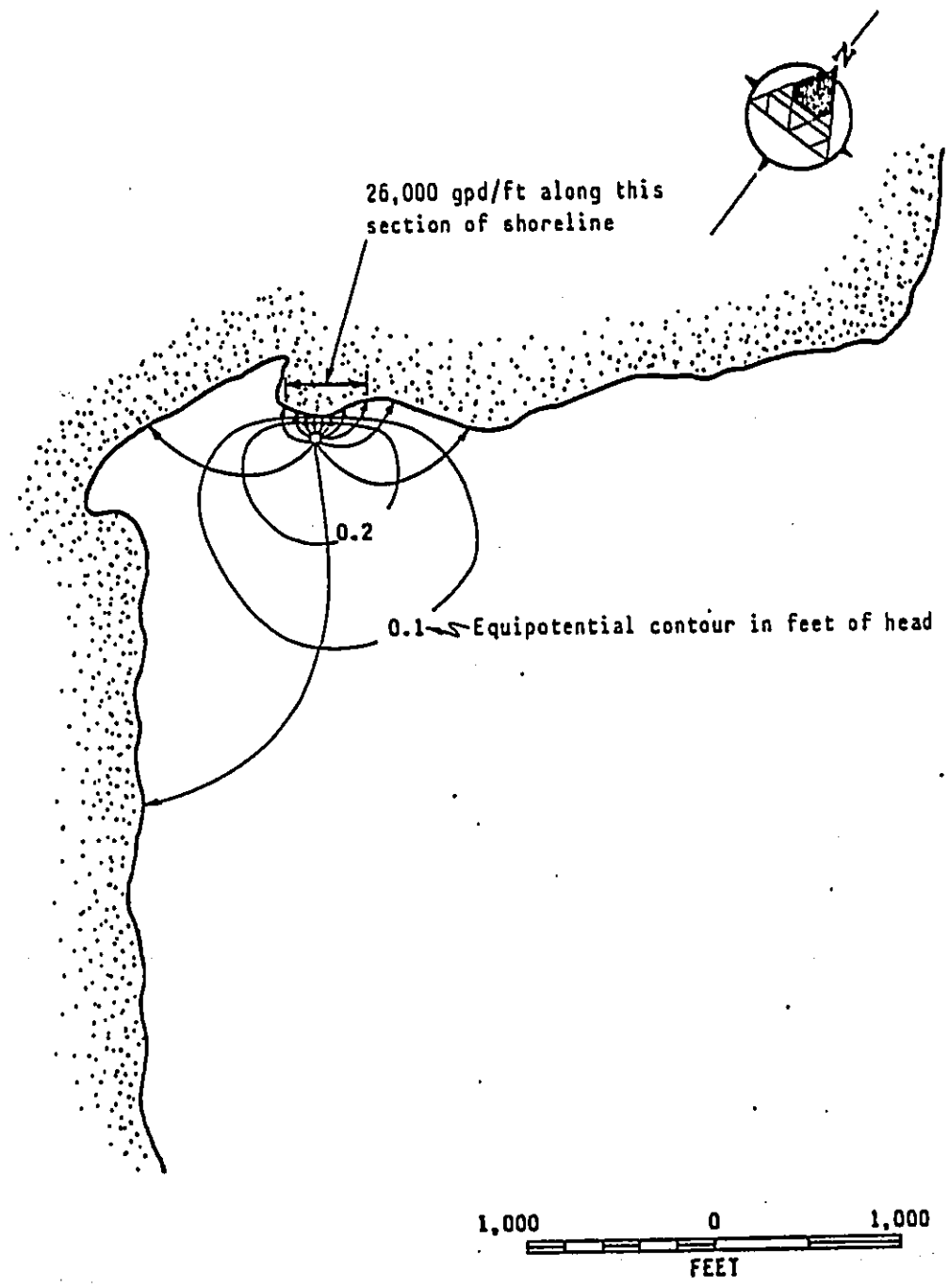
Water Resources Research Center, University of Hawaii, 1980, Proposed Prototype Testing Program, Land Disposal by Injection Wells of Ocean Water Effluent at Seacoast Test Facility, Keahole Point, Hawaii Island.


Unualoha Point
N
0 400 800
Feet
Makako Bay
Hoona Bay
Discharge Canal
(3,000-16,100 gpm)
Keahole Point
Injection Wells
(16,100 gpm)
Pump Station
Lighthouse
Pump Station
Disposal Trench
(16,100 gpm)
Disposal Trench (16,100,
25,900 & 42,000 gpm)
80' Road & Utilities Corridor
Kalihi Point
PLATE 1
BJ GRAPHICS



DISTRIBUTION OF DEEP WELL INJECTION DISHCARGE (16,100 GMP)
ALONG APPROXIMATE -300-FOOT CONTOUR

PLATE 2
DAMES & MOORE

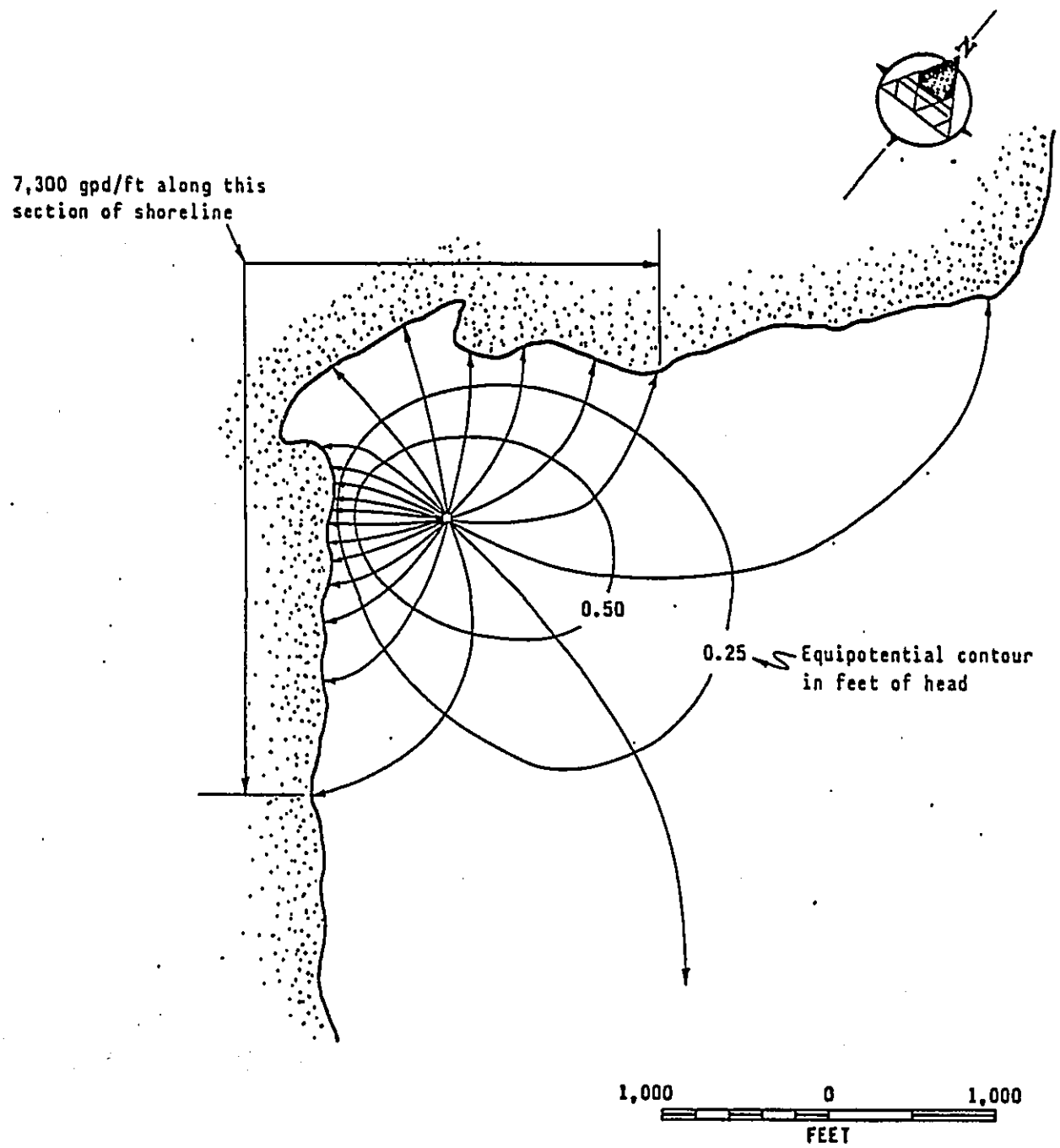


FLOW NET

DISCHARGE TO DISPOSAL TRENCH WITHIN NELH

(16,100 GPM)

PLATE 3
DAMES & MOORE

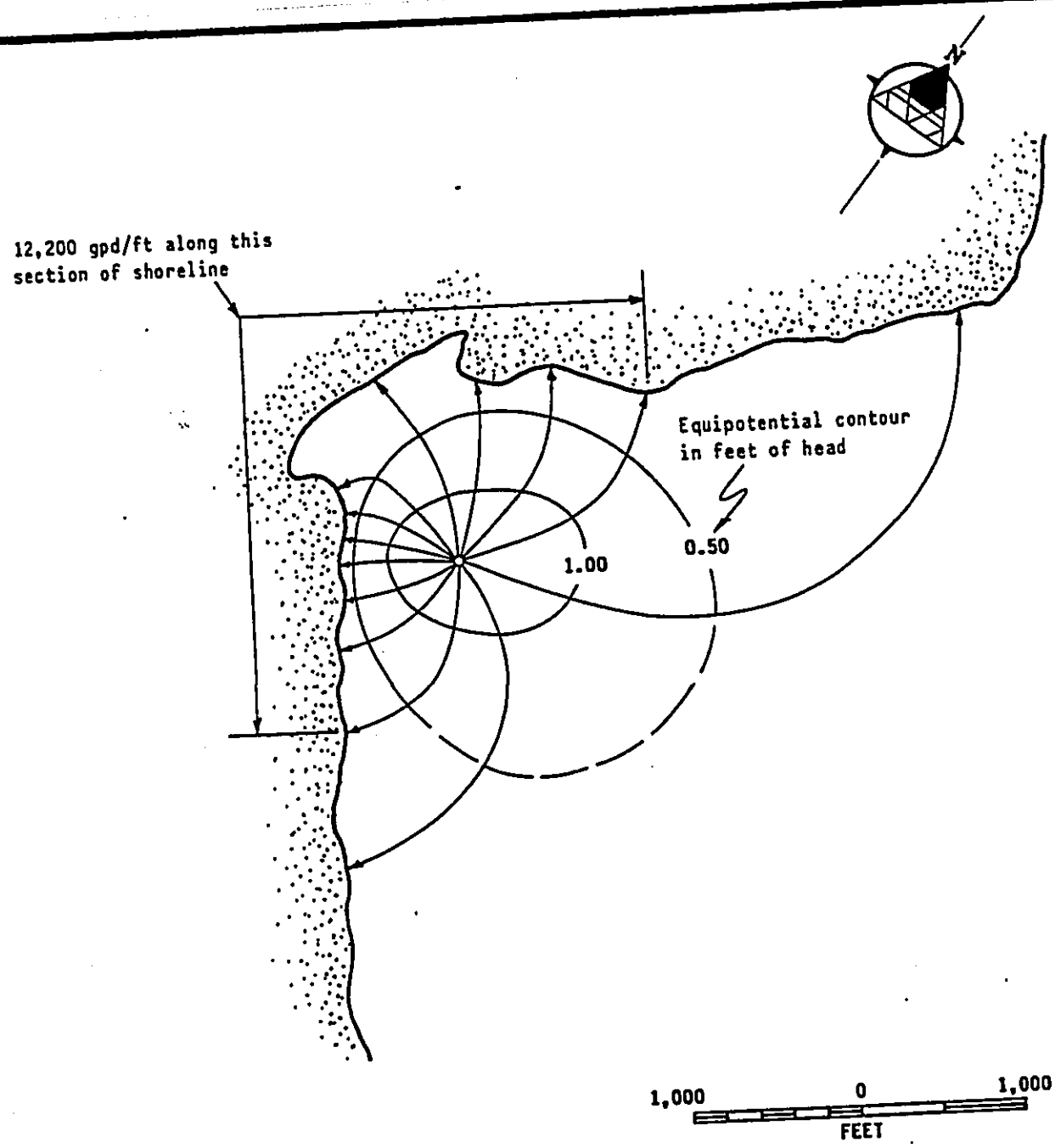


FLOW NET

DISCHARGE TO DISPOSAL TRENCH ALONG ROADWAY TO NELH

(25,900 GPM)

PLATE 4
DAMES & MOORE



FLOW NET

DISCHARGE TO DISPOSAL TRENCH ALONG ROADWAY TO NELH

(42,000 GPM)

PLATE 5
DAMES & MOORE

APPENDIX

HYDRAULICS OF ON-LAND OCEAN WATER DISPOSAL

1. Known Hydraulic Parameters and Assumptions.

a) The regional hydraulic conductivity k is assumed to be 5,000 ft/day. Hydraulic conductivity values reported by Kanehiro and Peterson (1977) were 3,369 ft/day as computed by tidal analysis and 9,032 ft/day as computed from the flow equation.

b) The effective porosity n of lava formations is assumed to be 0.10.

c) The ocean water to be disposed is assumed to be relatively free of solids, contaminants and entrained air.

2. Shallow Trench Disposal at Roadway towards HOST Park

For shallow trench disposal at the roadway towards HOST Park, it is assumed that the trench would be 5 feet wide and 5 feet or 10 feet wide and 10 feet deep with the trench bottom close to the groundwater level due to the low ground elevation at the site. It is anticipated that the half-cylinder shaped plume analysis would be relevant for this site.

Total disposal quantity equation for the half-cylinder shaped plume is:

$$Q = \frac{k\pi s x}{\ln\left(\frac{r_e}{r_o}\right)} \qquad (1)$$

where,
Q = the total disposal quantity = 23 mgd, 37 mgd, and 60 mgd
k = hydraulic conductivity = 5,000 ft/day
s = injection head = 5 ft or 10 ft
x = length of trench
re = minimum distance from the trench to the coastline = 750 ft
ro = half width of the trench = 2.5 ft or 5 ft

For a 5 feet wide and deep trench, solving the equation for x yields trench lengths of 225 feet, 362 feet, and 587 feet for disposal quantities of 23 mgd, 37 mgd, and 60 mgd, respectively. For a 10 feet wide and deep trench, solving the equation for x yields trench lengths of 98 feet, 158 feet, and 256 feet for disposal quantities of 23 mgd, 37 mgd, and 60 mgd, respectively. These distances should be multiplied by an appropriate factor of safety for design.

3. Shallow Trench Disposal Within the NELH Laboratory Compound

For shallow trench disposal within the laboratory compound, it is assumed that the trench would be either 5 feet wide and 5 feet deep or 10 feet wide and 10 feet deep with the trench bottom close to the groundwater level due to the low ground elevation at the site. It is anticipated that the half-cylinder shaped plume analysis would be relevant for this site.

For a 5 feet wide and deep trench, solving equation 1 for x yields a trench length of 144 feet for a disposal quantity of 23 mgd. For a 10 feet wide and deep trench, solving the equation for x yields a trench length of 59 feet. This distance should be multiplied by an appropriate factor of safety for design.

4. Deep Well Disposal.

The feasibility of ocean water disposal by wells was examined by using the Theis non-equilibrium equation:

$$S = \frac{Q}{4\pi T} \int_{u}^{\infty} \frac{e^{-u}}{U} \, du \qquad (2)$$

where, s = drawdown or build up of water level in a well
Q = disposal rate
T = coefficient of transmissibility
$U = r^2 S/4Tt$

where, S = coefficient of storage
t = time since disposal started
r = distance from well

A computer program, consisting of a solution of the Theis non-equilibrium equation modified to include the interference effects from multiple wells, was applied to study the hydraulics of disposal by wells.

The following hydraulic properties were used for the lava formation: the coefficient of transmissibility (T), 3,740,000 gpd/foot (for K = 5,000 [illegible]day), effective aquifer thickness in well vicinity of 100 feet); the coefficient of storage [illegible] 0.1.

5. Shallow Trench Disposal.

The feasibility of ocean water disposal by shallow trenches were also examined by modeling the trenches as shallow wells and using the Theis non-equilibrium equation.

The ocean boundary was modeled using image pumping wells located equidistant from and on the opposite side of the ocean boundary.

The ocean boundary was modeled using image pumping wells located equidistant from and on the opposite side of the ocean boundary. For the model, the injection zone was assumed to be a confined aquifer and the ocean boundary assumed to be the contact zone of the injection zone with the ocean floor.

6. Residence Time Computation for Enlarging Sphere Model

Point disposal of a volume per unit time is expressed as:

$$Q \quad dt = \frac{4 \cdot n \cdot \pi (r+dr)^3}{3} - \frac{4 \cdot n \cdot \pi \cdot r^3}{3} \tag{6}$$

where,
- Q = constant rate of disposal
- r = distance from point of disposal
- n = affective porosity = 0.10
- t = residence time

Eliminating the higher degree differentials give:

$$Q \cdot dt = 4 \cdot n \cdot \pi \cdot r^2 \cdot dr \tag{7}$$

and by integration,

$$r = \left(\frac{3 \cdot Q \cdot t}{4 \cdot n}\right)^{1/3} \tag{8}$$

or

$$t = \frac{4 \cdot n \cdot \pi \cdot r^3}{3 \cdot Q} \tag{9}$$

7. Residence Time Computation for Enlarging Cylinder Model

The plume formed is envisioned to be an over enlarging cylinder. The governing equation is:

$$r = (Q \cdot t / n \cdot \pi \cdot z)^{1/2} \tag{10}$$

or

$$t = \frac{n \cdot z \cdot \pi \cdot r^2}{Q} \tag{11}$$

where, n = effective porosity = 0.10
z = aquifer thickness, for anisotrophy of 5 horizontal to 1 vertical, z would be 150 feet for a flow distance of 750 feet to the shoreline.
= 3.1416
r = distance to shoreline
Q = constant rate of disposal

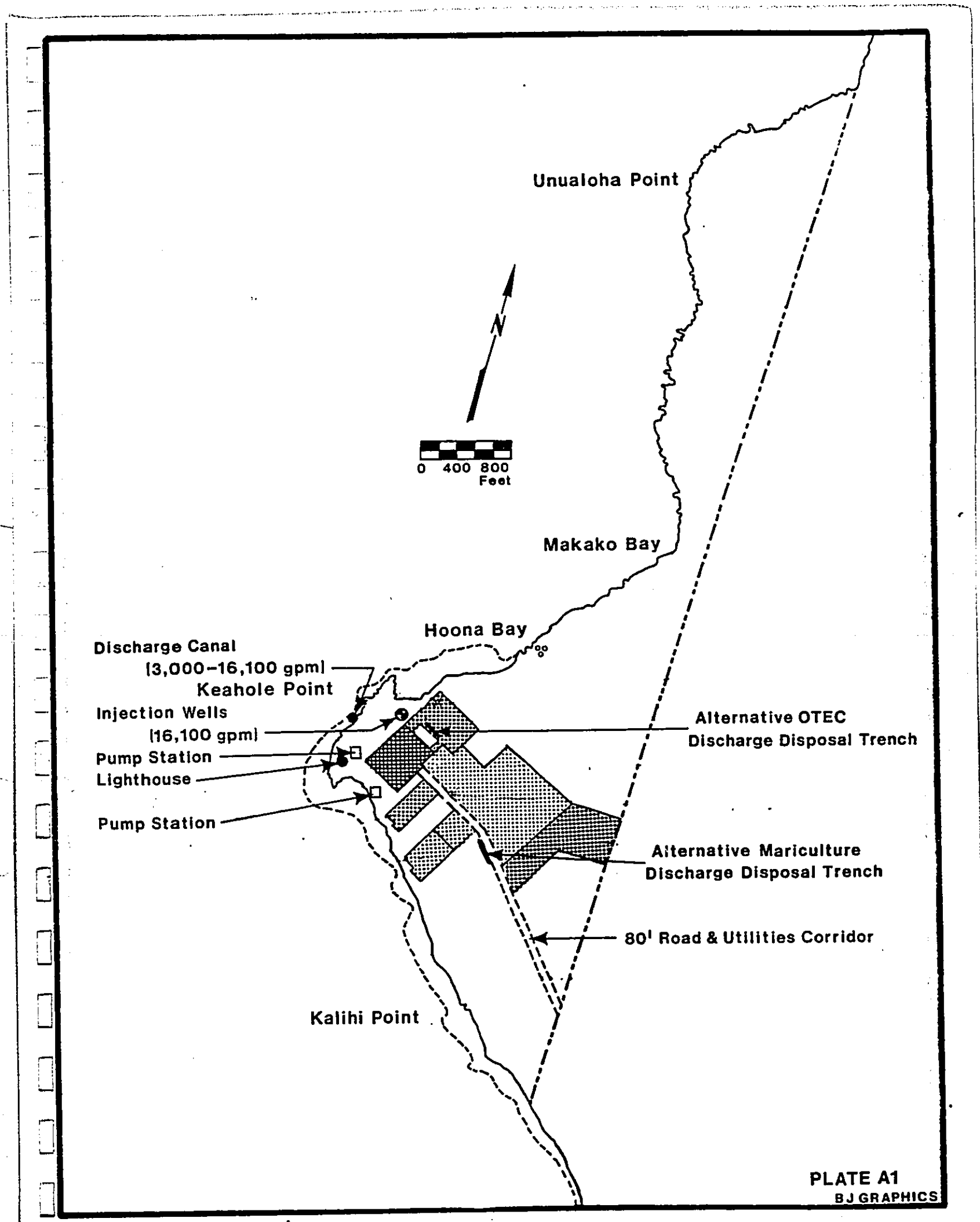
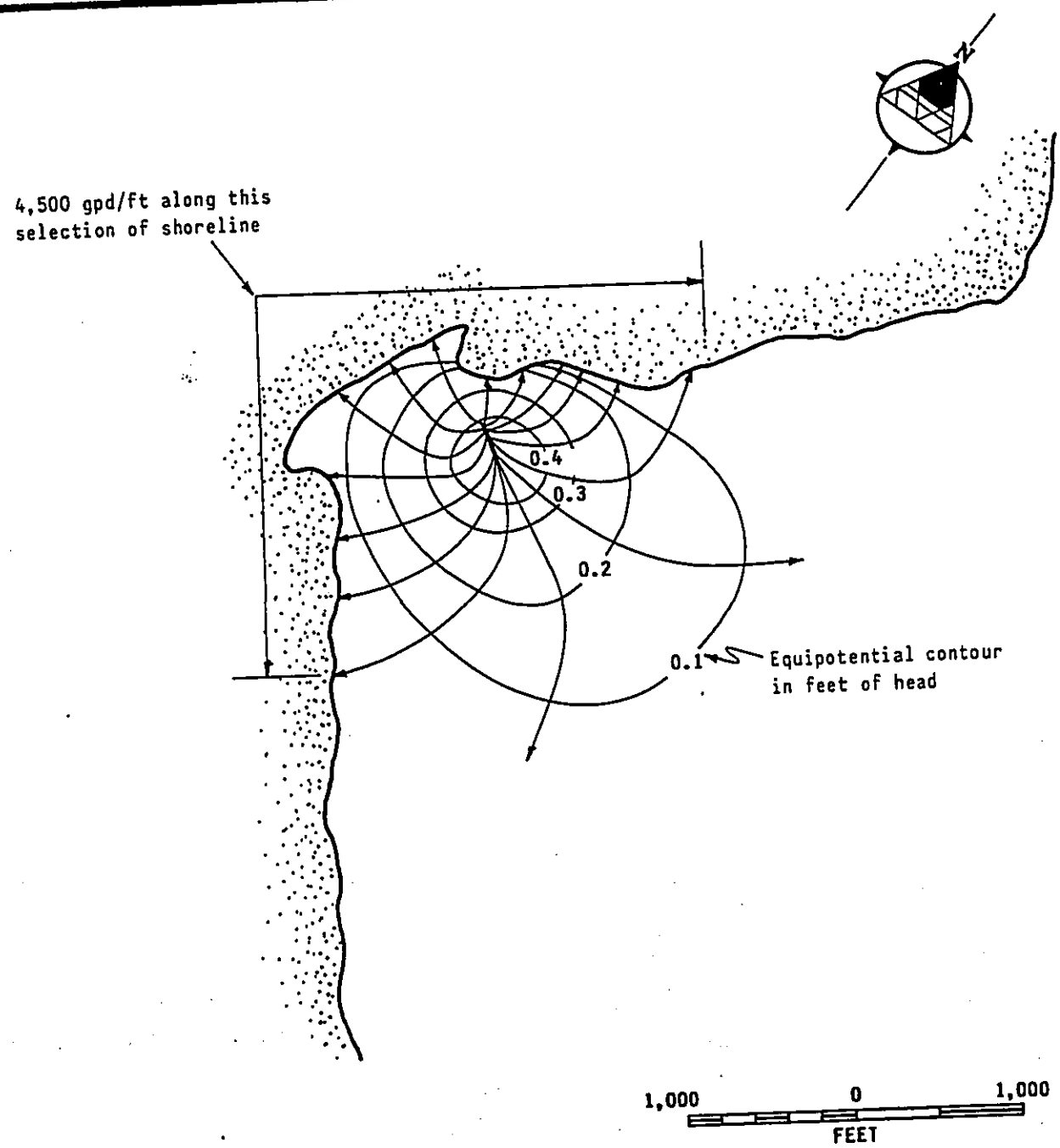


PLATE A1
BJ GRAPHICS



FLOW NET

DISCHARGE TO ALTERNATIVE DISPOSAL TRENCH WITHIN NELH

(16,100 GPM)

PLATE A2
DAMES & MOORE

APPENDIX D

HISTORIC PRESERVATION CONCERNS AT NELH

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DEPARTMENT OF LAND AND NATURAL RESOURCES

HISTORIC SITES SECTION

HISTORIC PRESERVATION CONCERNS -- NELH GENERAL PLAN

Inventory of Historic Sites

A total of 10 archaeological studies have taken place in the NELH parcel (Table 1). A Bishop Museum study (Clark 1984) summarized much of this work and concluded that all historic sites had been found -- a total of 24. The State's Historic Sites Section agrees with this conclusion and has recently conducted fieldchecks of many of these sites (Cordy 1986). Table 2 lists the sites and briefly describes them. Map 1 locates them.

The NELH parcel cuts across two traditional land units (ahupua'a), Kalaoa 4 and 5. Current findings suggest that a small prehistoric population settled Kalaoa 5 about A.D. 1500 and gradually expanded into Kalaoa 4 by A.D. 1600. The archaeological remains of the permanent dwelling sites are small clusters of pavings, platforms and enclosures found at sites D15-11, -12, -13, -14, -15 and D16-5, -6 and -12. These include remains of dwellings and work areas. These sites are small in area and contain shallow deposits. Archaeological population estimates based on these sites suggest that about 50 people lived in these ahupua'a at European Contact.

Other prehistoric sites present are two short-term or temporary occupation sites, caves D15-24 and -25. Also, prehistoric trails linked the permanent dwellings to their inland agricultural fields near today's Mamalahoa Highway. Remnants of trails are present near the Queen Kaahumanu Highway, and some of the trails found in NELH's parcel may be prehistoric.

Beginning in the mid-1800s, most of the population of the Keahole area of North Kona shifted their permanent residences inland among the agricultural fields, and permanent coastal housing was generally abandoned. An interesting exception is the cluster of high-walled enclosures and platforms between the NELH lab and the 1801 lava flow (D16-6 through -11). These are historic dwellings, but little is known about their age or why they were here. Trails (D16-14, -15, -16, -17) and shelter caves in NELH undoubtedly date to this period too.

The present condition of these NELH sites is fairly good. Some caves (D15-25, -26) were partly looted before 1975, and the filled crevices were looted between 1984 and 1986.

again, fortunately, these crevices proved not to be historic sites.) Waves and vehicles have caused some damage at D15-13. But, generally, the NELH sites are intact.

Significance

The significance of these sites has been assessed in consultation with the State's Historic Sites Section. Table 3 presents the assessments. All the sites still contain signficant information on the prehistory of this area. We still need to carefully evaluate the age of these sites to study settlement and population growth, to evaluate the patterning of remains to identify former activities at these sites and their locations, to evaluate food remains to determine exploitation patterns, and to better understand settlement in the late 1800s. These questions are important not just for understanding the Keahole Point area's history but also that of Kona and Hawaii Island in general.

Additionally, it has been agreed that 1 site and a set of 6 sites are also significant as excellent examples of types of sites within the North Kona region. Site D15-12 is a prehistoric permanent dwelling site which includes a nicely walled enclosure with an internal house platform and with external work structures, at least one petroglyph, and salt pans. Sites D16-6 through -11 are a complex of historic period (mid-1800s to early 1900s) dwellings and larger structures, including two canoe-houses and a modified anchialine pond.

Potential Impacts

Several impacts to these historic sites are expected in future development. First, as land is leased to prospective firms, land alteration and potential destruction will likely occur. Also, pipeline expansion to service NELH and HOST Park will likely occur, again with potential site destruction. Second, as the NELH/HOST shoreline is opened up and improved with parking and restroom facilities, increased recreational use may lead to inadvertent damage and littering at many of the sites. Toilet paper and some refuse already are present in some sites. Third, greater access might lead to site looting although recent studies by the Historic Sites Section indicate that looting at the coastal sites has generally not occurrred in this area since 1975, despite greater access. In sum, adverse impacts could well occur to all NELH's historic sites.

Mitigation Plans

Mitigation plans have been developed by NELH in consultation with the State's Historic Sites Section, and some have already been put into effect.

First, the 7 sites in the two site groupings that are significant as examples of types have been set aside for preservation. These are sites D15-12 and D16-6 through -11. These sites are in "no build" areas, and buffers to prevent direct and indirect damage have been determined in consultation with the Historic Sites Section. In the case of D15-12, the buffer will be marked with low posts. These sites will also have interpretive signs prepared by the Historic Sites Section. Public access to these sites will be maintained.

Second, the remaining 17 sites, those significant solely for their information content, will be protected until archeological data recovery occurs. Many of these sites may be protected permanently by choice of the leasees -- as an option to data recovery. To ensure protection, the borders of the accessible sites have been marked in company with Historic Sites Section staff and will be surveyed in on base maps, so planners, potential leasees and construction teams will know their locations. Litter problems are anticipated to be reduced by placement of trash cans at various locations along the shore and by the construction of restrooms in the HOST Park. The possibility of looting is expected to be reduced by closing off the NELH access road at night, by periodic patrol of the shore, and by public participation in notifying facility staff of such problems.

Archaeological data recovery plans have been prepared in detail by the Historic Sites Section, based on a review of prior work (e.g., Clark 1984) and fieldchecks. These plans are summarized in Table 4. These plans will be followed when archaeological data recovery is to occur.

It is recognized that an important part of archaeological data recovery is to ensure that the work is done correctly. To ensure this is done, each time data recovery is to occur, the Historic Sites Section and the County of Hawaii's Planning Department will review and approve the detailed scope of work, verify the satisfactory conclusion of fieldwork, and review and approve the final archaeological report.

Last, if new historic sites are discovered, such as hidden caves, these will be protected until the sites are documented, their significance is assessed and appropriate mitigation plans are developed in consultation with the Historic Sites Section and the County of Hawaii's Planning Department.

Table 1

References for Prior Archaeological Studies at the NELH Parcel

1. Reinecke, John 1930. Survey of Sites on West Hawaii. Bishop Museum Manuscript. On file, Historic Sites Section. [1930 Survey]

2. Ching, Francis Jr. and Deborah Cluff, Thomas Riley 1968-69. Preliminary Report of Archaeological Surface Survey & Salvage Operations at Keahole, North Kona, Hawaii Island. Section II Keahole Point Airport & Kailua-Kawaihae Road. Manuscript H-50. On file, Historic Sites Section. [1968-69 Survey]

3. Rosendahl, Paul and Patrick Kirch 1975. Archaeological Reconnaissance Survey of the Ke-ahole Point Natural Energy Laboratory Site, North Kona, Hawaii Island. Bishop Museum Manuscript 111775. On file, Historic Sites Section (H-81). [1975 Survey]

4. Cordy, Ross 1975. Scale maps of sites analyzed for Ph.D. work, with dates and interpretations. On file, Bishop Museum & Historic Sites Section. [1975 Survey w/excavations & dates]
   ------ 1978. A Study of Prehistoric Social Change: The Development of Complex Societies in the Hawaiian Islands. Ph.D. thesis, University of Hawaii. [Same 1975 study]
   ------ 1981. A Study of Prehistoric Social Change: The Development of Complex Societies in the Hawaiian Islands. New York, Academic Press. [Same 1975 study]

5. Rosendahl, Paul 1976. Additional Archaeological Reconnaissance Survey at the Ke-ahole Point Natural Energy Laboratory Site, North Kona, Hawaii Island. Bishop Museum Manuscript #111775 Appendix. On file, Historic Sites Section (H-81). [1976 survey]

6. Rogers-Jourdane, Elaine 1978. Archaeological Reconnaissance Survey of NELH Facilities Area at Keahole Point, North Kona, Hawaii. Bishop Museum Manuscript #061378. On file, Historic Sites Section (H-82). [1978 survey]

7. Rosendahl, Paul 1980. Intensive Archaeological Survey and Salvage Excavations at the Natural Energy Laboratory Hawaii (NELH) Site, Ke-ahole Point, North Kona, Hawaii Island: Final Report. Paul H. Rosendahl Company Manuscript 2-123179. On file, Historic Sites Section (H-81). [1978 survey w/excavations and dates]

8. Clark, Stephan 1984. An Archaeological Reconnaissance of Natural Energy Laboratory Hawaii (NELH) Property, Keahole Point, North Kona, Hawai'i. Bishop Museum Manuscript 110784. On file, Historic Sites Section H-439). [1984 survey & summary of prior work]

9. Cordy, Ross 1985. Working Paper 1. Hawaii Island Archaeology: Ooma & Kalaoa Ahupua'a, Kekaha, North Kona. Manuscript. On file, Historic Sites Section. [Summary of prior work]

10. Cordy, Ross 1986. Field Check of Some Sites in the NELH Property. Kalaoa 5 Ahupua'a, Keahole Point, North Kona, Hawaii. Manuscript. On file, Historic Sites Section. [1986 fieldcheck]

All these reports are on file at the Historic Sites Section, Dept. of Land & Natural Resources, State of Hawaii. The public may consult these reports at that office.

Table 2

List of Sites in the NELH Parcel

Site	Function	Nature
Kalaoa 4 -- North of NELH Lab (13 sites)		
D16-5	Permanent Dwelling	Enclosure with papamu
D16-6	Permanent Dwelling	Enclosure with internal enclosure & external platform
D16-7	Permanent Dwelling	Long, narrow enclosure & 2 platforms
D16-8	Permanent Dwelling	2-sided enclosure with cement foundation
D16-9	Permanent Dwelling	Long, narrow enclosure, C-shaped enclosure, modified anchialine pond
D16-10	Unknown	Enclosure
D16-11	Permanent Dwelling	Enclosure
D16-12	Permanent Dwelling	Enclosure, terrace
D16-13	Short-term occupa.	Cave
D16-14	Trail	Opihi-shell lined
D16-15	Trail	Opihi-shell lined
D16-16	Trail	Stepping stone
D16-17	Trail	Opihi-shell lined
Kalaoa 5 -- South of the NELH Lab (11 sites)		
D15-11	Permanent Dwelling	4 enclosures
D15-12	Permanent Dwelling	Enclosure, 2 platforms
D15-13	Permanent Dwelling	Platform
D15-14	Permanent Dwelling	Platform, 2 enclosures
D15-15	Permanent Dwelling	10 features = 2 enclosures, platform, 2 caves, 2 pools, etc.
D15-21	Unknown	8+ filled crevices*
D15-22	Unknown	Filled crevice*
D15-23	Unknown	Small platform, enclosure
D15-24	Short-term occupa.	Cave, C-shaped enclosure
D15-25	Short-term occupa.	Cave, platform
D15-26	Unknown	Stone cairn

*A 1986 fieldcheck indicates that these may not be historic sites (Cordy 1986). This is being further evaluated.

Table 3

Significance Determinations of the NELH Sites

Site	Information Content	Example of Site Type
Kalaoa 4 -- North of the NELH Lab		
D16-5	x	
D16-6	x	x
D16-7	x	x
D16-8	x	x
D16-9	x	x
D16-10	x	x
D16-11	x	x
D16-12	x	
D16-13	x	
D16-14	x	
D16-15	x	
D16-16	x	
D16-17	x	
Kalaoa 5		
D15-11	x	
D15-12	x	x
D15-13	x	
D15-14	x	
D15-15	x	
D15-21*	x	
D15-22*	x	
D15-23	x	
D15-24	x	
D15-25	x	
D15-26	x	

*These sites are filled crevices. 1986 fieldchecks (Cordy 1986) looked at many filled crevices and found none that were cultural sites. The remaining crevices will be checked, and if they also prove to be natural, these two sites will no longer be considered historic sites.

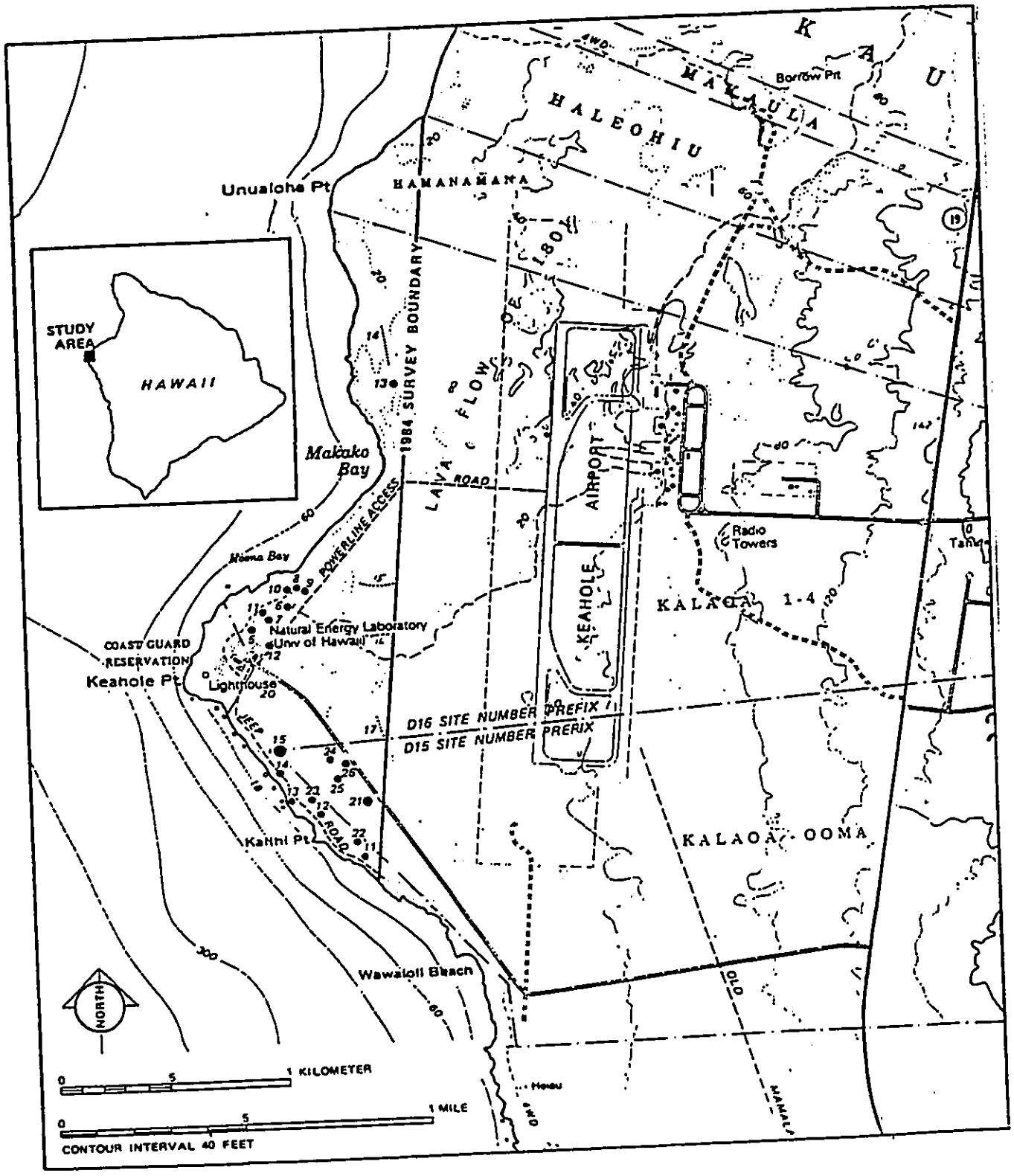
Table 4

Summary of Archaeological Data Recovery Tasks for NELH Sites

Site	Field Tasks		Post-Field Tasks	
	Mapping	Excavation*	Lab	Interpretation
Kalaoa 4 -- North of the NELH Lab				
D16-5		x	x	x
D16-12		x	x	x
D16-13		x	x	x
D16-14	x			x
D16-15	x			x
D16-16	x			x
D16-17	x			x
Kalaoa 5 -- South of the NELH Lab				
D15-11		x	x	x
D15-13		x	x	x
D15-14		x	x	x
D15-15	x	x	x	x
D15-21	Special problems**			
D15-22	Special problems			
D15-23		x	x	x
D15-24		x	x	x
D15-25		x	x	x
D15-26		x	x	x

* Surface collection will also be important besides excavation, and in sites with minimal deposits, surface collection will be critical.

** These sites need to be verified whether they are cultural or natural.



Map 1. Historic Sites in the NELH Parcel (Clark 1984).

APPENDIX E

IMPACTS OF OPEN CYCLE OTEC AND MARICULTURE DISCHARGES FROM THE NATURAL ENERGY LABORATORY OF HAWAII ON NEARBY ANCHIALINE PONDS

GK & ASSOCIATES

APPENDIX E

IMPACTS OF OPEN CYCLE OTEC AND MARICULTURE DISCHARGES
FROM THE NATURAL ENERGY LABORATORY OF HAWAII
ON NEARBY ANCHIALINE PONDS

GK & ASSOCIATES

October 13, 1986

ANCHIALINE POND BIOTA

Brock (1985) classifies anchialine pond organisms into two groups: epigeal, requiring sunlight, and hypogeal, occurring in both sunlit portions of the system and in the water table. The epigeal species are not unique to this habitat, but the hypogeal species are, and are thus the subject of conservation efforts. The hypogeal species include the endemic shrimps such as the opaeula.

DESCRIPTION OF NELH ANCHIALINE PONDS

The previous NELH/HOST Park EIS summarized the available literature on anchialine ponds within the site. Maciolek and Brock (1974) found three ponds on the present NELH site and six on the HOST Park site. The latter ponds have evidently filled in the intervening years, as recent surveys have failed to confirm their presence (M. Lee, Army Corps Eng., pers. comm. to M. Metz).

Of the three ponds found by Maciolek and Brock (1974) at NELH, one was less than 10 m^2 in area and the other two were between 10 and 100 m^2 in area. All were described as shallow with bottoms of rock and sediment. Salinities were in the range 7-8 ppt. Of the three, one was described as having trees, shrubs and emergent vines and succulents. The small (about 1 cm long) endemic red shrimp (opaeula), Halocaridina rubra, was found in one of the ponds, and the endemic prawn, Macrobrachium grandimanus, was found in two ponds.

On September 27, 1986, the anchialine ponds at NELH were examined. All three ponds were located, although at higher tides there is a very shallow surface interconnection between the two open ponds and they could be considered one pond. The more northerly pond covers an area of about 220 square feet and is about 125 feet inland from the ocean. Its bottom and sides are lava rocks with occasional reef rocks (Plate 1). Its maximum depth is about 1.5 feet and the salinity was 8 ppt. Deeper portions of this pond harbor growths of a green filamentous algae, probably Cladophora sp. (Plate 2) and a large snail population. Neither shrimp nor fish were observed in this pond, but it does connect with the other exposed pond to the south, and the latter has fish in the adjoining portion.

The more southerly pond is slightly deeper than its neighbor (about 2.5 feet at the center) (Plate 3). A single fish, possibly aholehole,

Kuhlia sandvicensis (Plate 4), and a crab (probably Metapograpsis sp.) were briefly observed in and around the deep portion which measured roughly 120 square feet. One portion of this pond is generally isolated from the latter area by a shallow rock sill, and in this area was a population of the endemic shrimp, H. rubra. Plate 5 shows the water exchange at high tide. Apparently the sill is effective in preventing entry of fish into this portion of the pond.

A third area of this pond is a nearly isolated circular basin about four feet in diameter and two feet deep. This area also supports a population of H. rubra (Plate 6). Where these opaeula are present, green algae are not apparent, and the dominant benthic flora is the typical anchialine pond cyanophyte community (Lyngbya and Schizothrix).

The third pond is located about 100 feet south of the exposed ponds. It's relatively large, with a surface area of approximately 750 square feet. Depth was about three feet at the deepest. (The tide was at about +2 feet, its highest point of the day.) The pond was beneath a fringing canopy of kiawe (Prosopis pallida). Around the pond were scattered to dense stands of the beach naupaka (Scaevola taccada) and pickleweed (Batis maritima) (Plate 7). This pond was slightly seaward of the two open ponds and the salinity was slightly higher, 10 ppt. A very dense growth of filamentous green algae was present, but neither fish nor shrimp were observed. The presence of the filamentous green algae indicates that the opaeula are absent because when they are present they crop this algae down and the blue-green algal community is visible. It may well be that there are fish present in this pond.

OTHER ANCHIALINE PONDS IN THE AREA

OI Consultants, Inc. (1985, 1986) examined the anchialine ponds at Kohanaiki, a land parcel immediately south of O'oma II also slated for resort development. The comprehensive baseline survey of anchialine ponds of the Kona coast by Maciolek and Brock (1974) identified the Kohanaiki ponds as having exceptional value, and potential impacts on these ponds were addressed in the modeling and analysis done for the previous HOST Park/NELH EIS. The OI surveys found a number of ponds not previously mentioned in the literature, bringing the total number known from that area to about 60. However, the biota of many of the ponds originally surveyed in 1972 by Maciolek and Brock (those in the northern half of the parcel, closest to the HOST Park/NELH site) has changed appreciably. Topminnows (Poeciliidae) are now present in these ponds, evidently at the expense of crustaceans and many algal species. The ponds in the southern half of the parcel remain of exceptional value in that they evidence the rich algal diversity and endemic crustacean fauna formerly found in the northern ponds. These southern ponds do not contain fish.

IMPACTS ON NELH ANCHIALINE PONDS

Disposal of the waste waters of NELH and the HOST Park into trenches will displace the groundwaters beneath the existing anchialine ponds at NELH. Because of the extent of the resultant subsurface plume, it does

not appear to be possible to mitigate this impact by altering the locations of the trenches. Rather, if mitigation is necessary, either an alternative to the disposal trenches could be implemented, or new habitat could be created. Alternatives to the trench disposal method are more expensive and may have greater impacts on the marine community.

It is now well documented that creation of anchialine habitat is possible. Borrow areas at Waikoloa were observed to flood at high tide. The Schizothrix community quickly established itself as did the opaeula and another endemic shrimp, Metabetaeus lohena (Army Corps of Eng., 1985). Test holes were colonized by opaeula within 10-14 days, indicating their ubiquitous nature in the water table. An artificial pond has been dug at Waikoloa to replace a portion of the habitat that has been lost through filling, and this pond is developing a typical anchialine ecosystem (Brock, pers. comm. to G. Krasnick, Oct. 11, 1986). Present plans at NELH do not include filling or otherwise physically altering any of the anchialine ponds there, so no habitat would be lost. Presumably this would mean that no replacement habitat is necessary if the displacement of groundwaters by NELH discharges does not reduce the quality of the habitat for the rare endemic shrimp species.

To the shrimp the primary differences between the groundwater and the NELH discharges would be the increased salinity and the reduced temperature. Brock (1985) reports that opaeula are found at salinities between 2 and 30 ppt, and temperatures between 22 and 30°C. Personal observations by Brock are that the opaeula will tolerate salinities to at least 45 ppt (Brock, LUC Testimony, Kona, Oct. 10, 1986). It therefore does not appear that replacement of the groundwaters with NELH discharge waters in the ponds will necessarily displace the endemic shrimp. Their diverse diet, consisting of detritus, benthic diatoms, phytoplankton, filamentous algae, vascular plant tissue and animal tissue (Wong, 1975), would allow ready adaptation if other components of the ecosystem would change. In sealed containers these shrimp seem to exist on bacterial films.

From the above, it does not appear that the impacts of disposal of NELH discharges into the ground will have a serious impact on the essential character of the nearby anchialine ponds. Nevertheless, the ponds should be monitored to observe any changes resulting from the NELH discharges. A monitoring program is outlined in Appendix C. Perhaps after establishment and thorough documentation of a new equilibrium condition, a restoration program could be implemented. This would consist primarily of fish removal.

Plate 1. Portion of northernmost exposed anchialine pond at NELH.

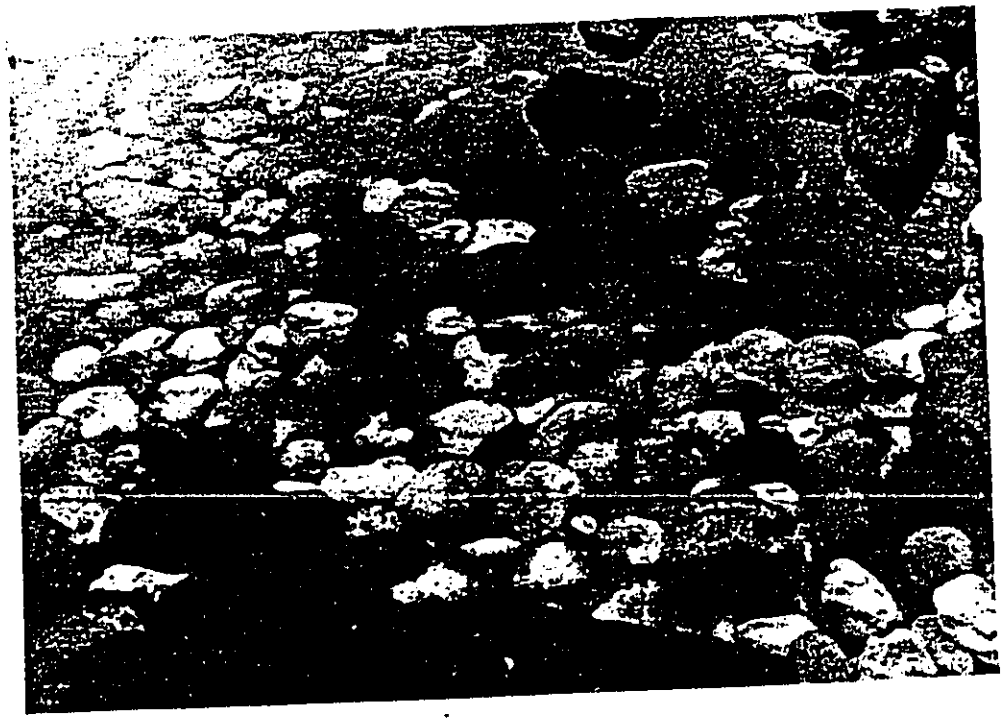


Plate 2. Deeper portion of northernmost exposed anchialine pond at NELH showing filamentous green algae.

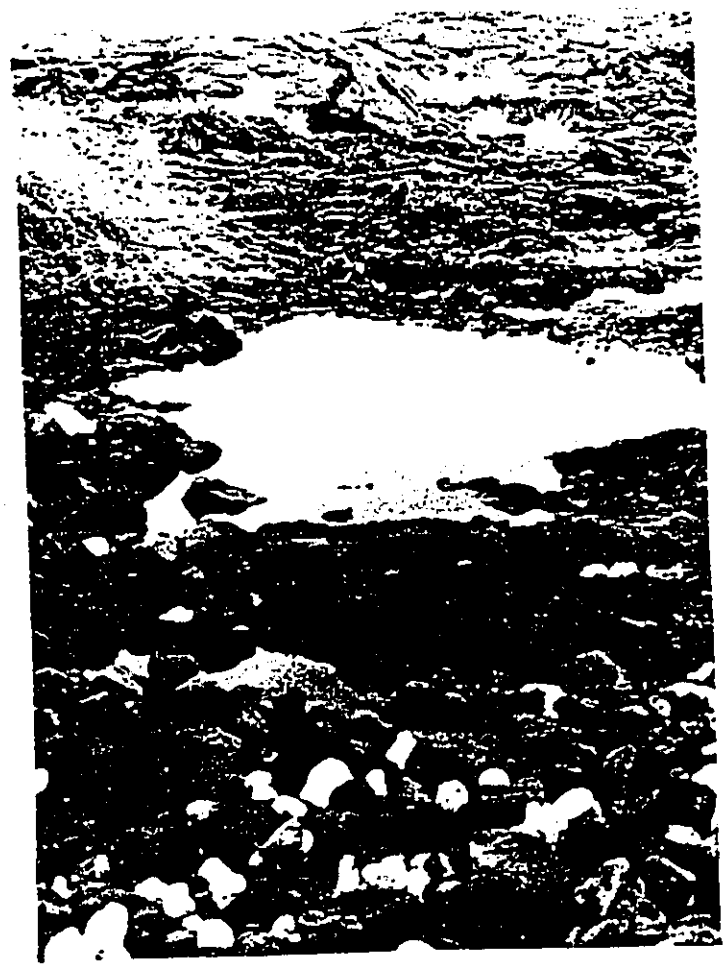


Plate 3. Southernmost exposed anchialine pond at NELH. Central portion contained fish but the small pool at lower center and the semi-isolated portion at the top contain the endemic *opaeula*.

Plate 4. Fish and filamentous green algae in deep section of southernmost exposed anchialine pond at NELH.

Plate 5. Sill separating portions of southernmost exposed anchialine pond at NELH containing fish or shrimp. Note floating green algae where fish are present.

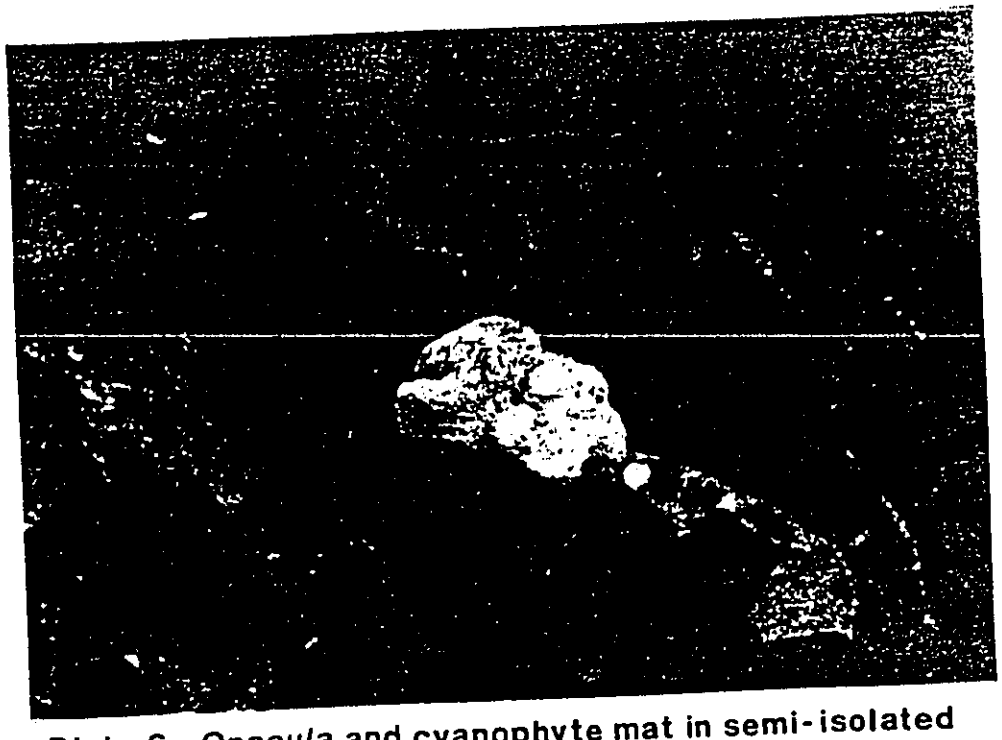


Plate 6. *Opaeula* and cyanophyte mat in semi-isolated basin at NELH.

Plate 7. Covered anchialine pond at NELH.

APPENDIX F

COST ESTIMATE DATA - PROPOSED DISPOSAL FACILITIES EXPANSION AT NELH

DAMES & MOORE

Dames & Moore

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(808) 735-3585
Cable Address: DAMEMORE

November 4, 1986
03014-119-11

R. M. Towill Corporation
677 Ala Moana Boulevard, Suite 1016
Honolulu, Hawaii 96813

Attention: Mr. Bud Villemont

Gentlemen:

Revised Cost Estimate Data
Proposed Disposal Facilities
Expansion of the NELH
Keahole, North Kona, Hawaii

Revised cost estimate data for the various disposal schemes are presented in this letter. These estimates are based on design considerations as discussed in the draft EIS, and discussions with contractors. Revised costs for an alternate trench location within the NELH compound are included.

Deep Well Disposal

Large diameter deep disposal wells have been used successfully in Hawaii to dispose of large quantities of treated industrial wastewater. For the OTEC activities, a disposal requirement of 23 mgd, it is estimated that 4 wells (2 primary and 2 backup) would be needed. The wells would be located immediately makai of the NELH laboratory. The wells would be drilled approximately 18 to 24 inches in diameter, 400 feet deep, and spaced at least 100 feet apart. For costing purposes, we have assumed the wells would be cased with 18" OD solid casing from 0 to 300 feet to limit discharge to a depth below 300 feet, and with 18-inch open hole from 300 to 400 feet. The wells may need to be deepened if low permeability zones are encounteed which reduce capacity. It is estimated that each well could handle about 11.5 mgd (8,000 gpm). Therefore, for a 23 mgd operation, only 2 of the 4 wells will be operating. The extra wells are standby capacity for planned maintenance, or in the case of 1 or more wells becoming inoperative due to clogging. The piping system and well head design would require careful engineering for smooth operation and ease of maintenance.

For the above well, we have obtained a quotation of $148,000 per well from Roscoe Moss Co. The total cost for 4 wells would be $592,000.

These wells would be designed for only the 16,100 gpm OTEC discharge, and a trench disposal scheme would still be necessary to handle mariculture discharges.

Shallow Surface Trench Disposal

Proposed locations of shallow surface trench disposal are along the roadway alignment from NELH towards the proposed HOST park and along the makai boundary of the NELH facility. We understand that current planning calls for trench excavation, and replacement with a perforated pipe and large boulder backfill. This would not enable maintenance of the trench, but the end of the trench would be designed to enable extension should clogging occur or if additional capacity is required during the phased development of NELH activities. For the purpose of obtaining a quotation, we assumed the trench cross section depicted on Attachment 1.

For the roadway towards the proposed HOST park, the proposed disposal trench orientation is roughly parallel to and approximately 750 feet from the shoreline. The ground elevation in the area is approximately 10 feet above sea level. For disposal of the anticipated project quantity of ocean water for 23 mgd from the OTEC activities, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 225 feet long. For planning purposes, it would be prudent to allow for twice the theoretical trench length. The extra trench length would provide an allowance for non-homogeneity of the hydrogeologic characteristics of the proposed disposal area subsurface materials and to mitigate silting and clogging problems that may occur in the initial start up stage. The trench should also be designed to allow for extension, if additional capacity is required or to replace clogged areas.

The performance of the disposal trench should be monitored to collect operation and maintenance data for subsequent phases of the expansion program. Assuming that the technical parameters used in the theoretical computations can be validated by the actual performance, the disposal trench can then be incrementally extended to handle more disposal quantity as NELH facilities expand. Theoretically, a 362-foot disposal trench 5 feet wide by 5 feet deep could handle the projected additional disposal quantity of 37 mgd from mariculture operations. Therefore, for the total proposed additional ocean water outflow of 60 mgd, the theoretical trench dimensions could be 5 feet wide, 5 feet deep, and 587 feet long.

The available length of the disposal area is more than 2,000 feet. The length of the trench, however, can be shortened by digging a deeper trench. A 10-foot wide by 10-foot deep trench would require theoretical trench lengths of 98 feet, 158 feet, and 256 feet, respectively for disposal quantities of 23, 37, and 60 mgd, respectively, without allowing for any safety factors.

For the trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly parallel to and approximately 100 feet from the shoreline. For disposal of the anticipated projected quantity of ocean water of 23 mgd from the OTEC activities, the theoretical trench dimensions could be

5 feet wide, 5 feet deep, and 144 feet long. A 10-foot wide by 10-foot deep trench would require a theoretical trench length of 59 feet. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

For the alternate trench within the NELH laboratory compound, the proposed disposal trench orientation is roughly perpendicular to and approximately 250 feet from the shoreline at the closest point. The theoretical trench dimensions could be 5 feet wide, 5 ft deep, and 193 feet long. A 10-foot wide by 10-foot deep trench would require a theoretical trench length of 79 feet. The above discussions regarding increasing the design length and monitoring the performance of the trench would apply.

We have obtained, from Isemoto Construction, a cost estimate of $160/ft for the 5 ft x 5 ft trench. This would be reduced to $135/ft if the trench is 600 feet or longer.

For the 10x10 feet trench, a cost estimate of $245/ft was quoted. This would be reduced to $210 ft if the trench is 600 feet or longer.

A research trench within NELH has been recommended. Such a trench would be approximately 5 ft x 5 ft x 45 ft long.

Cost estimates for the various schemes are tabulated below:

TABLE 1

DISPOSAL TRENCH COSTS

Location	Size (ft)	Discharge (gpm)	Length (ft)	Cost ($)
Existing Road to HOST Park	5 x 5	16,100	450	72,000
		25,900	724	97,740
		42,000	1,174	158,490
	10 x 10	16,100	196	48,020
		25,900	316	77,420
		42,000	512	125,400
Within NELH	5 x 5	16,100	288	46,080
	10 x 10	16,100	118	28,910
Within NELH (alternate location)	5 x 5	16,100	386	61,760
	10 x 10	16,100	158	38,710
Research Trench	5 x 5	5,000	90	14,400

Canal Disposal

The canal option was determined to be unfeasible as NPDES permit requirements could not be met. This option is therefore not included in this cost analysis.

Cost Comparisons

Comparisons for the various alternatives are presented below:

Alternative 1:	
OTEC discharge (16,100 gpm) via deep wells	$ 592,000
Mariculture discharge (25,900 gpm) via trench on existing road to HOST Park	77,420
	$ 669,420
Alternative 2:	
OTEC discharge (16,100 gpm) via trench within NELH	$ 28,910
Mariculture discharge (25,900 gpm) via trench on existing road to HOST Park	77,420
	$ 106,330
Alternative 3:	
OTEC and mariculture discharge (42,000 gpm) via trench on existing road to HOST Park	$ 125,400
Alternative 4:	
OTEC discharge (16,100 gpm) via alternative trench within NELH	$ 38,710
Mariculture discharge (25,900 gpm) via trench on existing road to HOST Park	77,420
	$ 116,130

Alternative 1, 2, and 4 would minimize pumping costs, while Alternative 3 would incur high pumping costs to move OTEC discharges to the road leading to the HOST Park.

Alternative 1 would incur periodic well maintenance costs.

- oOo -

If there are any questions regarding this letter, please do not hesitate to contact the undersigned.

Yours very truly,

DAMES & MOORE

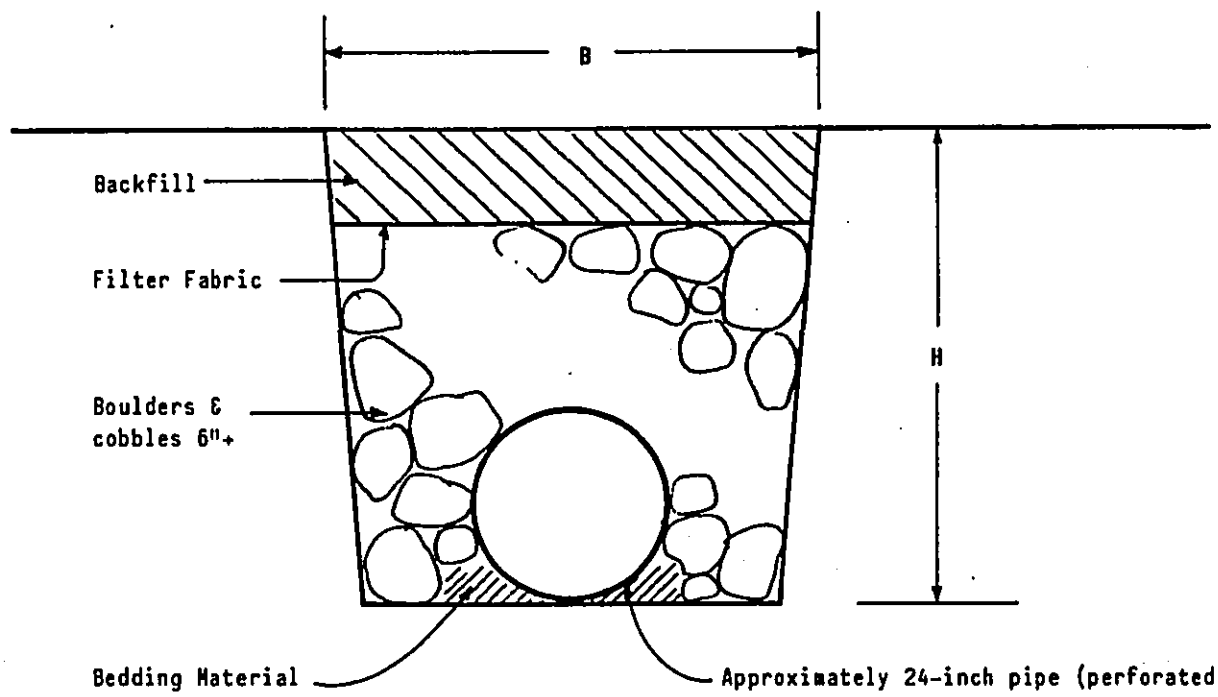
Masanobu R. Fujioka, P.E.
Principal-in-Charge

MRF:ob(3505A/303A:03014-119-11)

Attachment 1 - Disposal Trench Cross Section

cc: MCM Planning
Attention: Ms. Marilyn Metz

Oceanit Laboratories, Inc.
Attention: Mr. Patrick K. Sullivan



B = H = 5 or 10 feet

DISPOSAL TRENCH CROSS SECTION

DAMES & MOORE

ATTACHMENT 1

REVISIONS BY ____ DATE ____

FILE 3014-119

BY lml DATE 10/8/86

CHECKED BY ____