July 11, 2012

Mr. Gary L. Hooser, Director
Office of Environmental Quality Control
235 South Beretania Street, Suite 702
Honolulu, Hawaii 96813

Dear Mr. Hooser:

Draft Environmental Assessment
OCEAN THERMAL ENERGY CONVERSION TECHNOLOGY RESEARCH, DEVELOPMENT AND DEMONSTRATION FACILITY KEAHOLE, NORTH KONA, HAWAII

The Natural Energy Laboratory of Hawaii Authority has reviewed the Draft Environmental Assessment for the subject project, and anticipates a Finding of No Significant Impact. Please publish notice in the next available OEQC Environmental Notice.

We have enclosed a completed OEQC Publication Form and one (1) copy of the document in PDF format on a CD; and one (1) hardcopy of the Draft EA. Please call the Preparer, Proponent or Approving Agent if you have any questions.

Very truly yours,

Gregory Barbour
Executive Director

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Proponent: Barry Cole, Executive Vice President
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Approving Agent: Gregory Barbour, Executive Director
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Enclosure:

Project Name: Draft Environmental Assessment
OCEAN THERMAL ENERGY CONVERSION TECHNOLOGY RESEARCH, DEVELOPMENT AND DEMONSTRATION FACILITY KE'AHOLE, NORTH KONA, HAWAI`I

Publication Form
The Environmental Notice
Office of Environmental Quality Control

Applicable Law:	HRS 343
Type of Document:	Draft Environmental Assessment
Island:	Hawaii
District:	**North Kona**
TMK:	(3) 7-3-43:087(por.)
Permits Required:	NELHA Lease, Grading/Building, NPDES Construction Storm Water, FAA Hazard Evaluation Form 7460-1, County Height Limit Variance, Underground Injection Control (UIC), Individual Wastewater Disposal

Applicant

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Approving Agency

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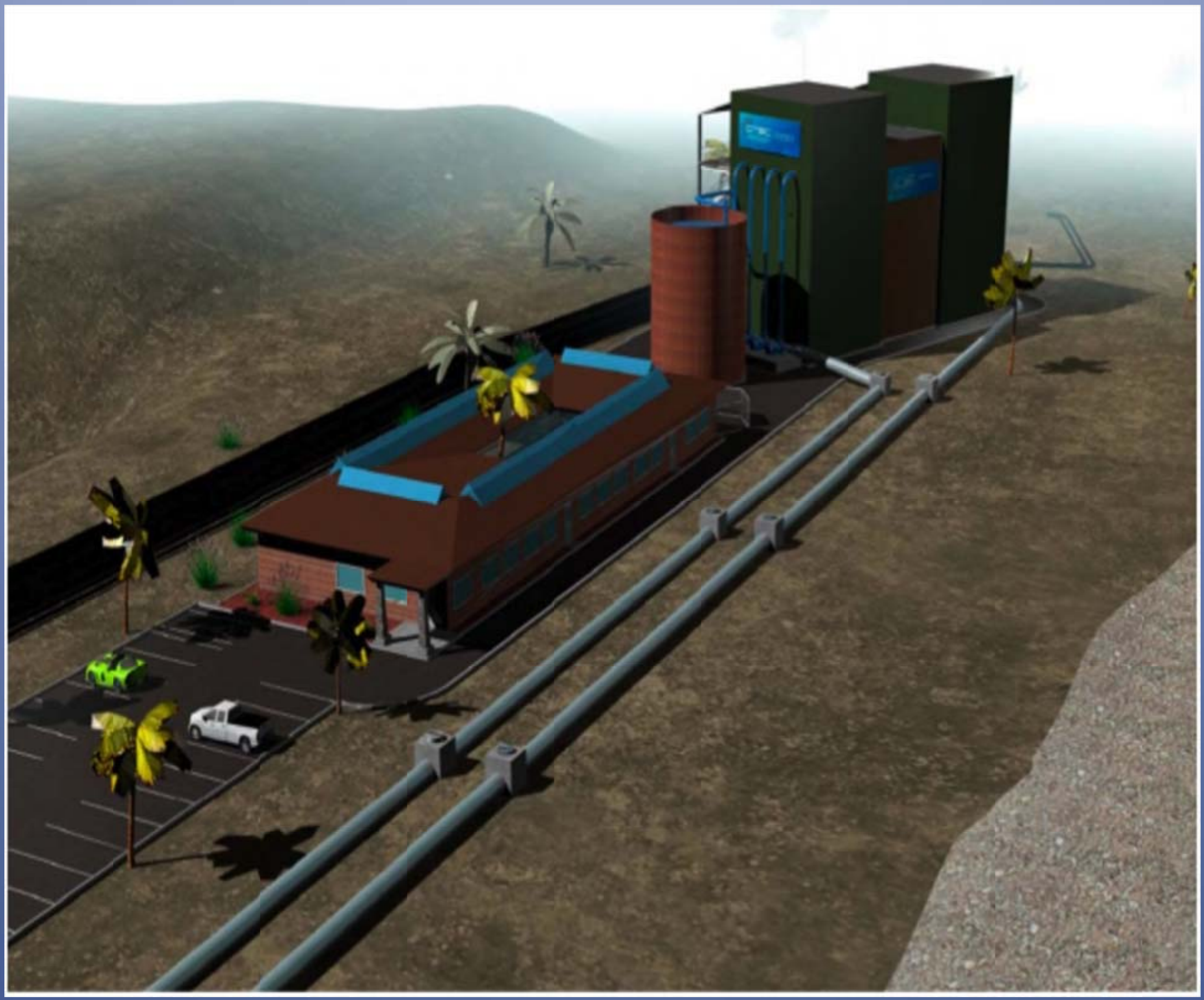
Project Summary:

OTI proposes to construct and operate a 1MWe Ocean Thermal Energy Conversion (OTEC) facility on NELHA's Hawaii Ocean Science and Technology Park. This facility is a test platform for research, development and demonstration (RD&D), which is a necessary step in the transition to a commercial OTEC industry. The proposed action uses the existing infrastructure, including a 55" seawater pipelines to access seawater, and is consistent with the objectives of NELHA. Seawater used for OTEC will either be distributed to other tenant of the HOST Park or disposed to large injection wells. These injection wells are designed to return the seawater to a depth near their origin in order to minimize environmental effects of the proposed action. NELHA anticipates a finding of No Significant Impacts pending receipt of comments from agencies and interested parties.



OCEAN THERMAL ENERGY CONVERSION TECHNOLOGY RESEARCH, DEVELOPMENT AND DEMONSTRATION FACILITY KE‘AHOLE, NORTH KONA, HAWAI`I

Draft Environmental Assessment
Prepared pursuant to Hawaii Revised Statutes §343-5

July 2012

Draft Environmental Assessment

OCEAN THERMAL ENERGY CONVERSION TECHNOLOGY RESEARCH, DEVELOPMENT AND DEMONSTRATION FACILITY KE‘AHOLE, NORTH KONA, HAWAI`I

Approving Agency

NELHA
Natural Energy Laboratory of Hawaii Authority

Proponent

OTEC International LLC

Prepared by

North Shore Consultants, LLC
P.O. Box 790
Haleiwa, HI 96712

July 2012

PROJECT SUMMARY

This Environmental Assessment has been prepared at the request of the Natural Energy Laboratory of Hawai‘i Authority (NELHA) to conform to the requirements provided under §343-5 Hawai‘i Revised Statutes (HRS) and §11-200-10 Hawai‘i Administrative Rules (HAR).

Name: OTI 1MWe OTEC Research, Development, and Demonstration (RD&D) Facility
Location: Keahole, North Kona, Hawai‘i
Judicial District: North Kona
Applicant: OTEC International LLC (OTI)
Approving Agency: Natural Energy Laboratory of Hawai‘i Authority (NELHA)
Recorded Fee Owner: State of Hawai‘i, Department of Land and Natural Resources
Tax Map Keys: TMK (3) 7-3-43:087(por.)
Land Area: 1.9 acres
Existing Use: Vacant

Proposed Use: OTI proposes to construct and operate a 1MWe OTEC facility on NELHA's Hawaii Ocean Science and Technology (HOST Park). This facility is a test platform for research, development and demonstration (RD&D) to refine progressive phases of innovation of the OTEC technology. Advances achieved at the RD&D site will facilitate installation and operation of commercial OTEC power plants.

Land Use Designations:
State Land Use: Urban District
General Plan: Industrial Designation
County Zoning: MG-3A, General Industrial
Special Management Area (SMA): Within the SMA (SMA Use Permit 239)

Major Approvals Required:
Lease agreement with NELHA
Grading/Building permits
NPDES Construction Storm Water Permit
FAA Hazard Evaluation -77CFR Part 14 Form 7460-1
County Height Limit Variance (structures >46 feet)
Underground Injection Control (UIC) Permit
Individual Wastewater Disposal (IWS) Permit

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Draft Environmental Assessment

OCEAN THERMAL ENERGY CONVERSION TECHNOLOGY RESEARCH DEVELOPMENT AND DEMONSTRATION FACILITY

KEAHOLE, NORTH KONA, HAWAI'I

1. Introduction

1.1 Applicant

OTEC International LLC (OTI), a Maryland Limited Liability Company, proposes to construct and operate an Ocean Thermal Energy Conversion (OTEC) Innovation and Demonstration Facility on land leased from the Natural Energy Laboratory of Hawai'i Authority (NELHA) at the Hawaii Science and Technology Park (HOST Park), Keahole, North Kona, Hawai'i. The Abell Foundation, Inc. (Abell) of Baltimore Maryland is the principal member and sponsor of OTI. Abell originally established Sea Solar Power International LLC, the precursor of OTI, in 2001 with a goal of bringing pioneering OTEC research by J. Hilbert Anderson and his son, James Anderson to technological and commercial maturity. To Abell's knowledge, no other private organization has devoted more capital and human resources to the objective of commercializing OTEC technology than Abell and OTI, and no other alternative energy has as great a near term promise for solving the base load energy needs of coastal countries and communities of the world in tropical and semi-tropical zones.

Abell and OTI's approach to OTEC leverages the more than 40 years of research and engineering by the Andersons on optimizing the OTEC cycle and its key components. Abell also is the exclusive worldwide licensee of the Andersons' work with OTEC, and the Abell portfolio of OTEC innovation includes substantial know-how, four patents issued and seven pending patents filed within the last two years.

1.2 Approving Agency

Authority for approval of the proposed project rests with The Natural Energy Laboratory of Hawai`i Authority (NELHA), organized in 1990 as provided by HRS §227D from its predecessor components within the Department of Business Economic Development and Tourism (DBEDT). The statutory purpose of NELHA is "to facilitate research, development, and commercialization of natural energy resources and ocean-related research, technology, and industry in Hawai`i and to engage in retail, commercial, or tourism activities…"

The principal natural asset offered by HOST Park's location is proximity to cold, deep ocean water as a result of the steep bottom gradient adjacent to the Keahole coastline. Both cold seawater drawn from intakes at depths of as much as 3,000 feet and warm surface seawater are available for distribution to tenants of the HOST Park facility for research and commercial development applications. NELHA will lease land to OTI for the purpose of constructing the OTEC demonstration facility. , The land lease from NELHA is the initial and most important discretionary approval need for the project to move forward; therefore, NELHA is designated the Approving Agency for this Environmental Assessment.

1.3 Scoping and Consultation

Throughout the project design and development process, OTI has relied heavily on the prior experience and expertise of NELHA operations staff to help identify logistic and management concerns arising from implementation of the OTEC facility. During the development of the DEA the proponent consulted a wide range of agencies, officials and interested parties to assess their concerns regarding the environmental and economic impacts of the proposed action. These agencies, organizations and individuals and others were consulted for scoping the assessment, and will be provided copies of the Draft Environmental Assessment for review and comment:

1.3.1 Federal Agencies

Department of Commerce, National Oceanic and Atmospheric Administration
Department of the Interior, Fish and Wildlife Service
Department of Transportation, Federal Aviation Administration
Environmental Protection Agency, Region IX
U.S. Navy SUBPAC Committee

1.3.2 State Agencies

Tim O'Connell, USDA/ Rural Development
Andrea Gill, HI DBEDT, Energy Office
NELHA Board of Directors
Gary Gill, State Dept. of Health
Richard Lim, DBEDT
Mark Glick, DBEDT Energy Office
Maria Tome, DBEDT Energy Office
Chris Pointis, DOH Clean Water Branch
Staff Engineer, DOH Safe Drinking Water Branch
Cameron Black. DBEDT Energy Office
Sam Lemmo, DLNR Office of Conservation and Coastal Lands
John Nakagawa, Office of Planning CZM Section
David Hind, Kona International Airport

1.3.3 Public Officials

Lt. Governor Brian Schatz, State of Hawai‘i
Delbert Nishimoto, US Senator Daniel Inouye's Office
Gilbert Kahele, HI State Senator
Denny Coffman, HI State Representative
Mike Gabbard, HI State Senator

1.3.4 County of Hawai‘i

June Horike, County of Hawai‘i Dept. of Research and Development
Vivian Landrum, Kona Kohala Chamber of Commerce
Dominic Yagong, Hawai‘i County Council
Donald Ikeda, Hawai‘i County Council
J Yoshimoto, Hawai‘i County Council
Dennis Onishi, Hawai‘i County Council

Fred Blas, Hawai‘i County Council
Brittnay Smart, Hawai‘i County Council
Brenda Ford, Hawai‘i County Council
K. Angel Pilago, Hawai‘i County Council
Pete Hoffman, Hawai‘i County Council
Mayor Bill Kenoi, County of Hawai‘i
Will Rolston, County of Hawai‘i
Bobby Command, County of Hawai‘i
Randy Kurohara, County of Hawai‘i Dept. of Research & Development
Wally Lau, County of Hawai‘i
Bobby Jean Leithead-Todd Department of Planning

1.3.5 Organizations and Individuals

Hawaiian Electric Company (HECO)
Henry Curtis and Kat Brady, Life of the Land
Reb Bellinger and Joe Van Ryzin, Makai Ocean Engineering
Jacqui Hoover, Hawai‘i Island Economic Development Bureau (HIEDB)
Yen Wen Fang and Glenn Manaba Engineering Partners
Keene Fujinaka, Bank of Hawai‘i
Leslie Agorastos, Real Estate
Barry Mizuno, BTM LLC
David DeLuz Jr., DeLuz Enterprises
Nancy Cabral, Day Lum Real Estate
Jay Ignacio, HELCO
Curt Beck, HELCO
Chen Chengwu and Norman Verbanic, HELCO
Pat Tummons, Environment Hawai‘i
Various members Kona-Kohala Chamber of Commerce
Sierra Club, Hawai‘i Chapter
Big Island Abalone Corporation
Koyo Water Company

1.3.6 University of Hawaii

Dr. Brian Taylor, UH Manoa School of Ocean, Earth Science and Technology (SOEST)
Rick Rocheleau, UH Manoa Hawaii Natural Energy Institute (HNEI)
Dr. Kim Holland, UH Manoa Hawaii Institute of Marine Biology (HIMB)
Sandy Shor, UH Manoa SOEST Engineering Support Facility
Katrina Ing Shum, UH Manoa SOEST
Dr. Lloyd Hihara, UH Manoa Dept. of Mechanical Engineering
Reza Ghorbani, UH Manoa Dept. of Mechanical Engineering
Chancellor Donald Straney, UH Hilo
Vice Chancellor Marcia Sakai, UH Hilo
Dr. Cam Muir, UH Hilo
Dr. Donald Thomas, UH Hilo Center for the Study of Active Volcanoes
Dr. Sonia Juvik, UH Hilo

1.4 Legal and Regulatory Background

Hawai‘i Revised Statutes (HRS) Chapter 343 provides for systematic, public disclosure and review of proposed actions that fall within specific categories, or “triggers”, as defined in HRS §343-5. The proposed facility will be constructed on public land, which is one of these triggers.

The environmental review system ensures that “environmental concerns are given appropriate consideration in decision making along with economic and technical considerations” [HRS §343-1]. The EIS law also provides that “[a] statement that is accepted with respect to a particular action shall satisfy the requirements of [HRS 343], and no other statement for the proposed action shall be required” [HRS §343-5(g)]. Regulatory guidance regarding the sufficiency of an accepted statement for the purposes of compliance with provisions of Chapter 343 HRS appears in Title 11 Chapter 200 Section 26 Hawai‘i Administrative Rules (HAR):

A statement that is accepted with respect to a particular action shall satisfy the requirements of [HRS Chap. 343] and no other statement for that proposed action shall be required, to the extent that the action has not changed substantively in size, scope, intensity, use, location or timing, among other things. If there is any change in any of these characteristics which may have a significant effect, the original statement that was changed shall no longer be valid because an essentially different action would be under consideration and a supplemental statement shall be prepared and reviewed as provided by [HRS Chap. 343]. As long as there is no change in a proposed action resulting in individual or cumulative impacts not originally disclosed, the statement associated with that action shall be deemed to comply with [HRS Chap. 343].

OTI has completed a comprehensive review of the previous environmental impact statements (EIS), Conservation District Use Authorizations (CDUAs) and Special Management Area (SMA) Permits that NELHA has obtained since its establishment. These previous works discuss and assess in detail previous OTEC research and demonstration projects, their environmental impacts and considerations as well as their application to OTI’s proposed OTEC facility. Statements previously prepared pursuant to HRS 343, as well as relevant permits and rulings are listed below.

1.4.1 Existing Environmental Impact Statements

1. <u>Environmental Impact Statement, Natural Energy Laboratory of Hawai‘i at Keahole Point, Hawai‘i (Phase I), Research Corporation of the University of Hawai‘i, 1976</u>. (R.M. Towill, 1976)

The original 1976 FEIS stated:

> *The basic purpose of the NELH is to provide the essential support facilities for future energy programs and to interest research organizations in using these facilities. By providing a centralized location with favorable conditions, it is hoped that research groups examining alternative sources of energy will select Hawaii as the location for their research and test facilities* (Towill, 1976, p. II-2).

This FEIS identified OTEC as the Laboratory's principal project, implemented through a "phased research and development program" beginning with "small-scale experiments in existing facilities" and ultimately developing to "a scaled prototype operation" (Towill, 1976, p. II-4). More specific description of the envisioned OTEC proof-of-concept appears in Appendix A, where a likely prototype of between 1 and 5 MWe in size uses ammonia as a working fluid and pumps between 250 and 1000 cubic feet per second each of deep sea and surface ocean water (Towill, 1976, p. A-2). Some discussion of potential environmental impacts of such a facility appeared in this EIS, but it mostly addressed the basic infrastructure of roads, potable water and power. Although deep and surface sea water delivery and disposal systems were envisioned, they were only discussed in general terms.

2. <u>Final Environmental Impact Statement, Development Plan for the Hawai'i Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawai'i, Keahole, North Kona, Hawai'i, High Technology Development Corporation, 1985</u> (Traverse Group, 1985). This second FEIS was prepared for construction and operation of the Hawai'i Ocean Science and Technology (HOST) Park and expansion of NELH. This EIS explicitly assessed operational parameters anticipated at the facility (Traverse Group, 1985). Among the actions assessed in this document was the pumping of 42,000 gallons/minute (gpm) from OTEC and mariculture operations at NELH and 100,000gpm from commercial operations at the HOST Park. Various seawater management methods were considered, and the preferred method selected for seawater disposal was on-site trenches. The 1985 FEIS also assessed a mixed seawater return pipeline, and this alternative was judged to be feasible and environmentally benign, but not cost effective.

3. <u>Final Environmental Impact Statement, Alternative Methods of Seawater Return Flow Disposal, Keahole, North Kona, Natural Energy Laboratory of Hawai'i, 198</u>7 (MCM Planning, 1987). The purpose of the third Statement (MCM Planning, 1987) was to assess best methods of seawater return. Alternatives included deep injection wells, direct surface discharge through a holding pond and into coastal waters, and the trench method of disposal. Although direct discharge of mixed seawater was most cost effective, it was determined to be infeasible due to the size of the pond required to return discharged seawater to ambient ocean temperatures and potential eutrophication of near-shore waters. Deep injection was judged to be the most environmentally benign of the considered methods of seawater disposal due to the extended residence time (3 and 4 months) of the return water. Dames and Moore evaluated the potential for discharge of up to 60,000 gpm of deep, surface, and mariculture effluents. Their models indicate that deep water could be injected at a 300 – 400 foot interval without risk of detection in the nearshore waters. The model utilized 2-foot diameter injection wells designed to dispose of 8,000 gpm each. The depth of DSW discharge is well below the unconfined brackish water aquifer, which has a net seaward flow. At 300 feet there is little or no net movement of the groundwater mass. Discharged DSW spreads laterally following the pattern of existing voids, fissures and cracks left by ancient lava flows. Density of DSW is slightly higher than warmer surface sea water, so unlike plumes from Wastewater treatment plants, the plume is not expected to rise from its discharge point. SSW is also injected at the lower limits of the brackish groundwater lens in order to maintain the environmental conditions that exist within the littoral zone.

The deep injection alternative was rejected due to its high cost, but not due to expected environmental effects. The 1987 FSEIS concluded that the use of a shallow disposal trench installed parallel and makai of the NELHA access road is the best method for OTEC seawater return. The trench would be approximately 250 feet from the shoreline at its closest point and contain a perforated distribution pipe beneath backfill materials to prevent biofouling. The flows discussed were up to 42,000gpm of mixed OC OTEC discharge and mariculture effluents (MCM Planning, 1987 Appendix C). The document observes:

"A cost effective disposal technique may make the difference between success and failure of the fledgling state-of-the-art businesses."

The document considers temperature and nutrient changes resulting from the shallow trench method, but concludes that these effects would not be significant to the near-shore ecosystem. Principal mitigation recommended in the 1987 Statement to address potential impacts of seawater discharge was a comprehensive Environmental Monitoring Plan (CEMP) established to monitor potential impacts resulting from the return flow. According to Dames and Moore (MCM Planning, 1987 Appendix C Addendum 1 pg. 3), the anchialine ponds to the south of the proposed development would not be within the area of influence of the discharge flow net for a 42,000gpm mixed discharge trench located in an area similar to the one proposed.

4. Final Supplemental Environmental Impact Statement. Development of Land Exchange Parcel, State of Hawai'i, Natural Energy Laboratory of Hawai'i Authority, September 1992. (GK and Assoc., 1992) In the most recently prepared FSEIS (GK & Associates, 1992), one of the primary activities assessed was an OTEC facility generating 1MWe gross power using an ammonia-based closed cycle heat engine powered by cold deep sea water (DSW) and warm surface sea water (SSW). The OTEC plant would supply DSW and SSW to an Ocean Science Center, Lobster farm and other NELHA tenants. Seawater return flow was to be disposed in 2 shallow trenches near the current site of the 55" pumping station.

1.4.2 Existing Conservation District Use Applications/Permits

1. CDUA HA-879	Approved 2-11-77**.**
2. CDUA HA-1862 (Supersedes HA-879)	Approved 7-31-86.
3. CDUA HA-1862 Amendment 2/11/94	Approved 2/11/94
4. CDUA HA-1862 Amendment 4/8/94	Approved 9/23/94

1.4.3 Land Use Commission (LUC) Rulings

1. The LUC approved reclassifying NELH land (currently considered the research area) from Conservation to Urban on 2-17-78.

2. The LUC approved reclassification of HOST Park from Conservation to Urban, except 39 acres for the beach park, on 11-5-85.

3. The LUC denied reclassification of 82.21-acre parcel from Conservation to Urban on 1-27-94. NELHA failed to prove by a clear preponderance of the evidence that the reclassification was appropriate under Section 205 HRS.

1.4.4 Special Management Area Permits

Pursuant to §205-21 of Hawaii Revised Statutes, Hawaii legislature has determined that *"special controls on developments within an area along the shoreline are necessary to avoid permanent losses of valuable resources and the foreclosure of management options, and to ensure that adequate access, by dedication or other means, to public owned or used beaches, recreation areas, and natural reserves is provided."* §205A-22 defines the special management area as the land that extends inland from the shoreline as delineated by maps filed. In the case of NELHA/HOST Park, the special management area extends from the shoreline to Queen Ka'ahumanu Highway. Special management area use permits are needed for developments with a valuation exceeding $500,000 or which may have substantial adverse environmental or ecological effect. The proposed project is located in the Special Management Area of HOST Park, and is entirely outside of the 40 foot shoreline setback.

NELHA/HOST Park has three separate SMA Use Permits which cover various land areas within the NELH/HOST Park control.

SMA Use Permit No. 27 was granted April 1977 and covers the general use of the land to establish the Natural Energy Laboratory of Hawaii.

SMA Use Permit No. 77 was granted in December of 1978, and covers research and development of the Natural Energy Laboratory Research Park at Keahole Point. Maps associated with the Permit show only the research Park area as covered. The Permit states: *"The purpose of the subject request is to establish research and development facilities that are essential to the study of one form of alternative energy, namely Ocean Thermal Energy Conversion (OTEC)*". Furthermore it states that *" The long-term objective of the proposed development will be to attract future energy research project of State and National significance to the Island."*

SMA Use Permit No. 239 was granted in June 1986 for the Hawaii Ocean Science and Technology (HOST) Park, which includes the area of the proposed project. This permit was approved "*to allow the development of the Hawaii Ocean Science and Technology (HOST) Park Subdivision and related improvements, including all future improvements and structures at Ooma 1st and 2nd, North Kona, Hawaii."*

The OTI RD&D facility is located within the special management area of HOST Park behind the 40 foot shoreline setback. NELHA/HOST Park has SMA Use Permit 239 which covers the area of the proposed project. Further discussion of the applicability and scope of these permits are discussed in Section 6.4.

1.5 OTI Compliance with HRS 343

The proposed OTEC RD&D facility is consistent with the primary objectives for establishing the HOST Park. Over the past 30 years, various OTEC demonstration facilities have been built and operated at the HOST Park, including Mini OTEC, OTEC-1, OC OTEC, and Makai Ocean Engineering's closed cycle OTEC. The 1992 EIS (GK & Assoc., 1992) assessed a 1MWe OTEC plant, which was one of the primary actions proposed by the KAD Partners for a large project involving OTEC, an aquarium, and a lobster farm. The OTEC plant proposed by the KAD

Partners was quite similar in scope to the proposed action covered in this assessment. None of the KAD project components were built. Other OTEC demonstration facilities are discussed as historical notes in the EISs reviewed.

OTI and its consultants have examined documents and permits associated with NELHA's existing and planned operations and their relationship to OTI's project to install, own and operate its OTEC research, development and demonstration facility on a 1.76 acre portion of NELHA's property. The detailed analysis of previously proposed actions that comply with HRS 343, as well as conditions established under existing land use permits at the HOST Park, appears in Appendix A.

Based upon this analysis, OTI has concluded that the proposed facility and its activities are permitted under NELHA's existing land-use permits (collectively, the "permits"), and have been adequately discussed and assessed in prior environmental impact statements and supplemental environmental impact statements. The analysis in Appendix A sets forth how the Facility and its activities comply with NELHA's existing permits and how it complies with the requirements of the Hawai‘i Environmental Protection Act (Chapter 343) and Hawai‘i Administrative Rules (HAR) 11-200. Descriptions in ensuing sections will provide details of the systems, processes, and seawater streams that will make up the RD&D facility. Although such a facility has never before been built, the seawater supply and seawater return volumes, methods and all proposed actions have been considered in previously accepted statements.

Consistent with its mission, OTI's pre-development planning included extensive review of existing environmental regulations and identification of best practice applicable to its proposed RD&D facility. NELHA has requested that OTI prepare an Environmental Assessment pursuant to §343-5 HRS in order to provide a comprehensive reference document for public disclosure of the full extent of proposed activities and their expected effects. The present document is offered in response to that request.

2. Description of the Proposed Action

2.1 OTEC Principles

Ocean Thermal Energy Conversion (OTEC) offers a sustainable alternative to fossil fuel-based technologies presently driving Hawai‘i’s energy economy. Unlike most of the renewable energy systems constructed and contemplated for deployment in Hawai‘i, OTEC is a base load, or firm power technology, producing electricity 24 hours a day, every day. Each megawatt of distributed OTEC power completely displaces equivalent power generated by fossil fuels, thereby precluding the need to import oil and coal that are both economically and environmentally costly. By contrast, non-firm power renewable technologies such as wind and solar photovoltaic do not eliminate the need to maintain fossil-fueled spinning reserve capacity for those times when wind and solar energy sources are absent or reduced. OTEC power facilities may be located in close proximity to major coastal cities with access to deep water. Unlike geothermal power in Hawai‘i, whose resources are restricted to certain areas of the Big Island, OTEC facilities would not require expensive inter-island cable systems to transmit power to load centers.

The surface of the ocean is the largest collector of solar energy in the world. The temperature of the ocean surface in equatorial zones between approximately 20 degrees north and south of the equator averages 80ºF. Cold water at approximately 40ºF circulates at a depth of 3000 feet (915 meters). By drawing in large quantities of warm surface water to boil ammonia, an ideal gas is produced to generate electricity using conventional turbine-generators. Cold deep ocean water is used to convert the ammonia vapor back to a liquid for recycling in a closed loop system. The key technical challenge for OTEC is to produce enough gross energy to run its power-intensive production facility and to efficiently generate net energy at competitive prices for the electric grid.

OTEC power plants can be land-based or offshore facilities. For land-based plants, the required large volumes of warm and cold seawater are pumped through long intake pipes extending from the shore-based power plant to the appropriate ocean depths. After passing through the OTEC power cycle, the water may be used for other beneficial purposes or returned to the ocean in an environmentally appropriate manner. Land-based OTEC plants have a higher parasitic load (i.e., internal energy demand) relative to offshore plants due to the pumping load required to bring large volumes of water onshore. OTI believes that land-based plants are appropriate for OTEC research facilities, but they do not generate the economic returns, at this time, to be commercially viable. Offshore OTEC power plants include water intake and power generation systems on site that are positioned in deep ocean water, generally several miles from shore. The first generation of OTI-designed commercial plants will be offshore facilities.

Initially, the plant will operate as an integrated test facility and as an important final step before offshore commercial deployment. Over the term of the lease, OTI will introduce and test technology enhancements to optimize the power cycle and to explore the full range of commercial opportunities.

2.2 Rationale for Facility Site at the HOST Park

In creating the Natural Energy Laboratory of Hawai‘i in 1974, the State envisioned a facility to attract researchers and proponents of breakthrough technologies to transform our energy infrastructure. The site location is in close proximity to the cold and warm ocean waters necessary for advancing prospects for OTEC development, offering unique access to deep seawater. In addition, the HOST Park is favored by a warm, mild climate and large amounts of available, vacant land and existing permits and infrastructure to support ocean research.

Historically, NELHA's primary focus was on thermal energy production utilizing deep-sea water. Its original mission as defined in its original FEIS (RCUH, 1976) was as follows: *[t]he basic purpose of the Natural Energy Laboratory is to provide the essential support facilities for future energy programs and to interest research organizations in using these facilities. By providing a centralized location with favorable development conditions it is hoped that groups examining alternative sources of energy will select Hawai`i as the location for their research and test facilities.*

Essential support facilities installed at the HOST Park principally include the seawater supply pipelines and pumps that bring both deep seawater (DSW) and surface seawater (SSW) onshore at three locations (Figure 1). Once ashore, DSW and SSW are distributed to users through two separate systems, one at relatively low pressure (8-12 psi) for low elevation tenants of the Research Park and the other at a higher pressure (30-40 psi) for tenants in the HOST Park area. Dimensions and capacities of DSW and SSW system components are shown in Table 1.

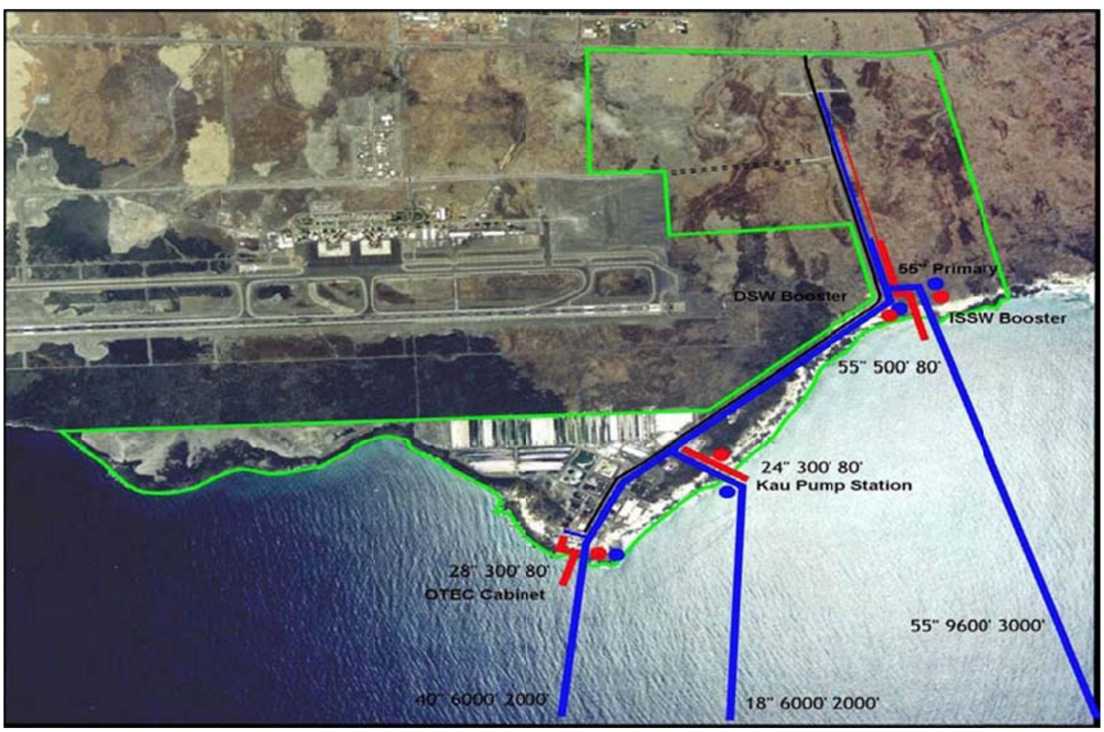

Figure 1. HOST PARK seawater intake and distribution pipelines

Table 1. Offshore pipeline dimensions and pumping capacities

INSIDE DIAMETER	INTAKE DEPTH	OFFSHORE PIPE LENGTH	PUMPING CAPACITY
DEEP SEAWATER (DSW)			
40-inch (100 cm)	2,210 ft. (674 m)	6,824 ft. (1,916 m)	13,400 gpm (0.84 m3/s)
18-inch (45 cm)	2,060 ft. (628 m)	6,180 ft. (1,884 m)	3,000 gpm (0.19 m3/s)
55-inch (140 cm)	3,000 ft. (915 m)	10,247 ft. (3,124 m)	27,000 gpm (1.80 m3/s)
SURFACE SEAWATER (SSW)			
28-inch (71 cm)	69 ft. (21 m)	535 ft. (163 m)	9,700 gpm (0.61 m3/s)
24-inch (61 cm)	33 ft. (10 m)	266 ft. (81 m)	5,400 gpm (0.34 m3/s)
55-inch (140 cm)	79 ft. (24 m)	540 ft. (165 m)	40,500 gpm (2.56 m3/s)

Because the OTI RD&D facility will be land-based, minimizing the length of onshore seawater supply lines will be critical to management of the higher parasitic loads inherent to onshore OTEC development. In a meeting with NELHA's Operations Manager in May 2011, OTI learned that various sites on the facility were available for placement of an OTEC facility. However, to minimize costs associated with infrastructure development to support this RD&D facility, the 1.76-acre site adjacent to the pumping station for the 55-inch SSW and DSW pipes on Lot 87 was recommended for use. OTI proposes to develop a portion of a parcel designated TMK# (3) 7-3-43:087. NELHA will subdivide parcel 87 into two parcels with separate TMK numbers at some point in the future. OTI will lease one of the subdivided parcels comprising 3 acres and restrict on site development to a fenced portion that encompasses 1.76 acres. OTI will also undertake ancillary development such as piping distribution, and pump replacement on parcel 87, however proposes to limit major site grading and development to the smaller 1.76 acre portion of the 3 acre parcel.

Figure 2 shows the site plan of the RD&D facility and illustrates its proximity to the main 55-inch pump station.

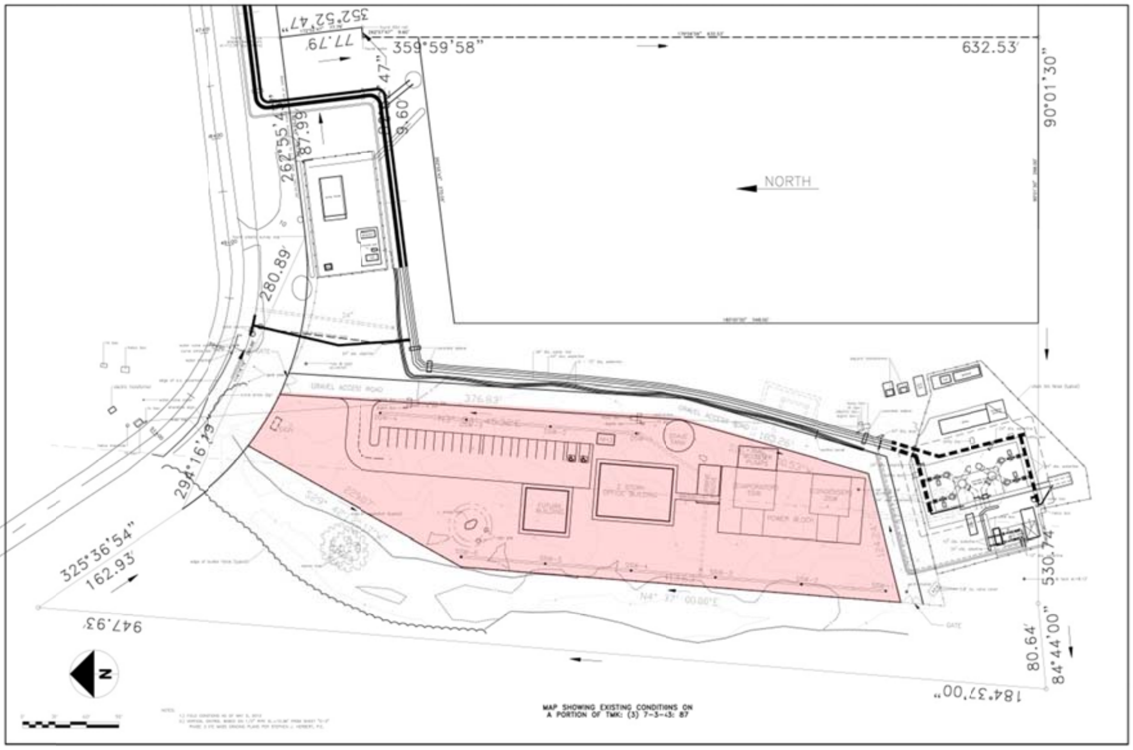

Figure 2. OTI 1MWe OTEC facility site plan showing the 1.76 acre footprint.

The development and operation of OTI's 1MW OTEC facility will serve to advance NELHA's mission as the world's preeminent OTEC RD&D Facility. This will be substantially enhanced by OTI's RD&D activities involving successive generations of OTEC technology advances and component improvements over its 30-year span of activity.

2.3 Appearance of the Proposed Facility

A key objective for a 1MW demonstration plant is to demonstrate the technical and economic viability of OTEC technology for commercial projects. OTI proposes to build a 1MW (gross) land-based power generation RD&D facility using power block components of its proprietary OTEC technology and the seawater intake infrastructure available at The HOST Park. The 1MWe plant will greatly increase the scale of OTI's existing University of Maryland research facility, introduce seawater operating conditions, and add all electrical equipment to demonstrate complete power cycle operations.

OTI's proposed commercial scale plant utilizes a floating spar platform design, which works with nature to minimize pumping by having all heat exchangers and turbine-generators below sea level. The demonstration project will emulate OTI's floating plant operationally but must pump substantial quantities of water above sea level for its land-based plant. The vertical arrangement of the spar is replicated on shore. The flow of warm water, cold water, and ammonia through the spar can be emulated by having the water pass vertically through the Heat Exchanger (HX) Towers, and by placing the turbine-generator decks between the HX towers, as they are inside the spar, to minimize the lengths of ammonia piping to and from the turbines. A schematic of the shore-based layout with water and ammonia flow paths for the modified process is shown in Figure 3.

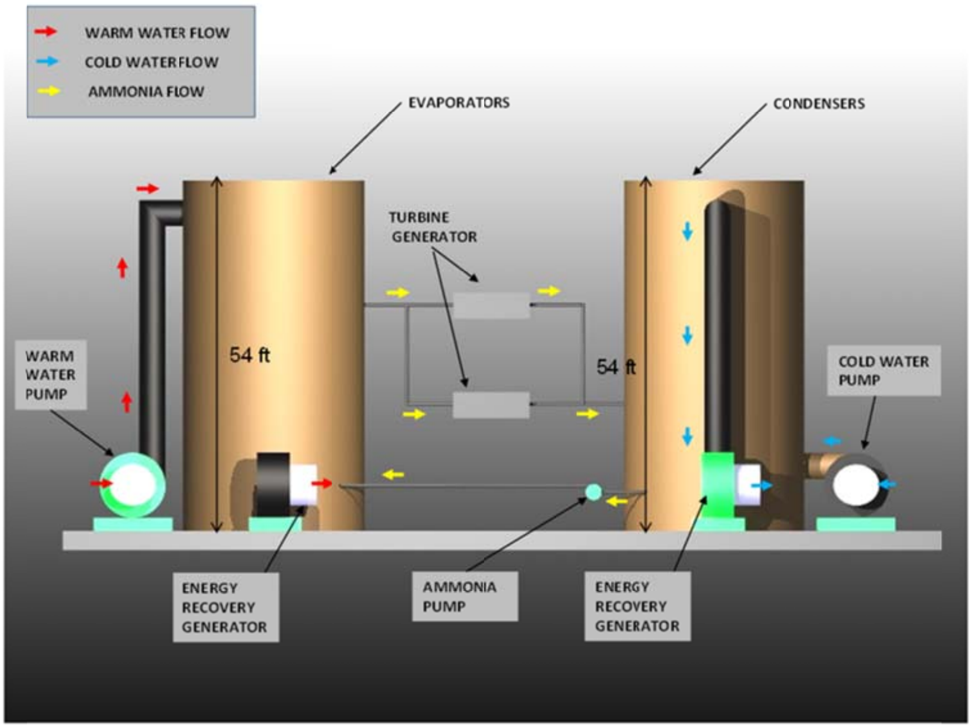

Figure 3. OTI 1MWe OTEC RD&D facility power block arrangement

OTI intends to erect the 1MWe OTEC Pilot Demonstration Plant Power Block, consisting of one evaporator heat exchanger (HX) Tower, one condenser HX Tower, a multi-deck Turbine-Generator and electrical switch gear housing, intake and discharge plenums, and two energy recovery hydro-turbine-generator sets. This equipment will be erected on a concrete slab with its top finished at 6 feet above sea level. The HX Towers, when finished and roofed, will stand approximately 54 feet above the top surface of the concrete slab, with a finished height above sea level of approximately 60 feet. The area of the slab is 120 feet by 90 feet. OTI will erect an office building containing a reception area, offices, lab(s), workshop(s), rest rooms, and conference room(s) adjacent to the power block. A parking lot with capacity for twenty vehicles will run from the office building to the 30-feet wide driveway connecting to the NELHA Access Road at the bend in the road near Wawaloli Beach Park. Manifold pipelines and ports for injection wells that comprise the seawater return systems will extend from the power block complex.

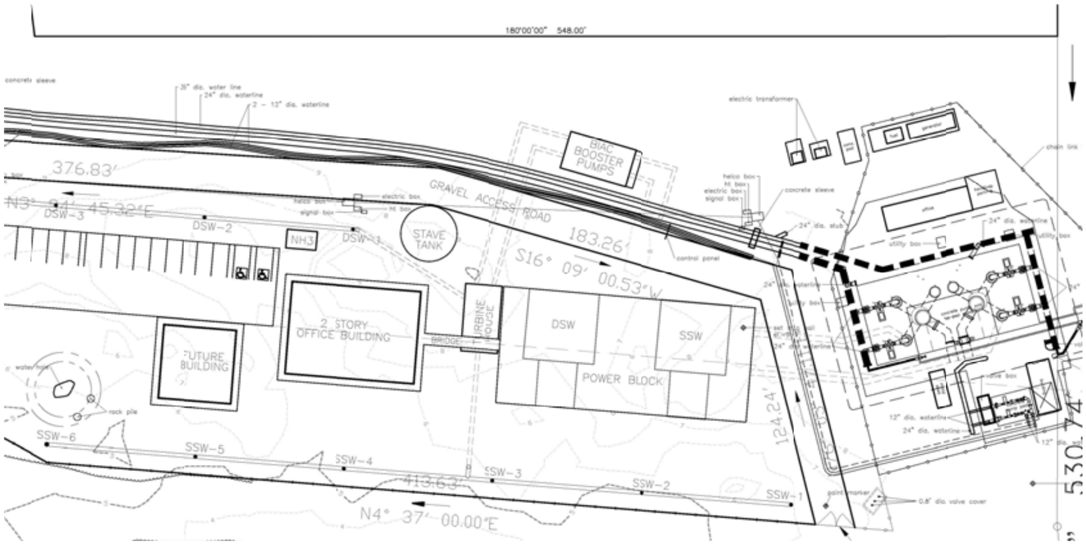

Figure 4. Compartments and arrangements layout of proposed OTI RD&D facility

Figure 4 gives a plan view of the major structures proposed for OTI's RD&D facility. Adjacent to the power block, OTI will erect a section of its 30' diameter cold water pipe design fabricated using its patent-pending interlocking staves. The structure will be used on site for water collection and storage, but it also will demonstrate the cold water pipe technology to be deployed as part of a 100MWe commercial OTEC plant. Figure 5, below, is a rendering of the facility proposed by the company selected by OTI as the design/build firm.

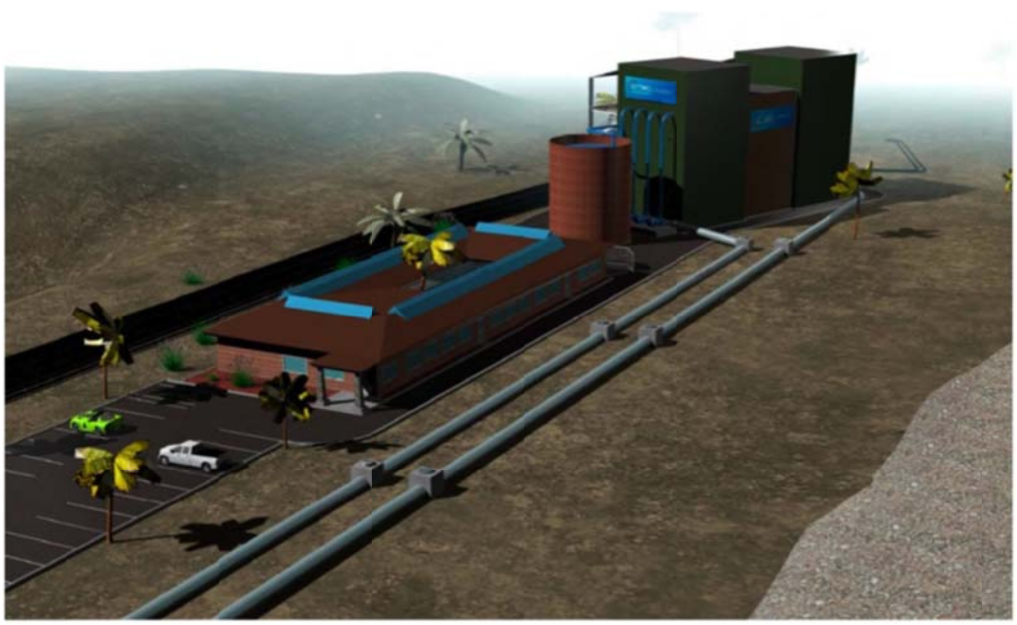

Figure 5. Artist's rendering of the proposed 1MWe RD&D facility

2.4 OTI OTEC RD&D Facility Inputs

OTEC evaporators transfer solar thermal energy stored in warm surface ocean waters to liquid ammonia causing it to boil, producing a working, pressurized vapor sufficient to power a turbine-generator. At the condenser side of the OTEC cycle, residual thermal energy in the ammonia vapor transfers to cold deep-sea water, and the working fluid returns to its liquid phase, ready to re-enter the power cycle. Large volumes of both warm surface and cold deep-sea water must be supplied continuously to provide the needed energy source and sink for the OTEC process. NELHA installed the 55-inch pumping station in 2001 for the purpose of actualizing the installation of a 1MW OTEC demonstration plant at the research and development facility. OTI will not exceed a maximum draw of 40,500 gpm of SSW and 27,000 gpm of DSW. OTI will be able to draw up to 45,000 gpm of SSW and 30,000 gpm provided they submit for review to NELHA documentation from the pipe manufacturer that the pipe will not fail at these levels and obtain prior written approval from NELHA to increase the volumes.

The pipeline design capacities were estimated to be the required flow for a 1MW (gross electrical output) OTEC plant which was to be built by KAD Partners to support its development of an aquarium, lobster farm and visitor center. The pumping capacity and the 1MWe OTEC facility were assessed in the Final Supplemental Environmental Impact Statement, Development of Land Exchange Parcel, State of Hawai‘i, Natural Energy Laboratory of Hawai‘i Authority, September 1992 (GK & Assoc., 1992). These facilities were never developed due to financial constraints. Demand from the 55-inch pumping station is considerably less than the existing capacity. The current demand for DSW and SSW from existing HOST Park tenants is approximately 14,000gpm (J. War, pers. comm.).

OTI proposes to utilize the 55-inch pumping station at its design capacity less the requirements of existing tenants and has developed a resource utilization plan that is responsive to all stakeholders. Specifically, OTI proposes to acquire and install new mixed flow wet pit discharge pumps: one 27,000gpm DSW pump and one 40,500gpm SSW pump. The existing pumps are not made of corrosion resistant materials, operate on only 480VA and have less than ten years of service life. The pumps that OTI will supply, at no cost to NELHA, will be made of corrosion resistant materials wherever there is a seawater interface, will operate on 4160VA, and will have a design service life of 25 years or more. The pumps will be installed with Variable Frequency Drives (VFD) so that as demand fluctuates, flows can be controlled accordingly.

2.4.1 Deep Sea Water – 25,400gpm

The 55-inch NELHA DSW pipe has a design capacity of 27,000gpm (Table 1), but not all of that water is available for OTEC use. The OTI plant uses ammonia as the working fluid. The ammonia flow is designed as a closed system that never comes in contact with water; however, there is always some risk for an ammonia leak into the seawater. While ammonia is a welcome additive to water going to algae and plant life, in sufficient quantities it can be harmful to small marine animals. In addition, any DSW required by the bottling operations must be “untreated” deep ocean water. Therefore, the bottling tenants and some mariculture operations will be supplied from a line that bypasses OTI’s plant, diverting approximately 1,600gpm and reducing available flow for OTEC to 25,400gpm. During installation of the new DSW pump, a “Y” with cut-off and back-flow check valves will be installed in the primary DSW discharge line and connected to existing piping currently delivering DSW to the bottling operations. The balance of DSW will go to the 1MWe OTEC plant, since downstream uses will be limited to plant culture (Figure 6).

2.4.2 Surface Sea Water

Alterations planned for the HOST Park piping system call for some SSW to be diverted to shrimp farming. These shrimp are the breeding stock for many of the shrimp farms around the world. Approximately 1600gpm of SSW must be diverted to this purpose prior to the OTEC plant. Present demand for warm SSW mostly arises from abalone farming operations. As with other marine invertebrates, abalone are sensitive to elevated ammonia concentrations. Current literature suggests that LC-50 for juvenile abalone is in the range of 980 ppb while growth reduction is observed when exposed to chronic levels around 150 ppb over a period of weeks (Aquaculture Volume: 261, Issue: 2, Pages: 678-687, 2006). Big Island Abalone has requested a limit of ammonia in excess of concentrations occurring naturally in DSW to be set to 70 ppb. The 70 ppb limit is derived through personal communication with Trident Seafood personnel and is apparently set to conserve a 2X safety factor over chronic toxicity levels.

The temperature exiting the OTEC evaporators will be nearly the ideal temperature for growing abalone without the delicate and deliberate task of mixing DSW and SSW to obtain the correct temperature. DSW and SSW from the OTEC plant will be returned to the NLEHA-owned distribution system for use by Big Island Abalone and future tenants in the HOST Park. The post-OTEC distribution system will be established with a chemistry monitoring and alarm and activation system connected to diverter valves each side of the OTEC plant. OTI's resource utilization plan provides for diversion of 6,000gpm of SSW from the input stream to the OTEC process in the event of an ammonia leak resulting in an ammonia concentration above 70 ppb. Of the remaining 34,800gpm that flows through the OTEC evaporator, a substantial portion is likely to be provided to the kelp and algae farming component of the abalone company, as the possible traces of ammonia will be a welcome addition to the plant culture medium. OTI has met with principals of the abalone farm and the NELHA staff to plan the downstream use of effluent OTEC water to the maximum benefit of other tenants and the future expansion of the HOST Park (Figure 6).

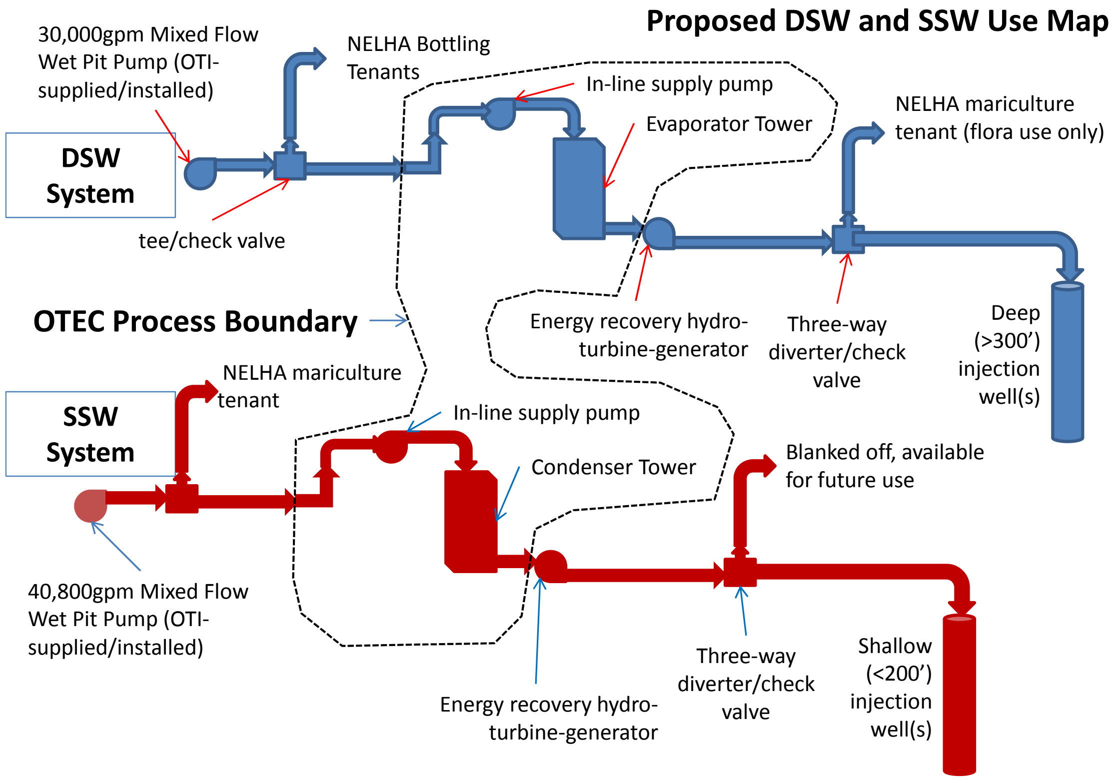

Figure 6. OTI 1MWe OTEC facility DSW and SSW piping systems. The dotted line indicates the commercial OTEC process boundary (Section 2.5).

2.4.3 Electricity

For startup, OTI will rely on electrical power from an on-site mobile synchronous diesel generator. After start up, the OTI 1MW OTEC Demonstration Plant will generate all of its own power. OTI will install all power block equipment necessary to assure frequency and cycle compatibility with the HELCO grid. Any electrical power in excess of the demands of the OTI 1MW OTEC Demonstration Plant can safely power the discharge pumps at the HOST Park 55-inch Pumping Station and the net power output can be safely delivered to NELHA's tenants or other third parties. Underground power conduits will be installed to those recipients. The power transmission system will conform to current design standards and safety requirements.

2.4.4 Fresh Water and Sanitary Sewage Discharge

The domestic water supply for the Host Park facility is near its maximum permitted capacity. There is a possibility that domestic water may not be available, so OTI will consider collecting fresh water condensate from the facility for sale or distribution to other NELHA tenants. Condensed fresh water should be of good quality, but no testing, certification, or other processing will be undertaken by OTI; therefore, the fresh water should not be considered potable. The usual staff loading for the facility will be three to four persons. Potable water will be used for drinking and hand washing. Statistically water and wastewater for non-residential applications is 25 GPD per individual. The administration building will be capable of accommodating visitors and meetings will be held at the site. Bathroom facilities will be oversized to accommodate additional personnel. Water and wastewater demands are expected to average 100 GPD.

The 1MWe RD&D facility will have its own wastewater disposal system. It will be designed, built and permitted in compliance with Hawai‘i Department of Health permit regulations.

2.5 OTEC RD&D Operating Processes

The OTI RD&D facility is intended to demonstrate and refine the thermodynamic, fluid dynamic, electro-mechanical and electrical performances and safety features of the OTI OTEC power block. OTI believes that a long-term, land-based RD&D facility is more prudent from a risk, operations, and cost perspective than a small-scale, offshore facility. A land-based plant, however, has parasitic loads that adversely affect its performance as compared to OTI’s offshore commercial design. These additional loads must be isolated and accounted for to accurately model the true net performance of OTI’s power cycle and to scale the demonstration results to its commercial offshore plants.

The power block components will be scaled to produce 1MWe gross within the OTEC process boundary (Figure 6). Net power from the commercial simulation will be between 580kW and 890kW. Monitoring equipment will measure the additional intake pumping and discharge requirements and the partial recovery of power through ancillary hydro-turbines to distinguish the net performance of the land-based RD&D plant from OTI’s offshore commercial facilities. At full capacity, the 1MWe facility is expected to produce between 320kW and 640kW in excess of internal demand for third party distribution.

2.5.1 Pumps

New mixed flow wet pit discharge pumps will be installed: one 27,000gpm DSW pump and one 40,500gpm SSW pump. These variable frequency drive (VFD) pumps will operate on 4160VA, and will have a design service life of 25 years or more.

2.5.2 Heat Exchangers (HX)

There will be two circular HX towers, each containing two chambers. Between the two towers will be two turbine-generator decks, which will also house the switchgear and transformers. These decks will be elevated so that the lower of the two decks will be at least 10 feet above mean sea level to prevent inundation from any ocean surge. Each HX tower will stand about 54 feet above ground level. Water will flow vertically through these towers at rates of about 25,400gpm DSW and 35,800gpm SSW. This much water cascading from a height of approximately 54 feet has enormous kinetic energy, so OTI will install an energy recovery hydro-turbine generator at the bottom of both HX towers.

Heat exchanger performance drives total power generation, including that required to offset parasitic loads, and it depends on optimizing not only heat flux but also pressure drop and mass flow. Heat exchangers are critical to an efficient OTEC system as they extract energy from the large quantities of ocean water flowing through the system. While heat exchangers are commercially available and used in a variety of industrial applications, off the shelf equipment has not been optimized for the heat transfer conditions of a low temperature OTEC power cycle that must operate for decades in a marine environment. A central goal of the OTI RD&D facility is to provide continuing testing capability to optimize and the OTEC HX design and other components for coming generations of commercial OTEC deployment.

2.5.3 Power Cycle

The OTEC RD&D facility will not be connected to the Island's public utility grid. During stabilization, including the 1000-hour operation test, electricity will be discharged to a load bank via the synchronous diesel-generator. This approach assures that OTI's plant is unaffected by any perturbations in the HELCO grid due to frequency fluctuations or power outages. It will also demonstrate the stability and reliability of the OTEC power plant. A load bank is a device that develops an electrical load, applies the load to an electrical power source, and converts it to heat that dissipates either through air or water.

Following stabilization, OTI will continue to produce electricity, running the plant constantly to emulate a floating OTEC platform supplying electricity to a utility grid. OTI will moderate power output to mimic peak load, nominal load and off-peak (minimum) load. The load bank assures that the plant can continue to operate even if the HELCO grid fails. Because the load bank is water-cooled, electrical energy is converted to heat and put back into the water being discharged from the plant. A sub-stream of DSW leaving the power block could be be routed to the load banks cooling pool and then discharged to the injection wells. In the instance of water-cooled load banks, the volume of water to be used is unknown, but only a small fraction of the total discharge stream, Mixing the load bank water discharge with the total discharge stream would mask temperature differences at the injection well head. Air-cooled load banks are being considered and an economical alternative to water-cooled system.

2.5.4 Condensate Water Collection

The HX towers will be made out of steel. The Condenser Tower will contain 40ºF DSW, which will chill the outside surface of the structure. Because the structure will be exposed to the weather, air-borne moisture will collect and cascade down the outside surface of this structure. The daily collection rate of condensation is estimated to be about 40,000 gallons. Consistent with OTI's philosophy of maximizing the use of every available natural resource, OTI plans to collect this condensation and make it available for agricultural use. The production of agricultural-quality water can be increased by passing DSW discharged from the Condenser Tower through cooling coils above collection tanks. This is an opportunity OTI is willing to pursue further if there is sufficient demand. Condensate may be utilized for non-potable use within the facility such as sinks and toilets.

2.6 OTI RD&D Facility Outputs

After providing water required for current NELHA tenants, there remains a need to return excess seawater downstream of the OTEC plant. OTI plans to do this in the manner most widely accepted as having the least potential impact on the environment. Based on the assumptions stated above, DSW effluent will be approximately 20,600gpm and SSW effluent will be approximately 34,800gpm (Figure 6).

The SSW and DSW will pass through the aluminum heat exchangers of the OTI plant with minimal chemical treatment; OTI may utilize very low concentrations of biocides such as bleach to prevent biofouling of heat exchangers. If microbial film development is observed, present plans call for daily 1-hour applications to the evaporators only to achieve inlet solutions at a concentration of 0.07 mg 1^{-1} (70ppb). By comparison the federal drinking water standard for chlorine in drinking water is 4 ppm, nearly 60 times higher. After reaction with oxygen and organic materials the residual chlorine is expected to be negligible at the time of discharge from the system (See section 4.2.4). No other chemicals are used to treat the water. Except for temperature changes, there will be no detectable differences in SSW or DSW as a result of its use. The OTI OTEC plant uses a sealed closed loop refrigerant system with the refrigerant being ammonia. The water discharged by the plant will be plumbed to go back into the HOST Park distribution piping, an injection well, or a combination of these. The OTEC process will elevate the DSW temperature by approximately 12ºF; the SSW temperature will be lowered by approximately 9ºF.

2.6.1 Deep Seawater Return

OTI has closely reviewed findings and recommendations of prior seawater return alternatives analyses and has concluded that underground injection provides the greatest benefit and lowest risk of unwanted impacts on the receiving environment. Based on model discharge plume calculations and results of regional hydro-geological surveys including sample well bores, OTI believes that a system of wells 2 feet in diameter and drilled to a depth of 400 feet, with solid casing down to 300 feet will provide adequate capacity to receive the projected DSW return rate of 20,600gpm. Injection pressure will be on the order of 4 feet at the well head. Present plans anticipate meeting the full OTEC DSW return flow with three deep wells. In the event that permeability either falls short of or exceeds expected conditions, injection well development will be adjusted to attain the needed return capacity and an acceptable margin of 15% surplus.

2.6.2 Surface Seawater Return

Results of previous seawater discharge evaluations at the HOST Park lead OTI to conclude that despite the higher volume flow rates, effluent SSW from the OTEC facility may be returned through a system of shallower injection wells. Five wells 2 feet in diameter and drilled to 150 feet are expected to be sufficient. Injection pressure at the SSW well head will be similar to that from the DSW wells. As with the DSW well plans, provisions exist to make adjustments as needed to achieve the required capacity.

2.6.3 Generated Power Distribution

Following the initial 1000-hour test, OTI will continue to produce electricity, running the plant constantly to emulate a floating OTEC platform supplying electricity to a utility grid. This means that OTI will moderate power output to mimic peak load, nominal load and off-peak (minimum) load. OTI may supply electricity to one or more NELHA tenants or possibly third parties on a cost-reimbursement basis. Underground power conduits will be installed to those recipients. The power transmission system will conform to current design standards and safety requirements. The power that OTI produces will be constant frequency and voltage because OTI will be running induction generators. By designing and connecting the power circuitry through a standby diesel generator, if there is an outage in the HELCO grid, a steady supply of electricity can be provided to the NELHA 55" pump station to sustain seawater flows.

2.7 Required Permits and Approvals

The proposed actions fall entirely within the description of actions assessed at the HOST Park in previous EIS, and supplemental EIS documents, and land use permits as discussed in Sections 1.4, 1.5 and further in Appendix A. Outstanding ministerial approvals are required from the Board of Directors at NELHA, the County of Hawaiʻi, and the Federal Aviation Administration as shown in Table 2 below.

Table 2: Required permits and approvals for completion of the proposed action.

Action	Permit Name	Agency	Approval
Construct OTEC RD&D	Environmental Assessment	NELHA Board of Directors	Lease Agreement
Construct Facility to 54 feet AGL	FAA Airport Obstruction Analysis Form 7460-1	FAA, State DOT Airports Division	Authority to Construct
Construct Facility to 54 feet AGL	Variance	County Planning	Authority to Construct
Building and Grading	Building and Grading permit	County Planning	Building Permit
Grading	NPDES Stormwater	Department of Health	NPDES Construction Permit
Dispose Domestic Wastewater	Individual Wastewater permit	Department of Health	Septic Tank Permit
Dispose Seawater	UIC Permit	Department of Health	Injection Well Permit

The proposed action does not require Clean Water Act (CWA) permits outside of those identified above because there is no discharge as defined by the Clean Water Act.

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.

Of particular concern are the requirements of CWA Section 316b, which is recently amended to reduce the impacts of power plant cooling water intakes on plankton and larvae. The rule states:

This final rule applies to new greenfield and stand-alone facilities that use cooling water intake structures to withdraw water from waters of the U.S. and that have or require a National Pollutant Discharge Elimination System (NPDES) permit issued under section 402 of the CWA. New facilities subject to this regulation include those that have a design intake flow of greater than two (2) million gallons per day (MGD) and that use at least twenty-five (25) percent of water withdrawn for cooling purposes.

The proposed action has no discharge and does not require an NPDES Section 402 permit; therefore is not required to obtain a 316 permit.

Also of concern is whether the proposed action is an OTEC facility under the definition of the OTEC Act of 1980 (OTECA), and requires a license to operate from NOAA. Although OTECA remains in place, the licensing rule 15 CFR Part 981 was rescinded in 1996 due to a lack of interest in OTEC development. In withdrawing the rule NOAA issued the following assurances to potential OTEC developers (Federal Register Vol. 61, No. 20).

When commercial interest in OTEC projects occurs, NOAA will issue a proposed rule appropriate to the regulatory needs at that time. For particular inquiries into the licensing of OTEC projects in the interim period, NOAA will provide actual and timely notice of applicable procedures and requirements to particular individuals.

NOAA currently retains the responsibility to regulate OTEC facilities and plantships under OTECA but must redraft rules to reflect the current regulatory requirements. This process would effectively delay construction of the proposed action to the extent that it would no longer be viable. The definition of what facilities are regulated under OTECA and what are not is of critical importance to the proposed action. 42 U.S.C. § 9102 defines an OTEC facility:

"ocean thermal energy conversion facility" means any facility which is standing, fixed or moored in whole or in part seaward of the highwater mark and which is designed to use temperature differences in ocean water to produce electricity or another form of energy capable of being used directly to perform work, and includes any equipment installed on such facility to use such electricity or other form of energy to produce, process, refine, or manufacture a product, and any cable or pipeline used to deliver such electricity, fresh water, or product to shore, and all other associated equipment and appurtenances of such facility, to the extent they are located seaward of the highwater mark;

While the proposed action will generate electricity from differences in ocean water temperatures, no portion of it is located seaward of the high water mark. The proposed action is a privately owned research, development, and demonstration facility, which utilizes an existing, permitted State-owned pipeline to derive water. The pipeline is not for the exclusive use of the proponent, but part of a much larger system that includes other thermal energy research, aquaculture operations, pharmaceutical companies, water bottlers, and educational institutions. NELHA retains full ownership of the infrastructure, its maintenance, operation and even ownership of the water. Users of the seawater infrastructure are required to pay for water supplied by NELHA, and rent for the ground. The same system has supplied thermal ocean water to volatilize ammonia and other working fluids for many years, and the aspect of whether these previous facilities produced a form of energy capable of performing work is debatable.

Upon review the proponent believes that the publicly owned infrastructure is not part of the proposed action, and has not been classified as such in previous demonstration facilities.

2.8 Research and Development on CO_2 Extraction

MELE has a Cooperative Research and Development Agreement (CRADA) with the Naval Research Laboratory (NRL) to work on a Synthetic Fuel Process System. The synthetic fuel process system is comprised of two major units (each with a number of components). The first unit is a carbon capture skid that is designed to extract CO_2 gas from seawater and generate hydrogen gas. The H_2 and CO_2 are used in the second unit (synthetic fuel processing) which consists of two significant closed components (chemical process reactors) in series.

By 2014 the proponent hopes to have scaled-up a seawater CO_2 extraction skid for co-location on site with the one (1) MW OTI OTEC process. The skid will be about 5' high x 10' wide x 10' deep and it will use about 150,000 gallons per day of seawater, about 15,000 gallon/day freshwater, and 25 kilowatts hours per day of electricity. The freshwater will be created from seawater by an evaporative process or through condensation. About 10 gallons of synthetic fuel will be produced per day. To produce this amount of fuel 230m^3/day of H_2 and about 75m^3/day of CO_2 is needed. If temporary storage of CO_2 and H_2 gases is needed, the gases will separately be compressed slightly and stored in gas tanks until used in the fuel conversion process. The processed fuel will be temporarily stored in an above ground 500 gallon tank. The fuel will be trucked to another site for use or the fuel will be used to run auxiliary equipment.

The discharge from the process will consist of processed seawater and a portion of the freshwater totaling 110 gallons per minute. The discharge will have a pH of 7 and salinity slightly higher than seawater. The discharge will be mixed with the much larger volume OTEC seawater discharge of 20,000 gallons per minute, so immediate dilution and mixing will take place prior to disposal in the injection wells. No chemicals are expected to be discharged with the effluent. The CO2 processing system will not generate significant amounts of air pollutants, but the precise quantity and characteristics of air emissions are not known at this time. All appropriate Clean Air Act, and other permits will be completed prior to construction and installation of the R&D equipment.

3. Description of the Affected Environment

3.1 Location

The HOST Park is situated near Keahole Point on the Island of Hawaiʻi, accessed by OTEC Road, which intersects Queen Kaʻahumanu Highway south of the entrance to Keahole Airport (Figure 7). As described previously, OTI has selected a portion of Parcel 87, just north of HOST Park's 55-inch pumping station, as the location for the OTEC RD&D Facility (see Figures 8 and 9). The OTI lot is located at 19º 42' 49.0"N, 156º 02' 54.0"W.

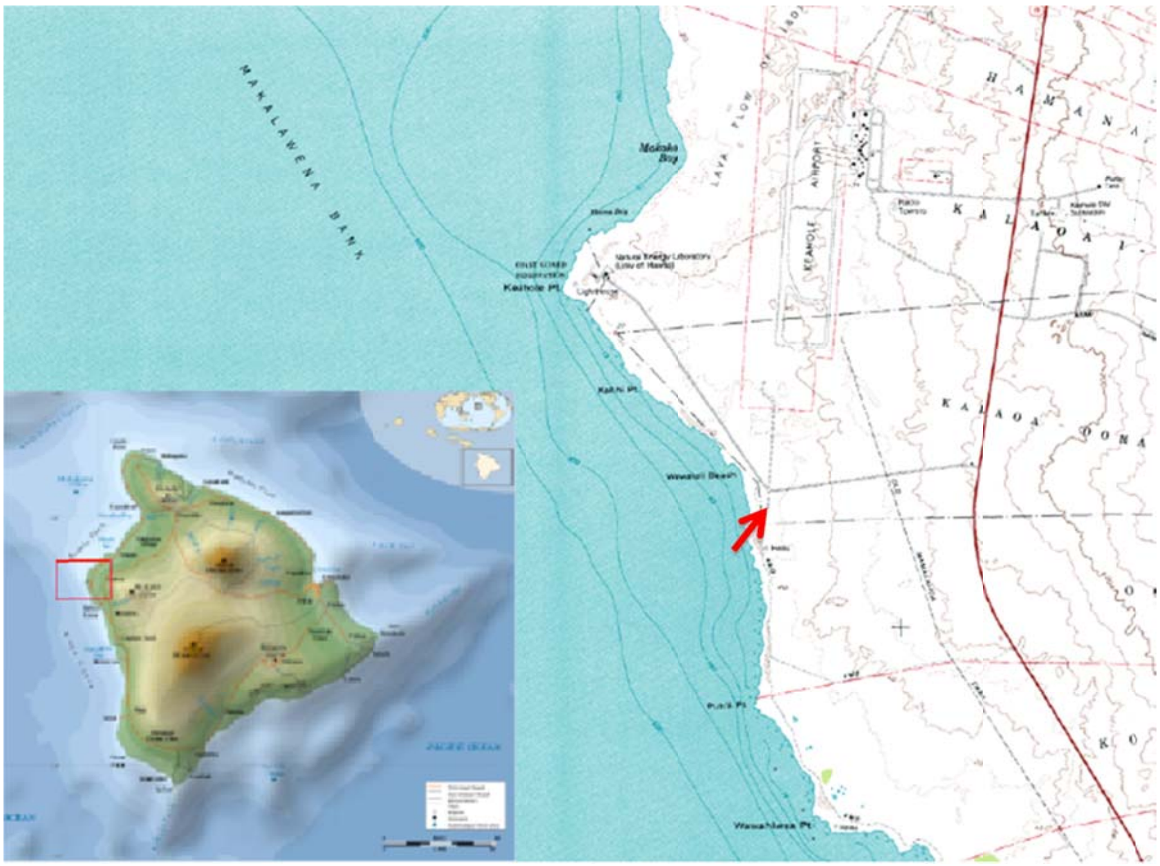

Figure 7. Island and regional map of Keahole Point

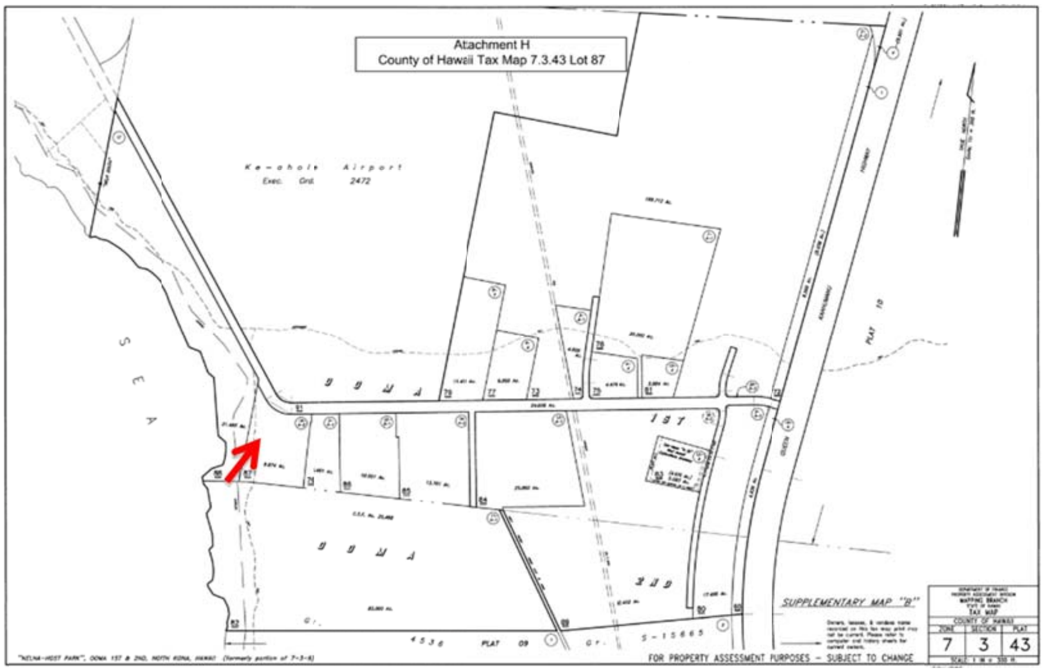

Figure 8. Tax Map, Plat 43; Lot 87 is at the bend in OTEC Road

Figure 9. Aerial photo of the 1.76-acre lot allocated for OTI RD&D Facility; NELHA 55-inch Pump Station is south of the OTI lot.

3.2 Climate

The climate in coastal areas of North Kona is arid to semi-arid, becoming more humid towards the higher elevations of the Hualalai mountain slopes. Temperatures are generally very consistent and moderate with an average daily temperature at Keahole Airport of 75ºF, typically ranging from 65ºF to 85ºF. The highest recorded temperature at the Airport was 89ºF, and the minimum was 54ºF (Traverse Group, 1985). Literature records indicate average annual precipitation in Kailua-Kona of 25 inches, however NELHA has 10 years of records from its own station at Keahole Point that indicate an annual precipitation of just over 13 inches. Pan evaporation is high with annual evaporation exceeding precipitation by a factor ranging from nearly four to well over seven (GK & Assoc., 1992). North Kona is largely sheltered from the predominant trade wind system by the landmasses of Hualalai, Mauna Kea, and Mauna Loa volcanoes. The prevailing wind is typically offshore in the early morning and onshore in the afternoon. Winds average approximately 8 mph in the Kona region.

Two major wind regimes exert controlling influences on the climate of Hawai‘i: prevailing northeasterly trade winds, and less frequent southwesterly “Kona” wind conditions. Responding to barometric pressure gradients surrounding the semi-permanent North Pacific high pressure region, the trade winds prevail about 65% of the year, with greater frequency during the summer months. Occasional reversals of the pressure gradient due to formation of low-pressure systems northwest of the islands produce the Kona storms, which occur most frequently during winter months and are accompanied by periods of heavy rain or thunderstorms. Most of the rain that falls in the Keahole area is the result of these infrequent Kona storms (Schroeder, 1993).

3.2.1 Flood Zones and Coastal Hazards

Tropical storms and hurricanes are rare events in the Hawaiian Islands, and they are most likely to occur during periods of highest sea surface temperatures, between July and September. Figure 10 depicts the paths of tropical storms and hurricanes that have passed close to the Hawaiian Islands since 1950. Studies of Hawaiian hurricane records conclude that all of the main islands have been affected by hurricanes, and no island is without risk. However, historical records of hurricane and tropical storm tracks indicate

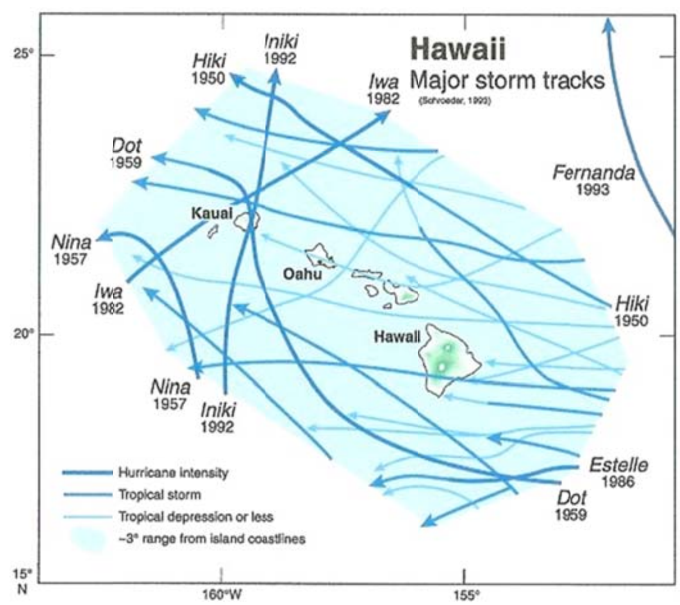

Figure 10. Tracks of major storms that have affected the Main Hawaiian Islands

that islands in the western end of the chain are more likely to experience the effects of these storms (Schroeder, 1993).

As shown by the above map, the Island of Hawaiʻi is seldom directly impacted by hurricanes. However, high waves from low-pressure systems and other storms affect the coastline on a regular basis. Other coastal hazards include tsunamis, coastal inundation and overtopping from large swells, sea level rise and coastal erosion. (Vitousek et al, 2009)

According to the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map, the flood zone is zone X for parcel 87 of the HOST Park, which means it is outside the 100- year area for coastal flooding (Figure 11). Closer to the shoreline, the flood zone is AE, which overlaps a small portion of the south part of the parcel well away from the building site for the proposed OTEC plant.

Tsunamis are a series of waves of very long wavelengths (100's km) and periods (10's minutes- 1 hour or more) that can travel up to 1000km/hr. in the open ocean. They are caused by disturbances that displace large volumes of water and are usually generated by seafloor displacement during earthquakes, submarine landslides, and oceanic bolide impacts (Vitousek et al, 2009). Approximately 50 tsunamis have been reported in Hawaiʻi since the 1800s. Historically, tsunami heights on the west side of the Island of Hawaiʻi have ranged from 0.6m-3.4m. Parcel 87 for the OTEC demonstration plant is in the tsunami evacuation zone as shown on Figure 12 (Vitousek et al, 2009).

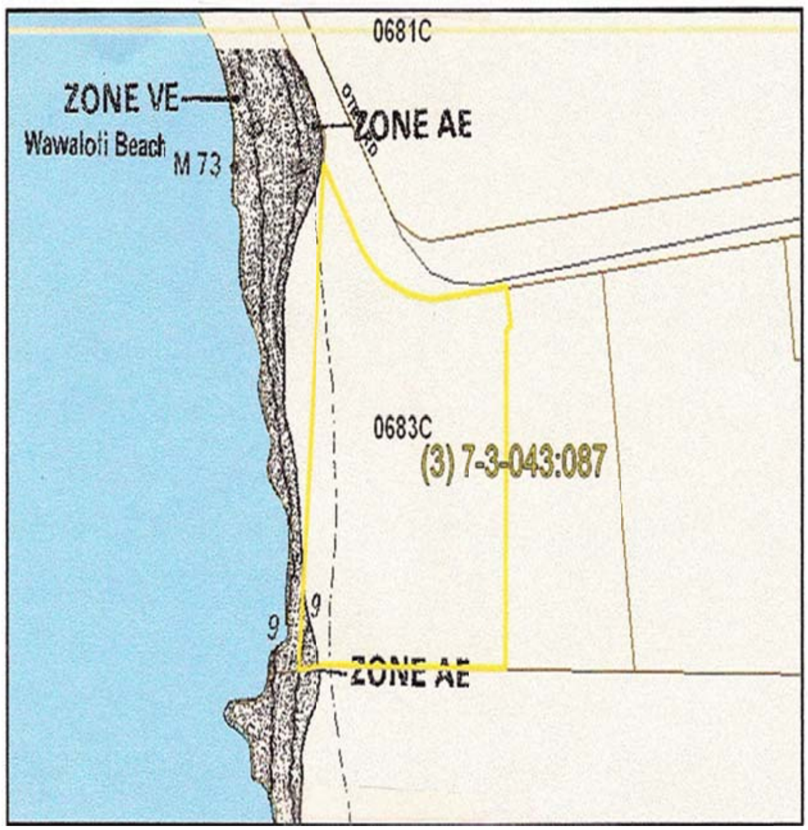

Figure 11: Flood zone map parcel 87 (http://gis.hawaiinfip.org/fhat/)

Figure 12. Tsunami Evacuation Zone Map of the HOST Park

The coast at the HOST Park is a primarily west facing coastline and receives large north and south Pacific swells during winter and summer months, respectively. These large swells produce coastal impacts in the form of coastal erosion, overtopping and inundation. However the nature of these impacts is seasonal: they occur during high swell season, and are followed by calm conditions, which favor recovery. Because 7 of the 8 main Hawaiian Islands are to the northwest of the Big Island, significant blockage and reduction in nearshore wave heights occurs (Vitousek et al, 2009).

Sea-level rise is a significant coastal hazard. The time horizons for such impacts are often distant, relative to the rate of sea-level rise and the elevation of structures at risk. When considering the interaction of sea-level rise with large wave and tide events, the potential impacts due to sea-level rise (in the form of increased overtopping frequency associated erosion and shoreline change) appear on a much shorter time horizon.

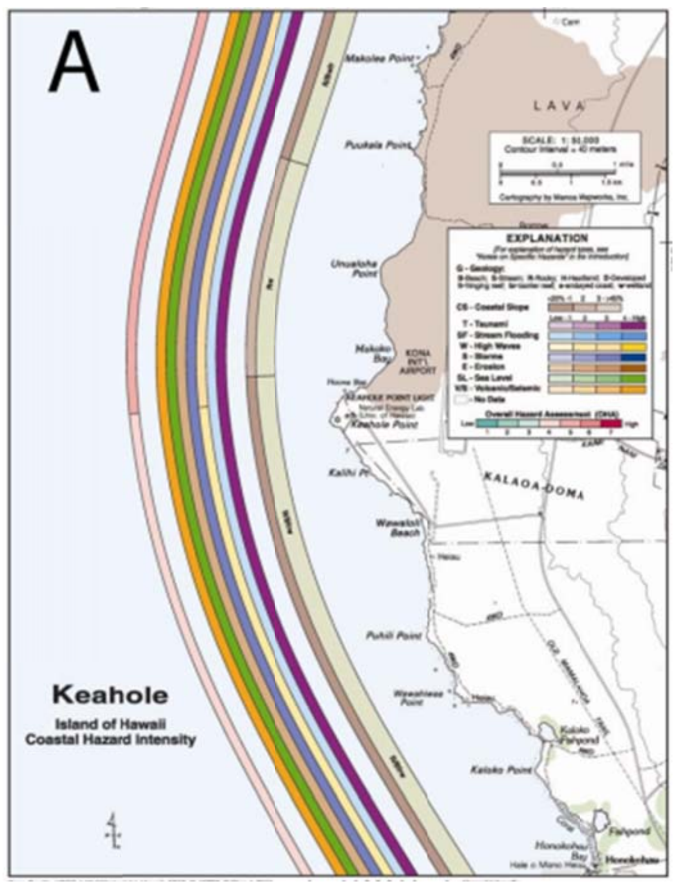

Figure 13. Coastal hazard intensity map for the Island of Hawai'i: Keahole

There is much debate over quantifying potential sea-level rise scenarios. In Hawaiʻi the sea-level rise ranges from ~1.4 mm/yr. to ~3.8 mm/year (Vitousek et al, 2009). The sea level rise is higher on the Island of Hawaiʻi (3.8mm/yr.) in comparison to the other Hawaiian islands due to an island subsidence rate of 3mm (0.12 inches) per year (USGS, 2000). A summary of the coastal hazards is seen in Figure 13 (Vitousek et al, 2009).

3.3 Geology and Hydrology

At a regional scale, the terrestrial setting in the vicinity of Keahole Point is well defined, primarily consisting of geologically recent, primitive basalts of the Hualalai volcanic series (Dames and Moore, 1985; 1986). Olivine basalts of this series are poorly layered and heterogeneous, comprised of *aʻa*, clinker and pahoehoe, with individual units extending laterally no more than several hundred feet and vertically less than 100 feet. Average flow thickness is about 10 feet, and in the region of the HOST Park, there are no known vertical intrusions. The lavas are poorly weathered, and surface flows are transected by extensive and irregular vertical fractures. Flank inclination near the coastline is less than 5 degrees, and lava tubes are common, some with collapsed surface openings and others at subsurface depths. These conditions are known to be favorable for highly permeable aquifers, but both lateral and vertical porosity varies at a local scale. Because of the high degree of fracturing of lava surfaces, infiltration rates in the Keahole region are extremely high, thus ponding and surface runoff is virtually nonexistent, even during major rainfall events.

A thin Ghyben-Herzberg lens of brackish basal groundwater with a thickness of less than 125 feet floats on the seawater that permeates subsurface strata. From the coastal region to a distance inland of about three miles, the groundwater is non-potable, discharging in a narrow band within the coastal intertidal zone. Estimates of hydraulic conductivity in the area range from 2,000 to 10,000 feet per day, with an average value of 5,000 ft./day, and effective porosity of the conductive substrata is estimated to be 0.1 (Mink, 1992). Water samples from coastal and inland wells in the region indicate a feeble gradient of 0.8ft. / 5,000ft, and best estimates of coastal groundwater effusion are on the order of 3mgd per mile of coastline (Oki et al, 1999).

Much of the information on regional geohydrology is derived from monitoring wells in the area, including the 34 wells on the NELHA property sampled by the NELHA Comprehensive Environmental Monitoring Program (CEMP). In addition to data available through the CEMP, comprehensive data also have been reported from sites immediately to the south of the prospective OTEC site. Nance (2008) summarizes his findings as follows:

Salinity, temperature, water level and water quality data from basal wells in the area all indicate that the flow rate is low compared to areas north of Keahole Point and south of Kailua Bay, that salt water circulation at depth exerts considerable influence on temperature in the basal lens, and that formation permeabilities are exceptionally high.

There are a variety of wells near Keahole, including shallow monitoring wells, including the ones at the HOST Park (W_{1-6}) and higher level drinking or irrigation water wells further inland. In order to understand the circulation of basal groundwater and its rate of flow, several studies have looked at temperature, salinity gradients and tidal variation within the wells.

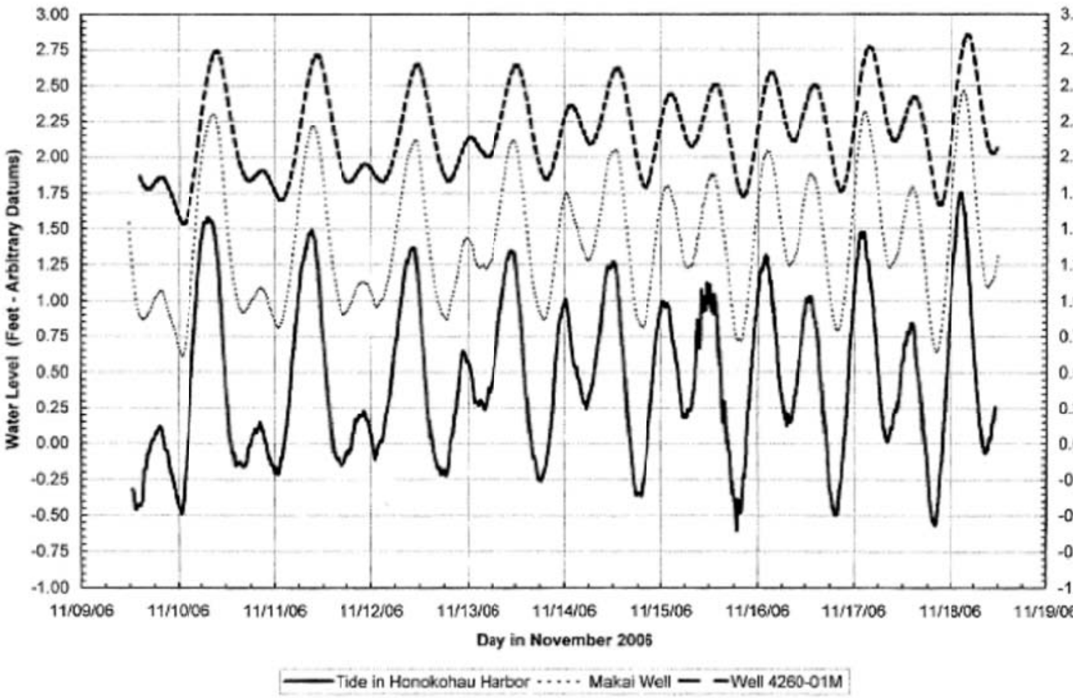

Figure 14. Tidal Variation in coastal and inland wells near Keahole Point

Nance studied tidal variation in 1991 to estimate hydraulic conductivity, and he found significant variation in the water levels correlated with tidal change (Nance 2008). Water levels in the makai well 450 feet from the shoreline at O'oma varied in amplitude 75% of actual tidal excursion, whereas the mauka well 5500 ft. from the shoreline varied only 45% and lagged by 1.4 hours from the actual tide (Fig. 14).

Salinity profiles of these two wells appear in Figure 15. Salinity in the upper 10 feet of the inland well is about 20% of ambient surface seawater. As the figure shows, the lens close to the coast is much thinner. Salinity, lens thickness, and the breadth of the transition zone suggest a moderate groundwater flow rate consistent with Oki's estimate of shoreline discharge (Nance, 2008).

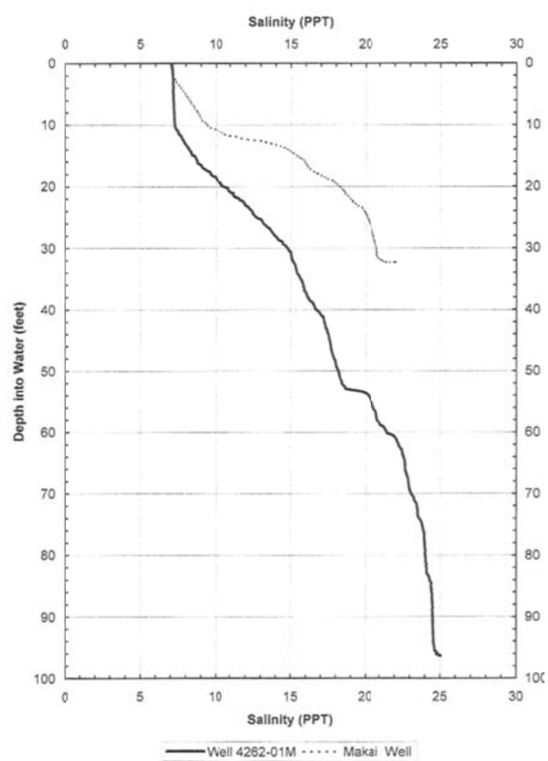

Figure 15. Salinity profiles in two wells at O'oma: the Makai well is 450' from the shoreline, and Well 4262-01M is 5,500' inland.

Figure 16 shows the temperature/depth profiles of the inland and coastal wells. Nance notes that these temperatures are unusually cold, some 5 to 10 degrees colder than that of the high level groundwater that is the source of the basal lens in this region. Evidently, seawater mixing with high-level groundwater to form the basal brackish layer must be in communication with cold seawater at offshore depths of 700’ or more (Figure 17). The mechanism of landward deep seawater flow mixing and coupled to seaward basal water movement is not understood, and the low temperatures of basal groundwater are unique to this region (Nance, 2008).

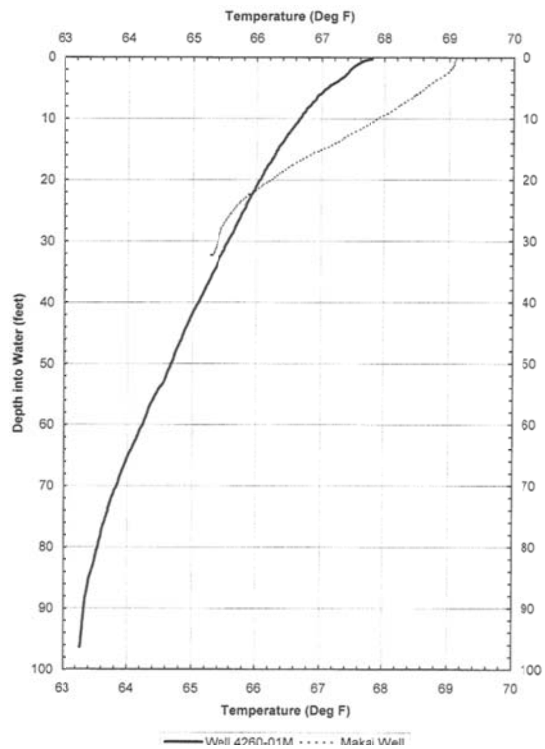

Figure 16. Temperature profiles in the inland and makai wells at O‘oma

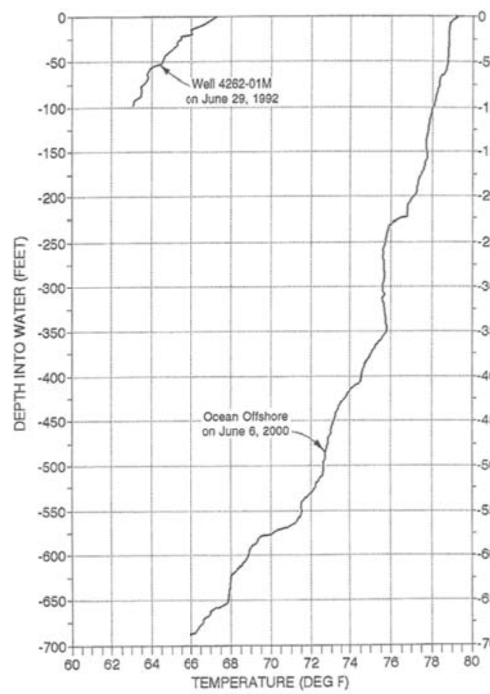

Figure 17. Temperature profile in the inland O‘oma well and offshore ocean waters

Hydrologic reports previously cited (Dames and Moore, 1985; 1986; Mink, 1992; Oki et al, 1999; Nance, 2008) offer insights suggesting that the regional substratum at Keahole is highly heterogeneous with regard to permeability. Additional evidence of the variable geologic features characteristic of lava at Keahole Point comes from drilling records collected in the course of monitoring well construction. For example, Figure 18 is a boring log for a well in the vicinity of the NELHA 55” pump station, showing layers of basalt and clinker gravel with varying degrees of both porosity and hardness, interspersed with voids, and cavities. Note that at this location, a continuous layer of clinker gravel and sand extends from a depth of 30’ to the bottom of the core at 55’. Locally, layers such as this provide channels for high rates of subsurface water flow. Drilling records like this offer the only practical means of collecting site-specific information needed to make engineering assessments on which to base reliable designs for subsurface seawater return systems.

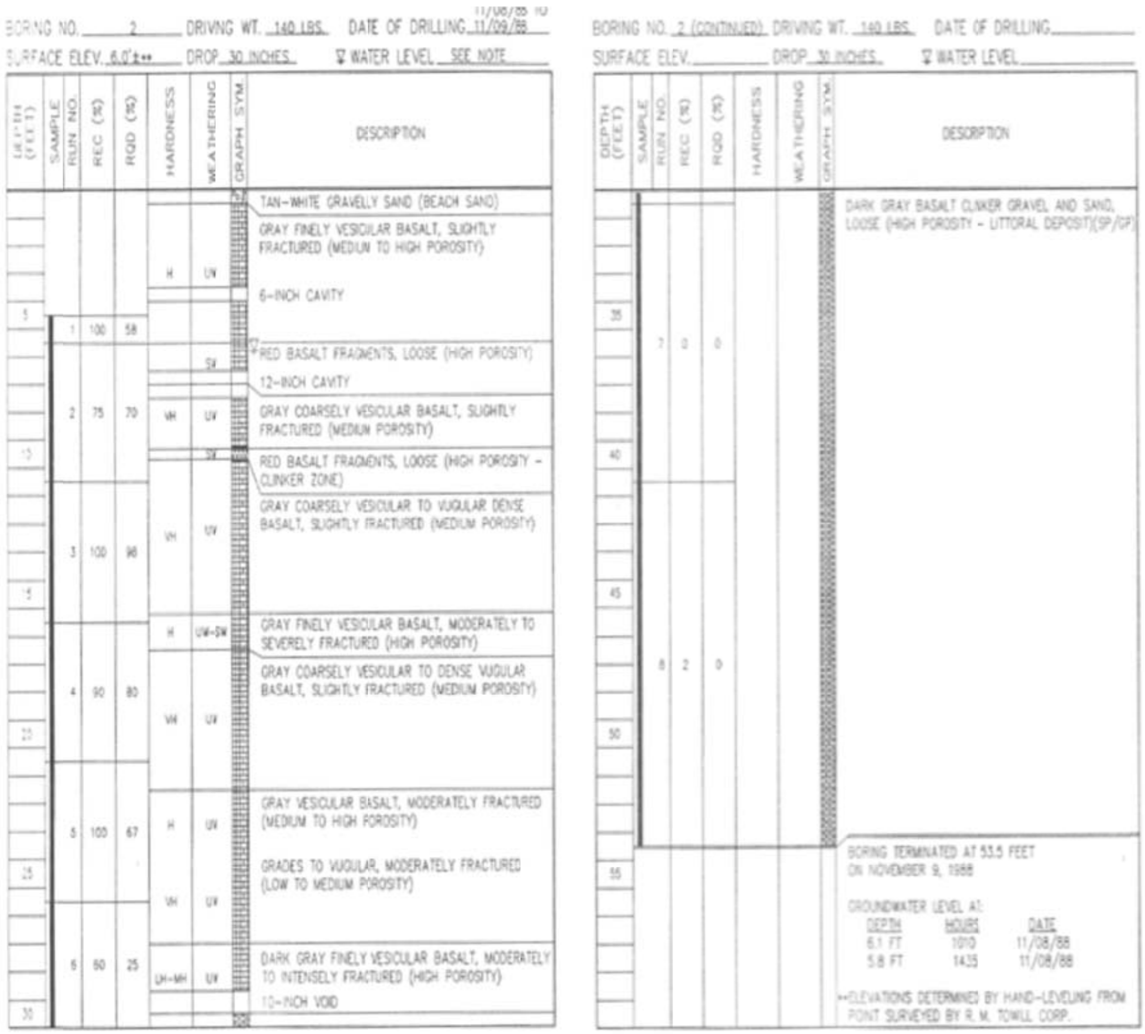

Figure 18. Geolabs-Hawai'i boring log, monitoring well W-2, the HOST Park

3.4 Marine Environment

Nearshore marine communities in the Keahole region are very well described (e.g. Brock, 1954; Brock and Norris, 1987a, 1987b, 1988; Brock and Kam, 1989; Brock, 1992; Dollar, 1986, 2008, Ziemann and Conquest, 2010). Each of the environmental impact statements prepared for proposed actions at the NELHA site (see section 1.4.1) includes extensive description and assessment of the physical and ecological structure of the coastal marine environment. In 1992, the CEMP established six transect areas, each with designated survey lines in each of the three near shore reef zones for surveys of benthic communities and fish resources, and these stations are regularly monitored (Olson, 2011). These multiple surveys and reports allow both a comprehensive description of the system, and, more importantly, they provide quantitative insight into long-term variability in community structure as well as trends in community responses to natural and anthropogenic influences. The descriptive and quantitative baseline allows identification of key communities and areas of interest relative to proposed activities that could affect long-term ecosystem stability.

The physical structure of the near shore marine environment offshore of the HOST Park is a basaltic ledge of pahoehoe lava with interspersed pockets of white calcareous sand. The intertidal platform is constantly subjected to the wash of the waves and is flooded in places to form tide pools. The seaward edge of the lava shoreline is composed of either basaltic boulder fields, or vertical sea cliffs 1-2 meters in height. There is a public beach on the southern end of the HOST Park property, Wawaloli Beach. Beyond the shoreline, water depth increases rapidly with distance from the shore off Keahole Point, with depths of 2,000 feet within a mile of the coast. Between the 500 and 2,500 feet depths, the bottom slope is approximately 30 degrees. Shallower than 500 feet, the slope angle decreases. The nearshore marine communities in the vicinity of Keahole Point have in the past been recognized as some of the most biologically diverse in Hawaiian waters.

Previous studies have pointed to the profound impact of natural stresses (storm surge, sedimentation, wave scour, etc.) on the composition and extent of the coastal biota (e.g., Dollar and Tribble, 1993; Scoffin, 1993). Understanding the extent and range of natural impacts to nearshore communities provides the context needed to evaluate effects of development activities on coastal water quality and community dynamics.

3.4.1 Water Quality

In general, regulatory limits relevant to OTEC disposal at the HOST Park are imposed in reference to Water Quality Standards (WQS) established under **§11-54-6(d)** HAR. Coastal waters in the region surrounding most of the Big Island are designated Class AA and extend to the limit of "*open coastal waters*", which are defined in HAR **§11-54-6(b)(1)** as, "*marine waters bounded by the 183-meter or 600-foot (100-fathom) depth contour and the shoreline*." The region offshore of Keahole Point is more narrowly defined in **§11-54-6(d)(1)** to include "*all areas from the shoreline at mean lower low water to a distance 1000 m seaward*." Thus, the absolute distance from the shoreline, rather than the 100-fathom depth contour determines the extent of Class AA waters off of the HOST Park.

According to DOH Water Quality Standards: *"It is the objective of class AA waters that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions"* (HAR**§11-54-03(c)(1)**).

Section **11-54-6(d)(1)(i)** establishes water quality criteria for waters having a salinity greater than 32.00 parts per thousand (ppt), including a table of geometric mean criteria values that define the acceptable concentrations of regulated parameters (Total Dissolved Nitrogen, Ammonia Nitrogen, Nitrate + Nitrite, Total Dissolved Phosphorus, Phosphate, Chlorophyll a, and Turbidity. Limits are defined for each parameter as acceptable geometric mean concentrations or units.

A different method, defined in **§11-54-6(d)(1)(ii)**, establishes water quality criteria for regions where near-shore marine waters have a salinity *less than or equal to* 32.00ppt. In these waters, nutrient parameters (with the exception of ammonia nitrogen) are defined in relation to salinity, based on the linear least squares regression,

$$Y = MX + B \quad \text{where:}$$

Y = parameter concentration in µg/l, M = regression coefficient or slope
X = salinity in ppt, B = the Y intercept.
For each nutrient parameter, the absolute value of the upper 95% confidence interval for the calculated sample regression coefficient must not exceed given values.

The intent of the modified water quality criteria as applied to Keahole Point coastal waters is to recognize and accommodate the natural condition of high rates of groundwater entry at the coastline. By using a hydrographic mixing model regression to establish a baseline, naturally occurring high concentrations of dissolved nitrate and phosphate theoretically would not lead to violations of established standards in the absence of anthropogenic influences. In practice, many researchers have noted that the criteria as implemented are not fully effective, and excessively high nutrient levels are measured even in regions where natural conditions prevail (Olson, 2011; Dollar, 2008; Traverse Group, 1985; Towill, 1982; WRRC, 1980).

Monitoring of water quality has been performed regularly through the CEMP at the HOST Park, but the design of the monitoring program does not lend itself to a definitive description of near-shore mixing and dispersion regimes along the Keahole coastline. Near-shore sampling since 2007 has conformed to Department of Health regulatory guidelines (*ref.* ***§11-54-6(d)(1)(iii) HAR***), and the requisite spacing of sample station locations is too broad to develop a well-defined gradient in parameters as a function of distance from the shoreline.

A more comprehensive data set exists for the coastal region immediately to the south of the HOST Park site, where Dollar (2008) has

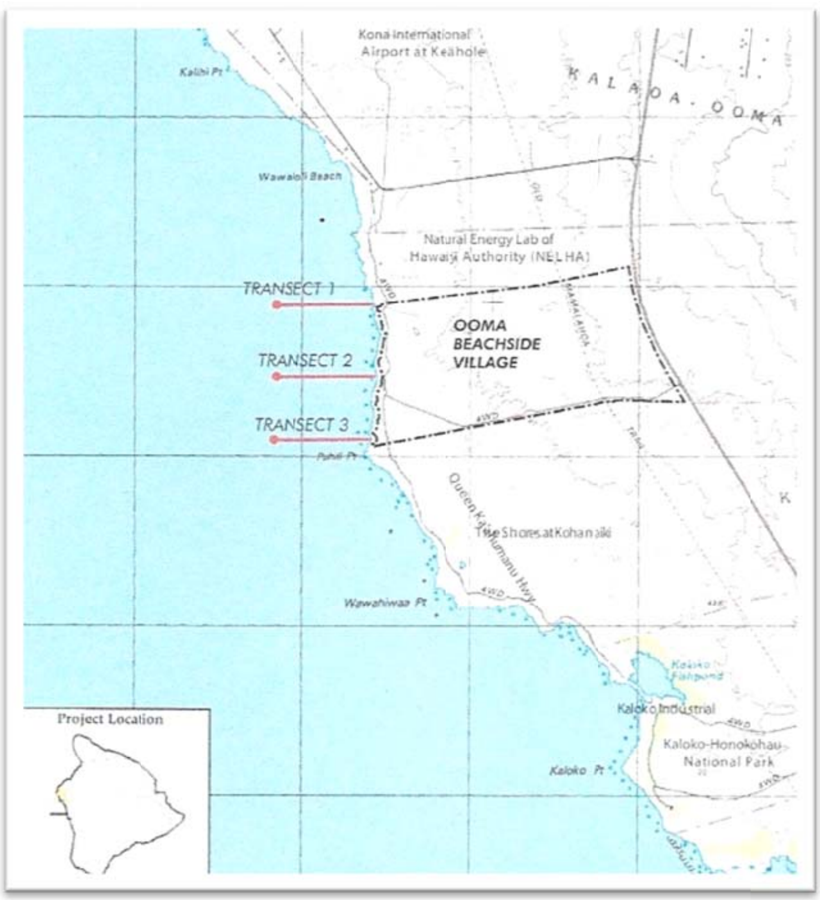

Figure 19. Map of North Kona showing O'oma Beachside Village and three water quality monitoring transects located offshore of the property. (from Dollar, 2008)

sampled three transects over a period of 14 years, most recently in 2006 (Figure 19). The purpose of this study was "to determine the contribution of groundwater to the marine environments" and "to evaluate the effects that this input has on water quality".

The work was performed prior to any alteration or development on coastal land adjacent to the shoreline, and thus it offers a long-term, comprehensive assessment of natural conditions in an area immediately adjacent to the coastline along which OTEC-related discharges may occur.

As indicated in Figure 19, the three transects are located immediately to the south of the bend in the NELHA access road that marks the location of the proposed OTI OTEC facility.

Groundwater entry along the Kona coast contributes a consistent signal of high nutrient, low temperature, and low salinity source water to shoreline communities. The transects established and monitored by Dollar offer clear evidence of both groundwater input adjacent to an undeveloped region and rapid natural mixing and dispersion of introduced physical and chemical signals within a short distance from the shoreline. Additional studies (Dollar and Atkinson, 1992) have demonstrated the influence of coastal morphology on nutrient flux and ecosystem response, leading to an understanding of the greater mixing and dispersion potential of open coastal as opposed to embayment systems.

Dollar's data indicate that mixing and dispersion effectively resolve perturbations of seawater components due to high-nutrient groundwater input at the shoreline, and virtually all of the parameters are in equilibrium with prevailing oceanic levels by a distance of 50m offshore. Although there was some variability between transects, the prevailing trends held consistently for those parameters most closely associated with groundwater. Analyses of samples along identical transects collected during 1991-1992 gave comparable results (Dollar, 2008), indicating an absence of any long-term changes in natural coastal water quality.

Dollar reported results of water quality samples from the O'oma transects in tabular form (Table 3); with values that exceeded the geometric mean water quality criteria shaded blue. Clearly, the high frequency of exceedances underscores the problem created by groundwater seepage at the coastline. However, once he applied the DOH least squares regression procedure, only nitrate measurements in one of the three transects exceeded the upper 95% confidence limit standard (Table 4). Thus, although not perfect, the method did accommodate much of the natural nutrient variability that exists in this region.

Table 3. Water chemistry measurements from ocean samples collected along three transects off the O'oma Beachside Village project site on November 3, 2006. Shaded and boxed values exceed geometric mean criteria for waters and salinity greater than 32 ppt. (from Dollar, 2008)

TRANSECT SITE	STA. NO.	DFS (m)	PO_4^{3-} (µg/L)	NO_3^- (µg/L)	NH_4^+ (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (NTU)	SAL (ppt)	CHL a (µg/L)	TEMP (deg.C)	O2 (%sat)	pH
OOMA 1	1S	0	5.27	67.76	7.14	1,231	8.37	91.70	13.64	166.60	0.20	32.917	0.69	26.64	106.4	8.25
	2S	1	15.50	125.30	4.76	2,105	11.78	111.30	27.28	241.36	0.29	31.482	0.74	26.75	105.3	8.27
	3S	2	3.41	109.34	8.26	1,850	9.92	96.04	13.33	213.64	0.21	31.952	0.56	26.89	107.0	8.27
	4S	5	8.37	104.72	5.60	1,810	8.37	94.22	16.74	204.54	0.13	31.987	0.91	26.99	107.5	8.27
	5S	10	2.79	94.64	5.04	1,792	12.71	114.80	15.50	214.48	0.20	32.048	0.94	27.00	106.4	8.26
	6S	15	1.24	80.36	3.50	1,451	8.99	99.26	10.23	183.12	0.14	32.655	0.71	27.01	104.3	8.25
	7S	20	0.93	78.26	5.04	1,324	8.68	87.50	9.61	170.80	0.12	32.839	0.63	27.06	104.8	8.24
	8S	30	0.93	56.00	6.16	1,091	10.85	92.40	11.78	154.56	0.14	33.147	0.39	27.09	103.5	8.22
	9S	50	0.93	8.12	8.96	199	8.37	80.08	9.30	97.16	0.10	34.548	0.20	27.10	108.1	8.16
	9D	50	0.62	BDL	12.60	83	8.37	82.04	8.99	94.64	0.08	34.721	0.17	27.23	107.2	8.15
	10S	150	0.31	3.08	12.32	70	8.68	96.46	8.99	111.86	0.07	34.727	0.15	27.25	105.1	8.15
	10D	150	0.93	4.20	7.28	59	8.06	84.00	8.99	95.48	0.10	34.758	0.14	27.24	105.2	8.16
OOMA 2	1S	0	0.93	224.56	8.96	2,061	8.37	118.86	9.30	352.38	0.78	28.977	1.22	26.89	105.2	8.07
	2S	1	0.93	26.88	7.56	861	9.30	97.86	10.23	132.30	0.18	33.123	0.40	27.01	105.8	8.26
	3S	2	0.93	15.12	8.54	854	9.30	92.82	10.23	116.48	0.18	33.064	0.87	27.01	104.6	8.33
	4S	5	0.93	25.48	6.02	858	8.99	104.86	9.92	136.36	0.14	33.205	0.28	27.04	106.3	8.24
	5S	10	0.93	7.56	8.68	401	8.68	89.18	9.61	105.42	0.11	34.081	0.34	27.10	104.5	8.23
	6S	15	0.93	5.74	10.78	325	8.68	83.58	9.61	100.10	0.10	34.233	0.73	27.13	105.5	8.22
	7S	20	0.62	2.52	10.50	249	8.06	91.00	8.68	104.02	0.08	34.408	0.28	27.19	106.4	8.21
	8S	30	0.62	2.94	10.78	205	8.68	99.96	9.30	113.68	0.09	34.521	0.34	27.20	101.2	8.18
	9S	50	0.62	2.66	7.28	168	8.37	96.60	8.99	106.54	0.08	34.605	0.38	27.23	104.5	8.18
	9D	50	0.93	2.10	8.26	82	8.37	74.62	9.30	84.98	0.07	34.720	0.13	27.33	102.2	8.16
	10S	150	1.55	1.96	5.18	74	8.99	81.34	10.54	88.48	0.08	34.729	0.12	27.24	105.5	8.16
	10D	150	0.93	1.68	7.42	55	8.06	90.72	8.99	99.82	0.06	34.781	0.14	27.22	104.3	8.16
OOMA 3	1S	0	19.53	642.18	14.14	10,342	6.51	59.36	26.04	715.68	0.13	17.149	0.44	26.54	107.4	8.18
	2S	1	1.24	159.04	17.36	3,051	9.92	147.56	11.16	323.96	0.15	28.751	0.27	26.99	105.5	8.28
	3S	2	0.62	124.04	15.68	3,024	10.85	130.90	11.47	270.62	0.22	29.265	2.00	27.01	104.8	8.31
	4S	5	0.93	116.90	9.94	2,838	9.30	106.12	10.23	232.96	0.15	29.642	0.64	27.21	106.3	8.32
	5S	10	1.86	118.02	9.10	2,872	7.75	116.62	9.61	243.74	0.13	29.618	0.46	27.14	105.3	8.32
	6S	15	1.24	77.70	1.96	2,220	8.68	128.38	9.92	208.04	0.13	30.853	0.46	27.15	108.4	8.34
	7S	20	1.86	25.76	0.84	926	8.68	101.92	10.54	128.52	0.10	33.332	0.39	27.21	103.1	8.29
	8S	30	2.79	21.00	3.08	698	8.37	90.02	11.16	114.10	0.09	33.777	0.45	27.22	104.3	8.26
	9S	50	11.47	4.76	0.98	185	0.62	105.00	12.09	110.74	0.09	34.595	0.22	27.27	108.8	8.19
	9D	50	2.79	3.08	1.54	119	6.51	98.00	9.30	102.62	0.07	34.720	0.13	27.26	107.6	8.17
	10S	150	1.86	6.30	1.12	189	7.44	105.56	9.30	112.98	0.07	34.575	0.13	27.25	105.8	8.14
	10D	150	1.86	2.10	BDL	106	7.75	102.20	9.61	104.30	0.08	34.700	0.15	27.24	105.7	8.15
W HI WQS (GEO MEAN)			5.00	4.50	2.50				12.50	100.00	0.10	*	0.30	**	***	****
ANCHIALINE POOL			205.84	1,492	8.96	28,170	9.92	582.40	215.76	2,083.20	0.12	15.02	0.27			7.74

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary more than one degree Celsius from ambient conditions.
*** Dissolved oxygen shall not be less than 75% saturation.
****pH shall not deviate more than 0.5 units from a value of 8.1.

Table 4. Slopes of linear regressions of nutrient concentrations as functions of salinity for surface samples on three transects offshore of O'oma Beachside Village. Also shown are DOH compliance slopes. Underlined values indicate absolute value of upper confidence limit exceeding DOH compliance slope. (from Dollar, 2008)

NUTRIENT	DOH	TRANSECT 1			TRANSECT 2			TRANSECT 3		
	SLOPE	SLOPE	LOWER CI	UPPER CI	SLOPE	LOWER CI	UPPER CI	SLOPE	LOWER CI	UPPER CI
NO_3^-	-31.92	-37.48	-40.41	<u>-34.55</u>	-38.67	-47.06	-30.28	-36.31	-41.50	-31.12
TDN	-40.35	-41.64	-47.58	-35.70	-43.86	-53.11	-34.62	-35.25	-38.43	-32.06
PO_4^{3-}	-3.22	-2.87	-5.58	-0.16	-0.01	-0.14	0.12	-0.77	-1.54	-0.01
TDP	-2.86	-3.63	-6.50	-0.76	0.00	-0.28	0.29	-0.85	-1.23	-0.46

These data underscore the importance of designing an OTEC effluent return system that avoids displacement of the groundwater lens. The regression coefficient model applies to water having salinity values that are less than 32.00ppt, *i.e*., influenced by an influx of brackish groundwater. We earlier noted the high frequency of standards violations in nutrient and other parameter levels measured against the geometric mean (GM) criteria established by DOH for Kona coast Class AA water (see Table 3). However, because low salinity measurements were common near the shoreline, the regression model applied, rather than the GM model. By these standards, only a single violation was noted. By implication, if a method of OTEC effluent discharge is employed that results in displacement of the groundwater flow at the coastline, salinities will not fall below 32 ppt, resulting in more stringent standards being applied.

Having considered both the structure and the process of sampling for compliance with prevailing WQS and further taking into account initial dilution, advection and dispersion in coastal waters more removed from the immediate shoreline, it is evident that in addition to posing less risk of harm to the ecosystem, entry of OTEC effluent through steady seepage into deeper waters further offshore offers significant compliance advantages. OTI's approach to designing the seawater return system from the proposed RD&D facility constitutes a conservative, precautionary strategy based on a premise of preserving the high quality of near shore coastal waters. Under the chosen discharge design conditions, OTI is confident that DOH water quality standards will be met or exceeded at all times.

3.4.2 Marine Ecosystem – Nearshore Benthos

As noted earlier, the marine environment in the Keahole region is very well described, and it corresponds in general zonation and community structure to characteristics documented for the Kona coast of the Big Island (Dollar, 1982). Marine community surveys have been conducted repeatedly in waters off of the Natural Energy Laboratory, including in the vicinity of the proposed OTI RD&D Facility (*e.g.*, Dollar, 1975, 1992; GK & Assoc., 1985; Brock and Norris, 1987a, b, 1988; Brock and Kam, 1989). Between 1991 and the present, contractors to the CEMP have conducted 33 surveys of benthic communities in near shore waters adjacent to Keahole Point (Zieman and Conquest, 2010). In addition, detailed studies to establish a baseline description of the marine ecosystem offshore of the O'oma resort development immediately to the south of the HOST Park property include one transect very close to the OTEC site (Transect I, Figure 19). As a result, over thirty years of descriptive data are available both to establish a detailed understanding of the components of the marine community and to assess changes in composition and extent resulting from natural and human induced perturbations.

Benthic marine fauna and flora, including hermatypic and ahermatypic corals, motile macroinvertebrates (echinoderms, arthropods, mollusks, etc.), and macroalgae occur in varying assemblages that reflect the physical and ecological constraints of their immediate environment. The occurrence, abundance, and diversity of the component organisms in a given area are what determine the community structure. Long-lived and mostly stationary biota will flourish when conditions favor their survival, but will decline in response to either acute or chronic environmental stresses. For this reason, time-series snapshots of community structure offer a reliable method of measuring systemic responses to both natural and anthropogenic disturbances.

Hermatypic or reef-building corals are particularly important, due to their abundant biomass and role both as productive biota and as a source of habitat and support for associated species.

Dollar (1975) cites five major environmental characteristics responsible for coral composition and distribution in Kona coastal waters: wave energy, light, sedimentation, available substrata, and interspecific competition. In near shore areas of West Hawaiʻi, these factors produce three broad zones of reef communities. Close to the shore, the shallowest zone is an extension of the lava shoreline bench, interspersed with scattered basalt boulders. In areas of frequent high wave energy, the principal coral is *Pocillopora meandrina*, a relatively fast growing and robust species, but *Porites lobata* occurs in greater abundance in more protected areas, especially to the north of Keahole Point.

Immediately seaward of the coastal boulder zone is a shallow reef bench extending from about 6 to 15m depth. The bottom in this region is mostly basalt, with emergent lava extrusions and sand channels, the so-called "spur and groove" zone. Fine-grained calcareous sands also occur, often in expansive sand flats where vertical relief is minimal. At these depths, periodic swells associated with Kona storms produce strong turbulence that scours and shapes the surge channels, producing undercuts and ledges that offer abundant shelter for fish and other macrofauna. However, prevailing levels of wave stress are lower here, and as a result, conditions are optimal for the abundance and diversity of reef corals that colonize much of the exposed rock surface. *P. lobata* again dominates in this zone, with observed coverage of up roughly 37% in the more protected waters north of the point.

The deep reef starts with a sharp increase in slope to an angle of between 20 and 30 degrees, and the substratum changes to a mostly unconsolidated aggregate of rubble and coarse sand, with basalt boulders up to a meter in diameter and infrequent rock outcrops. The predominant coral species in areas of lower wave stress is *Porites compressa,* but in more exposed regions, *P. lobata* again is more prevalent (Dollar, 1992).

Coral community structure varies both spatially and temporally, reflecting prevalent physical and ecological conditions. Results of two surveys performed in August and December of 1991 are indicative of the variable nature of West Hawaiʻi marine benthic communities. Dollar attributes much of the substantial decline in areal coverage of *P. lobata* on the reef bench at Site 3 to effects of wave activity between the survey times, although some of the difference may be a sampling artifact.

Observations of coral community structure on the transects off of Oʻoma (Dollar, 2008) illustrate long-term changes that reflect both the severity of storm impacts to the benthic near shore reefs and a resilience of coral communities to storms that is an evident adaptation to these impacts. A severe winter storm struck the area in February 1986, and its effects are reflected in the low level of total coral cover (20%) measured in the first survey later that year. By the time of the next survey four years later, total coral cover had climbed to 37%, and by 2006, coverage had increased to 47%. Thus, over a period of twenty relatively calm years, coral abundance in waters off of Oʻoma increased by a factor of over 2.5 (Dollar, 2008). Similar results emerge from surveys reported by CEMP contractors. No significant changes in mean total coral abundance were observed between May 1992 and May 1997, but mean cover nearly doubled from May 1997 to June 2002. Some decline in total coral abundance was evident over the following three years, but by 2010 total coral cover was 46.4% (Ziemann and Conquest, 2010).

At greater depths beyond 25m, reef coral growth declines and disappears, and the substratum consists of lava boulders and rubble with patches of primarily biogenic calcareous sediment with little organic content. The slope from 45 to 80m is fairly steep, about 40 degrees, and most level surfaces are devoid of encrusting biota, with a light cover of sediment. *Halimeda sp.*, encrusting coralline algae, sponges and tunicates are common on vertical or near-vertical hard surfaces, with antipatharians (*Cirrhipathes sp.)* being the most abundant macro fauna. At greater depths, echinoderms (*Holothuria atra* and *Chondrocidaris gigantea)* are most conspicuous (Harrison, 1985).

Benthic features in this region reflect offshore transport and deposition of calcareous sediments in substantial quantities, with an extensive sand terrace between 80 and 150m. Sediment surfaces show evidence of active infauna, with gastropod trails, burrow openings, mounds and pits, and films of epibenthic algae or diatoms are visible. Coralline algae and sessile invertebrates encrust hard surfaces, and as depth increases, sediment grain size increases, forming an armored bottom surface. Where bioturbation disrupts the surface cover, underlying sediments are contrasting fine white sands (Harrison, 1985).

Below 160 meters, the slope increases again to 40º, and hard surfaces have less encrustation than at shallower depths. Sponges, tunicates, hydroids, gorgonians, and occasional ahermatypic corals are present, and the most common invertebrate is the red and white banded shrimp (Harrison, 1985).

3.4.3 Marine Ecosystem – Plankton

The surface waters off Keahole Point are typically low in concentrations of dissolved plant nutrients and consequently support a low standing crop of phytoplankton indicated by levels of Chlorophyll *a* shown in Table 2. Noda et al. (1980) measured chl *a* profiles off Keahole Point that describe a shallow mixed layer about 60m deep increasing in concentration to a maximum concentration at 94m about three times the concentration of surface waters. Noda et al. attribute this maximum to decelerated phytoplankton sinking rates due to increased water density and to increasing intracellular chlorophyll concentrations as an adaptation to lower light levels. At greater depths, chl *a* concentrations decline with depth to insignificant levels below 200m (GK & Assoc., 1985). Similar profiles prevail for phaeopigment concentrations, with a shallow surface later with low concentration increasing to a subsurface maximum at or below the chlorophyll maximum and then declining with depth (Noda et al., 1980).

Using C-14 uptake methods, Noda et al. measured primary productivity on six cruises undertaken in support of the OTEC program. Variability in production with depth was slight, and neither surface sunlight inhibition of photosynthesis nor a subsurface maximum in productivity were detected. However, the rate of production per unit biomass decreased rapidly with depth, with nutrient limitation evident in surface waters, and light limitation curtailed productivity proportionally to increasing depth. Overall, depth-integrated production was highly variable over the cruises, with results on three of the cruises near the lower limits of detection (Noda et al., 1980).

Measured daytime zooplankton biomass was typically slightly lower in the upper 25m of the water column than in the depths from 25 to 200m. Nighttime concentrations in the upper 25 meters increased dramatically, while slightly decreasing in the 25 – 200m range.

Calanoid copepods were the most abundant zooplankton group sampled. In general, Hawaiian zooplankton assemblages tend to be high in diversity and low in abundance (GK & Assoc., 1985).

Midwater lantern fish larvae (*Myctophidae*) comprised the most abundant larval fish in the plankton tows collected on the HOTEC cruises. In themselves, lantern fish aren't economically significant in any fishery, but they likely comprise a substantial component of the planktonic food web due to their abundance (Noda et al., 1980).

3.4.4 Marine Ecosystem – Nekton

Coastal waters in the Keahole Point region harbor among the most diverse and abundant reef fish assemblages in the main Hawaiian Islands, as documented in multiple fish population surveys over recent decades (*e.g.*, Brock, 1954; ORCA, 1977,1978; Brock and Norris, 1987a, 1987b, 1988; Brock and Kam, 1989; Brock, 1992). Repeated surveys along transects coinciding with established benthic sampling areas occupied by CEMP contractors noted previously provide a robust and consistent description of observed fish populations in the three major near shore reef zones adjacent to NELHA (Brock, 1995, 2002, 2008; Oceanic Institute, 1997, 2007; Ziemann and Conquest, 2010). Reef fish studies in Hawai‘i and elsewhere describe natural variation in fish biomass per unit area as loosely correlated with the topographic complexity of the substratum. Greater habitat complexity offers commensurately more abundant shelter, and conversely, areas with less relief will support smaller fish populations. The diversity and abundance of fish in the Keahole region undoubtedly arises from the steep and rugged substrata that are characteristic of the near shore waters. Additionally, particulate food materials carried on the strong tidal currents that sweep the region help to sustain large standing crops of fishes (Brock, 1992).

Visual surveys of fish populations have been conducted repeatedly at stations that roughly correspond with the reef survey transect areas occupied by Dollar (1992). One of the fish survey sites includes three transects offshore of Wawaloli Beach, very close to the proposed OTEC RD&D facility site (Brock, 1992). These transects coincide with the same three reef zones previously described: the nearshore boulder zone, the shallow reef bench largely populated with *P. lobata*, and the deep reef slope. Emphasis placed on fish populations in these regions reflects both their greater accessibility and the presumption that biota here are more susceptible to impact from effluents arising from human activities on the shore.

Table 5. Summary of fish censuses from the May 1989, October 1991, and March 1992 surveys. (from Brock, 1992)

Location	May 1989 No. Spp.	May 1989 No. Ind.	October 1991 No. Spp.	October 1991 No. Ind.	October 1991 Biomass (g/m^2)	March 1992 No. Spp.	March 1992 No. Ind.	March 1992 Biomass (g/m^2)
Hoona Bay								
Boulder	26	389	24	339	105	32	263	108
P. lobata	33	430	34	399	187	28	144	36
P. compressa			35	481	170	32	382	166
18-Inch Pipe								
Boulder			39	510	379	37	274	230
P. lobata			32	604	327	31	467	158
P. compressa			36	824	271	29	499	248
Wawaloli Beach								
Boulder	25	187	30	209	210	25	204	113
P. lobata	37	346	33	237	51	26	341	138
P. compressa			28	188	57	24	272	54
Honokohau								
Boulder	30	265	28	180	72			
P. lobata	30	260	26	273	66			

The visual sampling methods employed in monitoring surveys off of the HOST Park provide a good basis for assessing conspicuous diurnal fish populations, but nocturnal and other cryptic species will not be represented in these counts. Thus, the reported numbers of species observed by Brock (1992, Table 5) are considerably less than the 120 species of reef fish reported in more comprehensive studies at a range of depths, seasons, and locations (ORCA, 1977). Nolan and Cheney (1981) offer the following sectional descriptions of commonly seen nearshore fish in the vicinity of Keahole Point:

> *Unualoha Point – Keahole Point*
>
> *The most frequently encountered species in the middle reef terrace (-20ft) include the yellow tang, Zebrasoma flavescens, the chevron tang, Acanthurus nigroris, the kole, Ctenochaetus strigosus (an important subsistence species), and the mamo, Abudefduf abdominalis. These species plus the olive damselfish, Chromis vanderbilti are also conspicuous in the lower reef terrqce (-30ft). The whitetailed damselfish, Chromis agilis, and the kole are common species at a depth of -50ft. The deeper reef slope (-90ft) harbors the blue damselfish, Chromis ovalis, and the black damselfish, C. verator.*
>
> *Keahole Point – Wawaloli Beach*
>
> *Large, roving predators like the omilu, Caranx melampygus, (an important market species) and the nenue, Kyphosus cinerascens, (an important subsistence species) frequent the surge zone. Other characteristic species include the mustard tang,*

Acanthurus guttatus, the Achilles tang, A. achilles, the humuhumu nukunukuapua'a, Rhinecanthus rectangulus, the mamo, and the stickfish, Aulostoma chinensis.

At least 55 fish species inhabit the middle reef terrace (-2 to -50ft), the most prominent being the olive damselfish. Also common are the kole, the yellow tang, and the hinalea lauwili, Thalassoma duperreyi.

At least 51 species have been recorded on the lower terrace (-40 to -60ft) in spite of the low density of live coral in this depth zone. In addition to the species which are common on the middle terrace is the lavender tang, Acanthurus nigrofuscus.

At least 43 species occur in the transition zone from terrace to offshore slope (-50 to -60ft). The predominance of juvenile fishes in this zone coincides with the habitat provided by lush colonies of the finger coral, P. compressa. The most frequently observed species are the yellow tang, the kole, the olive damselfish, the whitetailed damselfish, and the pebbled butterflyfish, Chaetodon multicinctus.

The upper portion of the offshore slope (-60 to -100ft) supports at least 37 species, the most abundant of which are the whitetailed damselfish, the damselfish, Chromis hanui, the blue damselfish, the yellow tang, the kole, and the pebbled butterflyfish.

Manta rays (Mobula japonica) and the 'oio, Albula vulpes, an important food fish, occasionally are observed in this depth zone The rare butterfly fish, Chaetodon tinkeri, is occasionally sighted, but the abundance of this species has been greatly reduced by aquarium fish collecting.

Important market species, including the weke 'ula (Mulloidichthys vanicolensis), the omilu, the uku (Aprion virescens), and the awa awa (Chanos chanos) have also been sighted during diving surveys off Keahole (ORCA, 1978).

Wawaloli Beach – Wawahiwa'a Point

A very abundant and diverse fish fauna has been surveyed by Nolan (1978) in the vicinity of Wawahiwa'a Point. Over 53 species occur in this area. Most abundant are the whitetailed damselfish, the hinalea lauwili, the yellow tang, the kole, the butterflyfish Hemitaurichthys zoster (=H. polylepis) (at depths exceeding 60 feet), the weke 'ula, the opelu Decapterus macarellus, and the skipjack tuna Katsuwonus pelamis are also observed near shore. Dense beds of the finger coral, P. compressa, provide important habitat for juvenile fishes.

Harrison (1985) observed a diverse and abundant fish fauna in deep water surveys conducted from a submersible. The most common species seen along the boulder-strewn slope at depths from -150 to -250ft were acanthurids, especially kole, but the assemblage also included ta'ape, *Lutjanus kasmira*, longnose butterfly fish, *Forcipiger sp.*, the lemon butterfly fish, *Chaetodon miliaris*, the false Moorish idol, *Heniochus diphreutes*, and various parrotfishes. In the more gently sloping region from -250 to -300ft, boulders and large rock outcrops were surrounded by enormous aggregations of ta‘ape, interspersed with occasional surgeonfishes. Rock crevices housed squirrelfishes and occasional moray eels. Below the abrupt slope transition to a sandy terrace at -300ft, ta‘ape were seen foraging, and at about -500ft, where the sand rolls off to another steep, rocky slope, squirrel fishes and anthiines predominate, along with an occasional snapper of the species, *Symphysanodon typus.*

3.4.5 Protected Marine Species

Under federal law, all marine mammals are protected under the Marine Mammal Protection Act (MMPA). Some marine mammals, including humpback whales and Hawaiian monk seals, also are protected as endangered species under the federal Endangered Species Act (ESA). ESA protection extends as well to all species of marine turtles that occur in Hawaiian waters.

Humpback whales (*Megaptera novaeangliae*) congregate in Hawaiian waters during the winter months for mating and giving birth. Although frequently seen in waters off the Kona coast, Humpbacks seldom venture into waters shallower than 20m. Hawaiian Monk Seals (*Monachus shauinslandi)* are among the most critically endangered mammals, and they will haul out on beaches and rocky shores to rest. The Monk Seal population is highest in the Northwestern Hawaiian Islands, but a growing number of seals inhabit the Main Hawaiian Islands (MHI).

Green Sea turtles (*Chelonia mydas*) are the species most frequently seen in waters off the Kona coast, although Hawksbill turtles (*Eretmochelys imbricata*) have been known to occur as well. Very rarely, an Olive Ridley turtle (*Lepidochelys olivacea*) is seen on the Big Island.

3.5 Anchialine Ponds

Anchialine ponds occur as depressions in highly permeable, most often relatively recent lava benches close to sea level. Although they lack a surface connection to the adjacent ocean, the permeable substratum allows for oceanic influence and mixing of seawater with groundwater flowing towards the coast. As a result, waters in anchialine pools are measurably saline, and the pond water level rises and falls with the tide, albeit with varying degrees of delay.

Previously, only two clusters of anchialine ponds were known to occur on NELHA’s property. One of these, the southern complex, is located close to Wawaloli Beach and mauka of the bend in the HOST Park access road, in a pahoehoe lava flow more than 70m from the shoreline. The nearest anchialine pond in this cluster is approximately 120 meters north of the project site and cross or slightly upgradient. This complex of ponds is of interest, both because of the high quality of the biotic assemblage in these pools and due to its proximity to the site of the proposed OTEC RD&D facility. These ponds are protected by the Hawai‘i Department of Health Clean Water Branch. Hawai‘i Administrative Rules (HAR) states in 11-54-5.2 *“Natural freshwater lakes, saline lakes and anchialine pools will be maintained in the natural state through Hawaii’s ‘no discharge’ policy for these waters. Waste discharge into these waters is prohibited (see paragraph 11-54-3(b)(1)).”* Water quality and biota are monitored regularly by NELHA.

In their pristine state, anchialine ponds harbor a distinctive assemblage of organisms. Certain of these organisms (hypogeal organisms), primarily decapod crustaceans, move between the open waters of the ponds and the interconnected water table below. The ponds at the HOST Park have a mixed assemblage of opae'ula (*Halocaridina rubra*) and small, unidentified red amphipods. One pond also has opae'o'haa (*Macrobrachium grandimanus*). Brock (1992) noted that these ponds, unlike many in West Hawai'i, are free of exotic fishes (*Poecilia sp.*) that prey upon the indigenous opae'ula. However, by 2007, all ponds at NELHA except those that are dry at low tide harbored populations of introduced exotic fishes, and the endemic decapods were observed during surveys conducted that year (Ziemann and Conquest, 2010). As a result of exotic fish eradication efforts undertaken in 2007, all but four of the ponds in the southern complex appear free of invasive fish, and native hypogeal opae'ula and amphipods have returned wherever fish are absent (Ziemann and Conquest, 2010).

Recently, NELHA personnel came upon a small anchialine pond located within the parcel proposed as the site for the OTI RD&D facility. This small well previously had been identified and described along with other features of SIHP Site 10182 (Barrera, 1985), and it was included in a mitigation program entitled "Hawai'i Ocean Science and Technology Park Work Program for Archaeological Data Recovery" generated by the State of Hawai'i Department of Land and Natural Resources (DLNR) Historic Sites Section. Detailed mapping, excavation, and data recovery of SIHP Site 10182 was completed (Barrera, 1989), and the DLNR determined that the site was satisfactorily mitigated. Much of the site subsequently was bulldozed.

Figure 20 shows the surface appearance of the well feature. As described by Barrera, the well consists "of a cavity in the lava measuring 1.7 by 3.5 meters. The cavity narrows towards the bottom, such that the surface of the water, which lies at a depth of 1.7 meters below the surface,

Figure 20. Anchialine pond surface opening (from Rechtman, 2012).

covers an area of only 0.85 square meters. The water level fluctuates with the tides, and is 0.3 meters deep at its maximum. The sides of the feature are nearly vertical on three sides, while access to the water could be gained via the sloping East side. Large water worn lava rocks are situated on this slope, obviously placed there to facilitate access. The feature clearly functioned as a water source, probably during the prehistoric period."

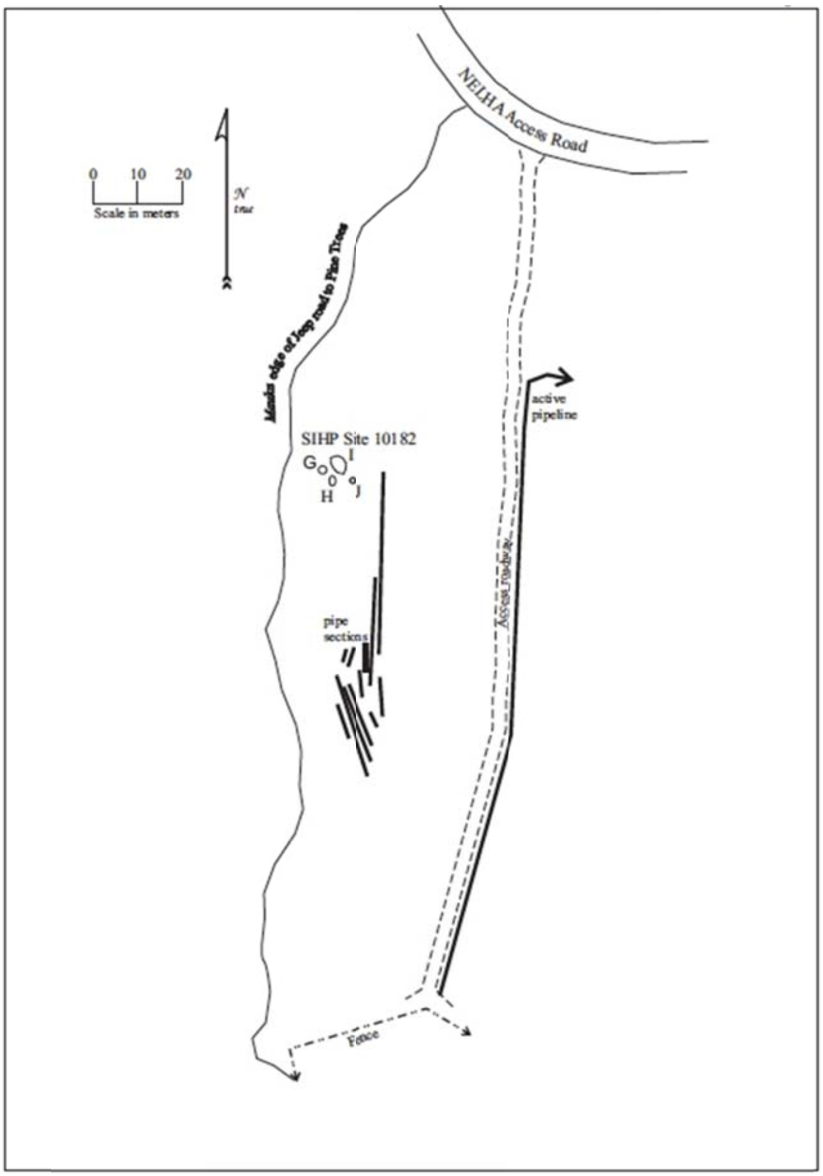

Figure 21. Remnant features of SIHP Site 10182. The anchialine pond is Feature I (from Rechtman, 2012).

Of the eleven features mapped and mitigated in the course of data recovery from Site 10182, only four, including the well, remain identifiable on the OTI parcel, and their location is shown in

Figure 21. Additional references to relevant archaeological surveys and data recovery findings appear in Section 3.8.3 below.

Recent work by Brock (Appendix C) provides more comprehensive physical and ecological descriptions of the pond. Confirming earlier descriptions, the well is small (0.85 square meters area) and tidal, with water present at all states of the tides. Salinity of the water is 10ppt, and water temperature averages 19.0ºC. Exotic Poeciliads are absent, and as a result, the well contains a thriving population of opae‘ula (*Halocaridina rubra*). Other species often seen in such habitat are not present in this well, and the numbers of opae‘ula fluctuate with the tide, more being present at higher levels of tidal excursion.

NELHA and OTI are committed to protection and preservation of the well as a valued resource and a high quality example of an anchialine ecosystem. Following consultation with the State Historic Preservation Division (SHPD) of the DLNR, OTI intends to create a preservation buffer around the opening, clear weeds and vegetation from the immediate vicinity to reduce sedimentation and manage the feature to prevent surrounding uses that may impact the existing biotic structure of the feature. A fence will be constructed between three and five feet from the margins of the pond, and appropriate signage will be placed to inform construction personnel to keep clear. A protective berm will direct runoff and debris flow away from the well, both during construction activities and throughout the operational phase of the OTI OTEC RD&D tenure. Maintaining the well within the fenced perimeter of the OTI parcel will serve to protect the feature from unwanted biotic contamination with invasive fish or discarded refuse. As a component of known anchialine resources of the NELHA lands, OTI recommends that the CEMP add this anchialine pond to their ongoing anchialine pond monitoring program in order to establish and maintain records of water quality in compliance with DOH guidelines. OTI will ensure timely access to the feature for this purpose. No regular biotic monitoring is planned at this time.

3.6 Terrestrial Ecosystem

3.6.1 Flora

The 1.76-acre site designated for the OTI OTEC RD&D Facility lays entirely mauka of the 40-ft shoreline setback and is about 175’ from the closest shoreline (see Fig. 9). The parcel’s longest dimensions are roughly 675’ by 210’, ranging in elevation from 4 to 10 feet above mean sea level, with an average elevation of 7’. The terrain is generally level, bounded on the east border by an access road to the NELHA 55” pump station that is adjacent to seawater distribution pipes, and bordered to the west by the jeep road that parallels the shoreline. The adjoining parcel landward has been used as a stockpile area for excavated materials resulting from other HOST Park developments. Between the OTI parcel and the ocean, the vegetation is typical of a West Hawai‘i coastal strand with basalt boulders interspersed by coral rubble and white sand deposited by storms. Some scattered groups of kiawe (*Prosopis pallida*) occur in mauka areas, and clusters of naupaka (*Scaevola taccada*), hi‘aloha (*Waltheria indica* var. *americana*), beach morning glory (*Ipomoea brasiliensi*s), Bermuda gass or manienie (*Cynodon dactylon*), and tree heliotrope (*Messerschmidia argentea*) make up the remaining species (Char, 1985).

Much of the project site was altered by clearing and grading activities that accompanied construction of the 55" pump station and associated facilities. Existing scrub vegetation is composed of a mixture of various grasses including most abundantly fountain grass (*Pennisetum setaceum*) and native piligrass (*Heteropogon contortus*), as well as natal redtop (*Rhynchelytrum repens*) and ʻuhaloa (*Waltheria indica*). No rare, threatened or endangered plant species have been recorded from the project area, and species occurring there are commonly found in similar habitats throughout the West Hawaiʻi area (Char, 1985).

3.6.2 Fauna

Although most of the project site is comprised of a relatively dry, scrub expanse, the neighboring coastal strand with kiawe, naupaka, and other vegetation noted earlier provides habitat for a greater number of animal species than those frequenting the site itself. Surveys of similar habitats were conducted by Char and Associates (1985), as well as surveys performed by Bruner (2006) on the Oʻoma parcel. The only mammals seen in each of these studies were Indian Mongoose (*Herpestes auropunctatus*), although tracks of feral cats (*Felis catus*) appeared in sandy roadways along the shoreline. Char (1985) points to the likely presence of other mammals such as the common house mouse (*Mus musculus*) and the Polynesian rat (*Rattus exulans*). The endangered Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) has not been seen in any of the NELHA surveys, nor was it detected by ultrasound sensors deployed by Bruner (2006).

The presumptive presence of mice and rats in the area make it possible that the Hawaiian owl (*Asio flammeus sandwichensis*) could be an occasional visitor, and Krauss (1977) did note a pueo over the Keahole Agricultural Park area. However, none were seen in more recent surveys. Similarly, no endangered Hawaiian Hawk (*Buteo solitarius*) has been sighted at the HOST Park.

One endangered bird that may transit the area is the Hawaiian Stilt (*Hymantopus mexicanus knudseni*), which is known to be present in ponds to the north and south of the project site. Other indigenous birds, including the Golden Plover (*Pluvialis fulva*), wandering tattler (*Heteroscelus incanus*), Ruddy Turnstone (*Arenaris interpres*), and Sanderling (*Calidris alba*) may occasionally occupy shoreline areas. No seabirds inhabit or nest along the adjacent coastline, due to the presence of feral cats and rats.

Introduced birds that frequent the HOST Park area include the Indian gray francolin (*Francolinus pondicerianus*), the barred dove (*Geopelia striata*), the common mynah (*Acridotheres tristis*), the Japanese white eye (*Zosterops japonicus*), the house finch (*Carpodacus mexicanus frontalis*), the house sparrow (*Passer domesticus*), the cardinal (*Cardinalis cardinalis*), and the Brazilian cardinal (*Paroaria coronata*) Char, 1985).

Montgomery (2006) conducted a survey of insects and other land invertebrates present at the Oʻoma parcel immediately to the south of the OTI project area. Although a wide variety of species common to the dry coastal Hawaiian habitat, including spiders, scorpions, bees, wasps, moths, dragonflies, ants, and centipedes were noted, no threatened or endangered species were found.

3.7 Socioeconomic Environment

The NELHA property that OTI proposes to lease for the OTEC RD&D facility is located in the North Kona district of Hawaiʻi. US Census Bureau data records indicate that as of 2000, the total population in the North Kona and South Kohala tracts of the Big Island was 15,520. SMS Research conducted projections for population growth in these tracts, and predicted that the area would have 21,918 residents in 2007, a growth rate of 41%, or around 6% per year (SMS, 2007). By comparison, their predicted growth rate for the entire island of Hawaiʻi was just over 2% per year, compared with US Census data that show island wide growth averaging just under 2.5% per year during that decade. By the 2010 census, population in North Kona/South Kohala had grown to 27,674, and the island wide population stood at 185,079. Decadal average growth rate for the island was 2.2% per year, a slight decline from projections in 2007. However, the North Kona/South Kohala district grew by close to 7.8% per year, thus, the North Kona and South Kohala districts appear to be among the fastest growing regions in Hawaiʻi County. Principal drivers of this growth are a robust visitor industry, which in turn drives an active construction, retail, and support services economy (SMS, 2007). In particular, the visitor service sector has thrived over the past two decades of tourism growth. Hawaiʻi County data indicate that about 61% of average employment in 1980 was in the service industry, and that rose to 71.3% in 1990 and 78.5% in 1997.

3.7.1 Adjacent Land-Use

NELHA provides cold nutrient rich, pathogen free seawater pumped from 3000 ft. deep and warm surface seawater off Keahole Point for a variety of tenants. The scope of tenants at the NELHA facility includes pre-commercial, commercial, research and educational corporations or groups (www.nelha.org). The proposed site is near the southwest corner of the HOST Park property adjacent to the existing 55" pump station. The closest tenant is Big Island Abalone, which is approximately 120 meters to the east. The next closest is Moana Technologies, approximately 500 m to the northeast. Wawaloli Beach Park is approximately 200 meters to the north. West Hawaiʻi Explorations Academy is approximately 1 km to the northwest, and the active runway at the Kona Airport is 1 km to the north. Of the neighboring tenants, Big Island Abalone is expected to benefit from water discharged from the facility, and other tenants may get power produced by the facility. The remaining tenants of NELHA are not expected to experience any impacts. NELHA itself is expected to benefit from increased pumping capacity and substantially reduced pumping costs.

An airport obstruction analysis is in progress and will be determined prior to completion of building permits. The airport obstruction analysis is conducted by the FAA with input from local and state airport users. The height of the proposed facility is below the level of exclusion defined in FAA regulations, and it is expected that the facility will be allowed. OTI anticipates compliance with lighting or other markings recommended by the FAA.

With exception to the tenants identified herein, the remaining land within 1 km of the site is undeveloped and vacant.

3.8 Cultural Environment

The NELHA-HOST Park properties, including the 1.76-acre project site, have been extensively and intensively surveyed for historic properties. A list of the prior archaeological investigations of this area is set out in Table 6. These studies include a cultural impact assessment for a development project in ‘O‘oma 2nd as well as *‘O‘oma - Kāhi I Hānai Ai ‘O Ka-lani Kau-i-ke-aouli,* an archival and historical research report for the *ahupua‘a* of ‘O‘oma (Maly & Maly 2003). The report prepared by Kumu Pono Associates records the native Hawaiian traditions, cultural practices and detailed historical accounts, including oral history interviews with elder *kama‘āina* knowledgeable of this area, one of 24 *ahupua‘a* that traditionally comprised the Kekaha region of North Kona. Kekaha, also known as *Kekaha wai ‘ole,* is an extremely dry area known for its rich marine resources and extensive *mauka* (upland) agricultural field system. Access between dwellings along the shoreline (*kahakai)* and the upland gardens along an extensive network of foot trails were essential to life in the Kekaha region in pre-contact times. Native land use and resource management practices required the prudent and sustainable use of the natural resources in each of the *ahupua‘a* in the Kekaha region. Life in *Kekaha wai ‘ole* was made possible with resources harvested from the sea and use of the sun's energy to dry their catch and produce their daily salt. Similarly, the proposed OTI RD&D facility will also use the region's ocean and solar resources to advance the production of renewable energy consistent with the traditional native practices promoting sustainability of the region's resources.

The prehistoric and early historic background of the ‘O‘oma area in the Kekaha region of North Kona, the existing lifestyles, values and social cohesion in this ahupua‘a are well summarized in the Cultural Impact Assessment prepared for the ‘O‘oma Beachside Village Project proposed for adjoining lands in 2007 (see also PBR Hawai‘i, 2009, Appendix F). A brief summary is below.

3.8.1 Cultural History of the area

According to the models from Kirch (1985) and archival historical research from Kepā Maly (2000), the Hawaiian archipelago was thought to be first settled or colonized in A.D. 300-500 by ocean voyagers possibly from the Marquesa Islands. It wasn’t until 1778 that James Cook ‘discovered’ the Hawaiian Islands by landing in Kauai, thus breaking the barrier between Hawaiian civilization and the outside world. Conservative estimates of the Hawaiian population at this time were 200,000. Kohala and Kona areas of the Island of Hawai‘i were thought to support a population in the tens of thousands (Kirch 1985). Pre-European contact, the Hawaiian economy was centered upon agriculture and fishing. Whole islands or parts of islands were divided into independent chiefdoms called “*moku”*. The lands were divided into large radial sections called *ahupua’a* which extended from the ocean shoreline to the mountains or some other feature of geological significance (Maly 2000). Each of the *ahupua’a* was controlled by lesser chiefs (*ali’i’ai ahupua’a*) and stewards (*konohiki*) (Kirch 1985). The HOST Park is located in the *ahupua’a* of *Kalaoa,* which was part of the larger region (*kalana*) of the district of North Kona known as *Ke-kaha* (the arid shore). A number of tropical root, tuber and tree crops, the most important being taro (*kalo, Colocasia esculenta*) and sweet potato (*‘uala, Ipomoea batatas*) were cultivated in the upland areas of *Kalaoa ahupua’a***.** The shoreline was popular for fishing. At Keahole Point, Rosendahl and Kirch (1975) recorded a number of fishing camp sites in lava tube shelters as well as open sites (Kirch 1985). Aquaculture was well developed with a series of fishponds to increase marine production of certain fish such as mullet (*Mugil cephalis*) and milkfish (*Chanos chanos*). Archaeological evidence of the fishponds has been found at Kaloko and Honokohau both located to the south of the HOST Park.

Trails (*ala hele*) and thoroughfares (*ala loa*) are an integral part of the cultural landscape of *Ke-kaha*. The *ala hele* provided accesses for local and regional travel, subsistence activities, cultural and religious purposes, and for communication between extended families and communities. Trails were and remain important features of the cultural landscape (Maly 2000). Historical accounts describe at least two trails of regional importance, *ala loa*, in the Kekaha region. One *ala loa* crossed the *makai* (near shore) lands, linking coastal communities and resources together. By the middle nineteenth century, sections of this trail were incorporated into the *Ala nui Aupuni* (Government Road), referred to as “Mamalahoa Trail” or the “King’s Highway”. The other major trail through this region was called “Kealaehu” (The path of Ehu), and was situated in the uplands. This trail provided travelers with a cooler *mauka* access to inland communities and resources and allowed for more direct travel between North and South Kona and both the coastal and upland regions of South Kohala (Maly 2000). It wasn’t until the 1970s and the construction of Queen Ka’ahumanu Highway that travel for the general public was possible across the shoreward plains of much of Kekaha. Part of the old Mamalahoa Trail runs through the upper part of the HOST Park, *mauka* of the OTEC parcel (Maly 2000).

In the 1800s cattle ranching changed the traditional agricultural practices and necessitated the construction of rock walls to control movement of the livestock. Coffee farming also developed in importance. The development of tourism was slower in Kona than in other areas in Hawai‘i. The first major hotel, the Kona Inn was built in 1928. Starting in the 1960s, the area between Kailua-Kona and Keauhou became increasingly dedicated to resort residential land use, while Kekaha for many decades had only one hotel, the Kona Village. The development of the Kona International Airport along with the construction of Queen Ka’ahumanu Highway changed this linking Kona and Kohala with the rest of the world (Marine Mammal Center, 2011).

Gradually the isolated beaches of Kekaha that were formerly enjoyed only by Hawaiian families and ranchers were converted to easily accessible public parks and “backyards” of hotels and resort residential housing. However, the native Hawaiians continued their cultural practices of fishing, gathering and ceremonial uses despite these changes. The importance of perpetuating access for these practices and the rights of native Hawaiians to continue them has been affirmed in several Hawai‘i Supreme Court decisions involving land use in Kona (Marine Mammal Center, 2011).

3.8.2 Public Shoreline recreation

The 1.76-acre parcel proposed for OTI is located mauka of the 40-foot shoreline setback. A jeep access road to the shoreline from O’oma through the HOST Park is located makai of the boundary of the parcel. Wawaloli Beach is located on the shoreline to the north of the parcel. The Mamalahoa trail is well mauka of the parcel (Figures 22 and 23).

Figure 22. Map showing Wawaloli Beach Park, Jeep trail and Mamalahoa trail in relation to parcel 87(arrow)

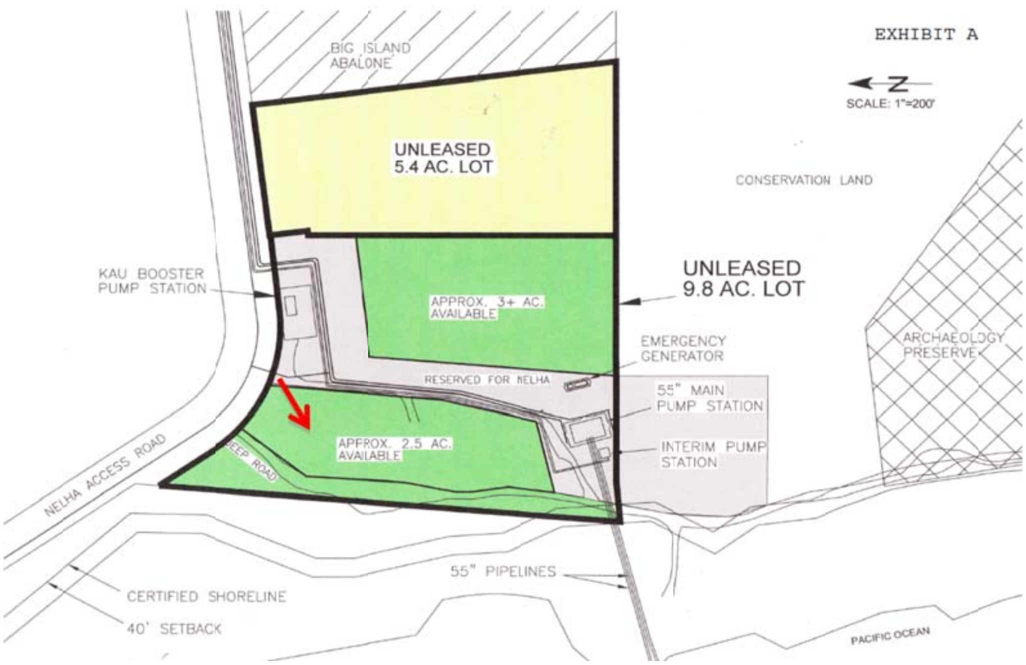

Figure 23. 1.76 acre parcel in proximity to the existing jeep trail. Jeep trail to remain open and accessible.

3.8.3 Archaeological Setting

As noted earlier in this Assessment, prior surveys of the project area (Barrera, 1985) identified an aggregate of features that were designated by the State DLNR as SIHP Site 10182. Data recovery, including detailed mapping, and excavation led to submittal of a detailed report (Barrera, 1989), and the SHPD determined that the site was fully mitigated. Subsequently, much of the project area was cleared and graded.. All of the NELHA properties have been thoroughly surveyed for archaeological resources (see Table 6). At the time of the HTDC FEIS (1985), there had been eight surveys of HOST Park and seven of NELH. Other surveys of the area had been completed prior to the creation of NELH. During preparation of the NELH SEIS (1987), Dr. Ross Cordy of the State Historic Sites Section (now Historic Preservation Division) again surveyed the NELH sites and prepared a preservation/ mitigation plan. This plan was subsequently expanded to include the HOST Park sites and those on the exchange parcel. Since that time, additional data recovery work has been completed on some of the sites. Until 1991 there remained three sites in the northwestern corner of the exchange parcel that were possible human burials. These were excavated and found not to be burials. There is a complete report of the data recovery for those sites and a summarization of the history of the site dating back to the sixteenth century in Appendix F FSEIS (GK and Assoc. 1992). A total of 28 archaeological sites have been identified at or near the HOST Park, mostly in the coastal portion of the property. There is now an archaeological preserve at the southern coastal corner of the property. Figure 24 shows locations of significant archaeological features in relation to the proposed site of the OTI RD&D facility although most of have undergone data recovery and will not be impacted by the project.

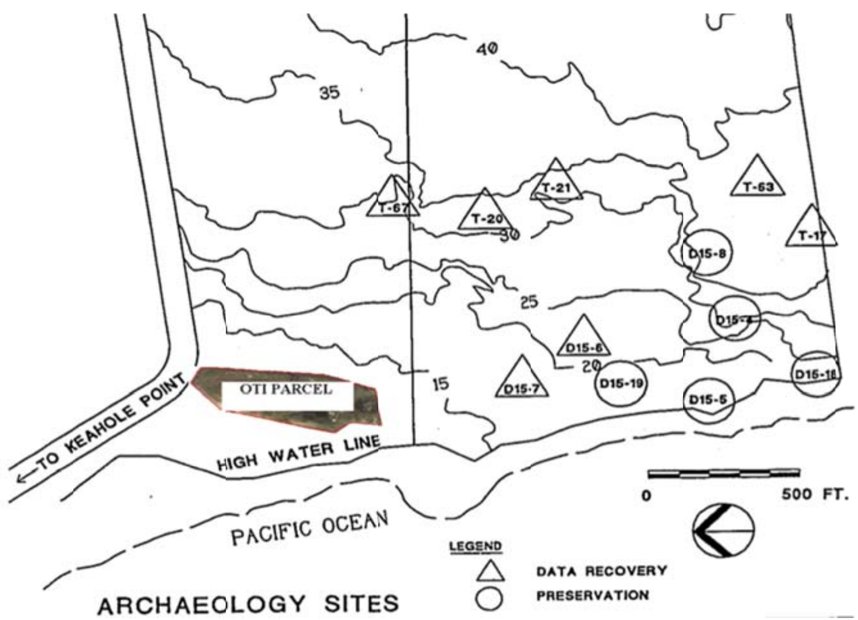

Figure 24. Locations of significant archaeological sites adjacent to the OTI parcel. (from GK &

Assoc., 1992)

Table 6 provides a summary of previous Archaeological and cultural investigations in the immediate vicinity of the propose site. None have revealed culturally sensitive sites on or near the proposed site except as noted above.

Table 6. Summary of Archaeological Investigations and Cultural Assessments of the ʻOʻoma-Kalaoa Region

Year	Project	Investigation	Reference
1930	*Survey of Sites of West Hawaii*	*Bishop Museum Manuscript*	***Reinecke, J.***
1968-69	*Kailua-Kawaihae Road & Keahole Point Airport (Section II)*	*Archaeological Surface Survey & Salvage Operations at Keahole, North Kona*	***Ching, F., D. Cluff & T. Riley***
1971-72	*State Site Inventory*	*Site Inventory files for Site Nos. 1910-1920*	***DLNR-Historic Sites Section***
1975	*Keahole Pt. Natural Energy Laboratory Site (1975 Survey)*	*Archaeological Reconnaissance Survey (B. P. Bishop Museum)*	***Rosendahl, P. &P. Kirch.***
1975	*Site Analysis with Maps and Interpretation (Ph.D. field work)*	*Archaeological Survey & Excavation of Selected Sites in North Kona*	***Cordy, R.***
1978	*A Study of Prehistoric Social Change: The Development of Complex Societies in the Hawaiian Islands*	*Ph.D. Thesis, University of Hawaii*	***Cordy, R.***
1976	*Keahole Pt. Natural Energy Laboratory Site (1976 Survey)*	*Additional Archaeological Reconnaissance Survey (B. P. Bishop Museum)*	***Rosendahl, P. & P. Kirch***
1978	*Archaeological Survey of NELH Facilities at Keahole Point*	*Archaeological Reconnaissance Survey (B. P. Bishop Museum)*	***Rogers-Jourdane, E.***
1979	*Keahole Airport Emergency Service Roads (1979 Survey)*	*Archaeological Reconnaissance Survey (Chiniago, Inc. Manuscript)*	***Barrera, W.***
1980	*Intensive Archaeological Survey and Salvage Excavations at the Natural Energy Laboratory Hawaii (NELH) Site, North Kona*	*Archaeological Data Recovery (PHRI Manuscript)*	***Rosendahl, P.***
1985	*Keahole Airport Emergency Service Roads (1985 Survey)*	*Archaeological Reconnaissance Survey of ʻOʻoma II (Chiniago, Inc. Manuscript)*	***Barrera, W.***

1985	*Working Paper I: Hawaiian Archaeology, ʻOʻoma and Kalaoa Ahupuaʻa, Kekaha, North Kona*	*Description of Archaeological Sites, ʻOʻoma and Kalaoa (Historic Sites Section, State Parks Division, DLNR)*	**Cordy, R.**
1986	*Field Check of ʻOʻoma II Sites, North Kona (Working Paper 2, Draft)*	*Review of Sites in ʻOʻoma II (Historic Sites Section, State Parks Division, DLNR)*	**Cordy, R.**
1987	*ʻOʻoma II Resort Project Area*	*Archaeological Inventory Survey and Testing (PHRI Manuscript)*	**Donham, T.**
1982	*Development of Land Exchange Parcel, NELHA*	*Archaeological Excavations, ʻOʻoma, North Kona (Chiniago, Inc., Appendix F of FSEIS)*	**Barrera, W.**
2000	*Archaeological Excavations of SIHP Sites 1916 and 18028 at the Natural Energy Laboratory of Hawaii Project Site, ʻOʻoma, North Kona*	*Archaeological Data Recovery (PHRI Manuscript)*	**Corbin, A.**
2002	*Archaeological Survey of an 83 Acre Parcel in ʻOʻoma II, North Kona.*	*Archaeological Reconnaissance Survey (Rechtman Consulting)*	**Rechtman, R.**
2003	*A Report on the Archival and Historical Documentary Research and Oral History for the Ahupuaʻa of ʻOʻoma II, District of Kona, Island of Hawaiʻi.*	*Cultural and Historic Research Report (Kumu Pono Associates)*	**Maly, K. & O. Maly**
2006	*Preservation Plan for Seven Archaeological Sites Located within NELHA Host Park (TMK 3/7-3-9:23) ʻOʻoma II, North Kona.*	*Archaeological Preservation Plan(Rechtman Consulting)*	**Rechtman, R. & M. Clark**
2007	*Archaeological Survey Update for the ʻOʻoma II Beachside Village Development Project.*	*Archaeological Inventory Update Survey (Rechtman Consulting)*	**Rechtman, R.**
2007	*Cultural Impact Assessment for the ʻOʻoma Beachside Village Project (TMK: 3/7-3-9:4 & 22).*	*Cultural Impact Assessment (Rechtman Consulting)*	**Rechtman, R. & K. Maly**
2010	*Letter Report dated September 3, 2010 to DNLR-SHPD for Lot 11A, HOST Park*	*Archaeological Assessment (Rechtman Consulting)*	**Rechtman, R.**
2010	*Letter Report dated December 14, 2010 to DNLR-SHPD for Lot 12A, HOST Park*	*Archaeological Assessment (Rechtman Consulting)*	**Rechtman, R.**

4. Description of Impacts and Mitigation Measures

4.1 Construction

Because the proposed construction site lies on level ground, OTI anticipates a relatively straightforward construction process. Some site preparation and conditioning will require conventional grading and leveling activities, accompanied by appropriate controls for fugitive dust and site drainage. The facility Power Block, the stave tank, and associated enclosures and maintenance structures will be placed on a concrete slab with dimensions of 120 feet by 90 feet, finished at an elevation of 6' above MSL. Depending on site-specific conditions, limited blasting and compaction may be required for site leveling and to achieve load-bearing capacities required by the Power Block structures. Other components to be installed are an office building, an access road and parking lot, and seawater return manifold piping for SSW and DSW running from the Power Block to the anticipated eight injection wells (Figure 2).

A temporary increase in traffic, dust and noise will occur during certain portions of the construction period. Construction workers and trucks will enter the proposed project area via OTEC Road during business hours. Up to 50 vehicles per day will be utilized and parked on the site. OTI will phase deliveries and site work as needed to minimize congestion. Traffic during construction would not restrict access for other tenants but may result in minor delays.

Dust, odor and noise during construction will be generated during certain periods of construction. Dust will be mitigated using water trucks as necessary. Construction noise is difficult to mitigate, but the project location is not close to residential areas and is in the flight path from Kona International Airport. Noise is expected to be noticeable by users of Wawaloli beach park during much of the construction period. Odors will be present during construction of the fiberglass stave-tank portion of the project. Large amounts of polyester resin will be used to build the tank. Odors associated with polyester resins will be detectable to nearby tenants and users of Wawaloli park during the three week construction period. All construction-related impacts will be managed through Best Management Practices (BMPs). BMPs may include a requirement for water-trucks dampening dust generated, soil erosion controls, staggering construction traffic to avoid "rush hour", and restricting blast activities to seasons when humpback whales are not present.

The existing site entrance is located near a curve in the NELHA Access Road. It has been used continuously since the HOST Park was developed. The flat topography allows unlimited site distances in each direction. The existing alignment will not be changed, but the site entrance may be paved or otherwise improved to reduce dust.

Installation of deep injection wells will require positioning and operating a large capacity drill rig and staging equipment. Tailings and fluids resulting from drilling will be contained and prevented from ocean entry. Effluent from pumping tests conducted to evaluate well capacities will be managed within permit guidelines at all times.

4.2 Operation

At full operating capacity, the OTEC RD&D facility will utilize 25,400gpm of cold DSW and 34,800gpm of warm SSW (Sections 2.4.1, 2.4.2). Both DSW and SSW will be drawn from the seawater supply infrastructure of NELHA's 55" pumping facility immediately to the south of the OTI parcel. The DSW intake lies in 915m (3,000ft) of water 3,124 meters or just less than two miles offshore. The SSW inlet lies in 24m (79ft) of water 165 meters (540ft) offshore. Both intake structures are elevated off the ocean bottom, and the shallow intake includes a hexagonal array of plate intake screens with slotted apertures to exclude large nekton. Deep intake wells at the pump station are equipped with mesh screens to intercept large entrained organisms, preventing their distribution throughout the HOST Park facility.

Principal issues of concern relating to OTEC operations have been discussed at length in various documents (Towill, 1976; Harrison, 1987; Traverse Group, 1985; MCM Planning, 1987; and GK & Associates, 1992). The major areas of interest are platform impacts, attraction of biota to floating structures in the ocean, cold and warm water withdrawal and entrainment and impingement of marine organisms, redistribution of oceanic properties, release of biocides used for heat exchanger cleaning, working fluid release, trace constituent release, and secondary entrainment of marine organisms in effluent plumes (Sands, 1980). Because the proposed OTI facility is land-based, attraction of biota to structures and lights will not be an issue. Similarly, biocide release is of minimal concern due to the very low concentrations used to periodically remove biofouling from the heat exchangers. Since the RD&D facility will return seawater using deep injection wells, the issue of secondary entrainment also is avoided. Thus, potential impacts from operations are limited to effects of cold and warm water withdrawal, redistribution of oceanic properties, and releases of working fluids and trace constituents.

During the operational phase of the project there will be minimal traffic. Site personnel will normally be limited to 4 or less. The facility expects to attract and will encourage visitors. However, all visitors will require a special appointment and larger groups will be scheduled at off-peak hours.

4.2.1 Seawater Intake –Impingement and Entrainment

The deep water pipeline and intake was designed and installed by NELHA in 1995 and has operated successfully since that period. Marine organisms may be impinged on screens or entrained in the seawater flowing through the heat exchangers. At full operational pumping, flow rates of SSW at the surface of the intake screens are calculated to be just under 1 fps, or about 0.6 knots. Animals large enough to be impinged on the screen plates, including larger fish, sea turtles or monk seals routinely inhabit regions with current regimes well in excess of this speed and are capable of much higher swimming speeds. Thus, impingement of large marine animals at the warm water intake is not expected to be a concern. Occasionally fish or other nekton are expected to appear in the pump vaults. These can be easily removed and returned using nets.

Entrained planktonic organisms at the warm water intake will be subjected to temperature change and the physical stress (acceleration, impaction, shear forces, and abrasion) associated with passage through the plant. Mortality rates of organisms entrained at the warm water intake are expected to be high, but survival after discharge is possible (Bienfang and Johnson 1980) for those animals in effluent waters from the RD&D facility that are distributed to other NELHA tenants for downstream uses. Full mortality is expected for animals entrained in waters discharged from the facility to the injection wells. Organisms entrained at the cold-water intake will be exposed to physical stress, a temperature change of approximately 20°C, and a pressure change of nearly 100 atm., all within a relatively short time. Organisms entrained at the cold-water intake may suffer 100% mortality (NOAA, 1981; OTC, 1983; OTC, 1984).

The categories of organisms susceptible to entrainment include phytoplankton, microzooplankton, macrozooplankton, ichthyoplankton, and some micronekton. Plankton entrainment rates are a function of plankton density and the rate of water intake. Although the intake rate can be predicted and information on average density of various planktonic groups is available, their vertical stratification is, in many cases, not clearly documented. Those motile organisms that aggregate at particular depths may be entrained at rates vastly different than predicted from their average density in the mixed layer.

The problem of determining ecosystem effects of large OTEC plants received considerable attention during environmental review of the proposed 40MWe OTEC facility at Kahe Point, Oahu. Although these prior assessments addressed seawater flow rates 1.5 orders of magnitude greater than those anticipated at the OTI RD&D facility, they offer a useful context in which to interpret the present proposal. There are differences between the Kahe and the Keahole offshore waters, both in oceanographic and biological parameters. However, as noted by Noda in his discussion of comparative phytoplankton community structure, "the two sites are similar with respect to features related to chlorophyll-a biomass; these include concentrations in the upper mixed layer at the maxima, the depths of subsurface maxima, and the persistent occurrence of a subsurface maximum as a characteristic hydrographic feature. Comparisons involving the depth-integrated data show similar annual ranges and means for chlorophyll-a. Data from both sites show that most of chlorophyll-a biomass occurs as extremely small cells in the 0.45-3.0 μm size fraction" (Noda, 1981). Zooplankton comparisons between the two sites are more difficult, both because of the greater variety of identifiable taxa and the lesser relative abundance. However, in both areas, calanoid copepods comprise the dominant fraction of identified zooplankton species, patterns of diel migration appeared similar, and taxonomic variability among samples is characteristically high. Looking at tables of horizontal tows taken in each area at similar times of the year, there appear to be higher amounts of ash-free dry weight biomass in the Kahe samples, but sampling differences between the areas make robust conclusions difficult. If the greater biomass levels off of Kahe point are reliable, the impact of OTEC seawater withdrawal in the Keahole region is likely to be less pronounced that what was calculated for the proposed 40MWe OTEC facility at Kahe Point. Thus, the values used for standing stock of plankton in waters off Kahe Point correspond reasonably with measurements of phytoplankton and zooplankton in the Keahole region (Noda et al, 1980).

Earlier studies of biomass loss attendant on OTEC operations (OTC, 1985) have applied the following formula:

Biomass loss rate	=	Intake volume flow rate	x	Natural standing stock concentration	x	Concentration factor due to due to OTEC presence	x	Efficiency of capture

Data from the common-base environmental study (Bienfang 1983) were used for natural standing stock values. With the exception of ichthyoplankton and micronekton, no concentration factor was projected for plankton organisms. The concentration factors for the ichthyoplankton and micronekton were based on locally observed fish attraction data. The natural reef value (0.045 kg wet weight,' m^{-2}) was divided by the open sand habitat value (0.004 kg wet weight ' m^{-1}) to derive a factor of 11. Such inferred statistics are subject to substantial error, but in the absence of more detailed information they represent the best available estimate of potential organism attraction rates. Capture efficiency, (i.e., the measure of an organism's ability to avoid ingestion while in the immediate vicinity of the intake) was assigned a value of unity for all groups. This is a conservative approach, since large micronekton in particular may be capable of avoiding the intake. Summarized plankton and micronekton biomass loss estimates are given in Table 7.

Table 7. Estimates of biomass loss by both impingement and entrainment at warm and cold water intakes of the 40MWe OTEC plant, Kahe, Point, Oahu. (from Harrison, 1987)

Intake	Taxa	Flow rate (m^3/day)	Natural standing stock	OTEC concentration factor	Capture efficiency	Intake rate
Warmwater	Phytoplankton	6.4×10^6	10.0 mg C/m^3	1.0	1.0	64 kg C/day
	Microzooplankton		0.2 mg C/m^3	1.0	1.0	1.3 kg C/day
	Macrozooplankton		1.0 mg C/m^3	1.0	1.0	6.4 kg C/day
	Ichthyoplankton		0.15–0.12 individuals/m^3	11.0	1.0	$1.1 \times 10^7 - 8.4 \times 10^7$ individuals/day
	Micronekton		6.0 mg wet wt/m^3	11.0	1.0	422 kg wet wt/day
Cold-water	Micronekton	7.8×10^6	3.75 mg wet wt/m^3	1.0	1.0	30 kg wet wt/day
	Gelatinous plankton		0.6 mg wet wt/m^3	1.0	1.0	5.0 kg wet wt/day

With calculated estimates of biomass loss due to impingement and entrainment, the impact of the OTEC seawater withdrawal may be assessed by comparing process losses to natural rates of mortality and production within the region of impact. In the case of the 40MWe plant, this region was found to be on the order of 1 km^3, based on the volume of seawater processed, the probability of ingestion into a plant intake, and residence time of water in the region of interest (OTC, 1985; Harrison, 1987). Because residence time of a water mass is determined by physical factors, principally tidal flushing, areas of vigorous mixing such as are found in the Keahole region provide for rapid replacement of biomass lost to an OTEC process. At Kahe, 1% of the region of interest volume would have been withdrawn each day by the plant, and at Keahole, the withdrawal will be roughly 1/40th of that amount. Eppley et al. (1973) estimate that daily natural mortality rate for phytoplankton ranges from 7 to 10%. For microzooplankton the range is from 3 to 10% (Heinbokel, 1978), and for macrozooplankton, the figures are 1 to 7% (Kremer and Nixon, 1978). Thus, plankton biomass losses due to seawater withdrawal and processing through the OTI OTEC facility represent a very small increase over rates of natural mortality. Such a loss would not be detectable, because the water withdrawn by NELHA is continuously replenished by surrounding unperturbed water.

As part of the RD&D activities OTI will sponsor research into plankton avoidance, and mortalities resulting from physical trauma, temperature shock and pressure changes within various stages of the plant. Data from this work will be used to model potential biological impacts associated with larger commercial plants as well as multiple OTEC facilities that may be co-located at some time in the future.

4.2.2 Seawater Return

As previously described, the proposed OTEC RD&D facility extracts thermal energy from SSW and DSW to produce power. The facility will then return seawater that is substantially unchanged to a layer of the ocean which is thermally similar to its characteristics upon exiting the plant. This seawater is expected to be chemically unchanged on its path through the plant. The high volume flow of deep seawater from the proposed action poses a potential threat to ecosystem stability of shallow, productive surface waters, due to the elevated concentrations of dissolved nutrients and depressed temperatures in DSW (Table 8). The principal goals for a successful seawater return design must be to protect the pristine quality of the coastal ocean environment by avoiding thermal or nutrient contamination of ocean water resources on which NELHA depends for its research and commercial operations.

The NELHA Seawater Return System Management Recommendations emphasize these goals explicitly:

It is critically important to offshore ecosystems and facilities uses that discharge from tenant operations not degrade the quality of coastal waters.

To avoid degradation of the receiving waters, a successful seawater return system must be engineered to: 1) discharge the effluent into rapidly mixing and transiting ocean water masses in order to spread the effluent over as wide an area as possible, which ensures a high initial dilution at the point of effluent entry into the receiving waters, and; 2) avoid impacts to sensitive systems such as intertidal nearshore waters and anchialine ponds.

Unlike many past and ongoing activities at the HOST Park, the OTI OTEC demonstration facility entails a use of deep and surface ocean waters that largely avoids changes to constituent properties of the inlet streams. The SSW temperature will be cooled by 9ºF, DSW will be warmed by 12°F, and under normal operating conditions a minimal amount of chemicals will be added or removed. Unlike mariculture operations, the OTEC process will not produce any biological or organic byproduct that becomes a component of the effluent.

Table 8. Comparative water quality parameters of OTEC effluents, groundwater, and open coastal ocean water at the HOST Park

	NO3	PO4	Temperature
DSW effluent	~40 µM	~3µM	52-56°F
SSW effluent	~0.25µM	~0.1µM	65-73°F
Brackish Basal Water	~80µM	~4µM	65-69°F
Coastal Ocean Water	~0.25µM	~0.1µM	75-83ºF

4.2.2.1 Injection Well System

After reviewing the many seawater return studies completed at NELHA, OTI selected the injection well systems because it is the most environmentally responsible method for returning seawater to the ocean. Disposal of effluent using deep injection wells is described in some detail in the Traverse Group FEIS (1985) and the MCM Planning FSEIS (1987). A deep injection well field parallel to and within several hundred feet of the shoreline was among the DSW injection designs evaluated by Dames and Moore (1986). OTI has considered various alignments and locations of injection wells for return of both DSW and SSW (See Appendix B).

Injection well systems can be designed to discharge effluents at a specific location and depth beneath the ground surface. OTI intends to discharge SSW into wells drilled to depths of as much as 150ft, with solid casing down to a depth below the lower boundary of the brackish groundwater lens. The precise depth of the solid casing will vary with each SSW well, depending on the permeability of successive layers encountered at each drilling site. The objective is to open the casing to injection within a highly porous region that is overlain by an impermeable rock layer, thereby preventing upward migration of the effluent plume. The required injection capacity for SSW return may be met by as few as 4 wells.

DSW will be discharged in deeper injection wells with slotted casing intervals between 300 and 400 feet below ground surface. Literature suggests that the proposed return flow of DSW may be accommodated with as little as 2 deep injection wells 2 feet in diameter and 400 feet deep. The subsurface geology at the HOST Park is extremely variable, and the number of wells required to accommodate discharge flows, with an adequate margin of safety will not be finally determined until the time of installation and testing.

The flow path from the top of the heat exchanger building to the bottom of the injection wells is a closed and pressurized system. The top of the tower contains a buffer tank, which provides constant head to the system, and is regulated by a float switch. Should an unanticipated resistance to flow arise in an injection well, the flow through the entire power cycle would slow down, resulting in a loss of power production, but not an overflow to the ground surface.

Development of an injection well field with a capacity sufficient to receive both DSW and SSW flows at full OTEC operational flows appears technically feasible. From a regional perspective, model simulations of injection wells produce hemispherical plumes radiating in all directions downward from the point of discharge. In the case of injection well arrays parallel and in relatively close proximity to the coastline, a half-cylinder geometry may be more appropriate (Mink, 1992). For injection wells deep below the level of the water table, lateral movement of effluent through the substratum will travel as an expanding plume whose boundaries are determined by variations of substratum permeability and by density-driven gravitational stratification (Dames and Moore, 1985; 1986). Injected effluent will enter the ocean via seepage through the ocean bottom at a range of depths that corresponds with the geometry of the plume at the point it intersects the ocean bottom interface. A plume introduced at a specified depth interval will migrate to a seepage field that reflects the combined influences of the depth of injection and the characteristics of density stratification. The stratigraphy of subsurface volcanic layers can be assumed to run at an angle similar to the slope of the coastal lands mauka of the shoreline, which is between 3% and 5% in the vicinity of Keahole Point.

In designing the seawater return system, the most important objective is to protect the regional groundwater resources by avoiding displacement of the basal lens, which has a great influence on the shallow water communities found near the project site. It is for this reason that OTI will not discharge SSW on the surface. In order to isolate the SSW discharge plume from interaction with the basal lens, OTI will construct SSW return wells that inject below the brackish lens in a region capped by a low porosity layer. Due to the higher density of the SSW on account of its higher salinity and lower temperature, the brackish basal lens has a natural tendency to float on the more dense seawater. With the integrity of the basal lens largely preserved, potential impacts both to shoreline biota and to the sensitive anchialine pond systems would be alleviated. The SSW effluent plume would enter nearshore waters at depths greater than 100 feet and at a distance of approximately 600 feet from shore. This design increases the discharge residence time, increases the dilution rate, and expands the zone of initial entry to deeper coastal waters farther from the shoreline.

Because of differences in the density of the DSW and the SSW, OTI expects the plumes from each discharge to stratify separately at different depths, aided by well designs that localize injection at or near the target depth of plume propagation. Figures 25 and 26 illustrate intermediate stages of DSW and SSW plume development following initiation of seawater return. Results of model studies discussed previously (Dames and Moore, 1986) indicate that at full development, the subsurface plumes will expand considerably beyond the illustrated lateral boundaries, resulting in even greater dilution of return waters.

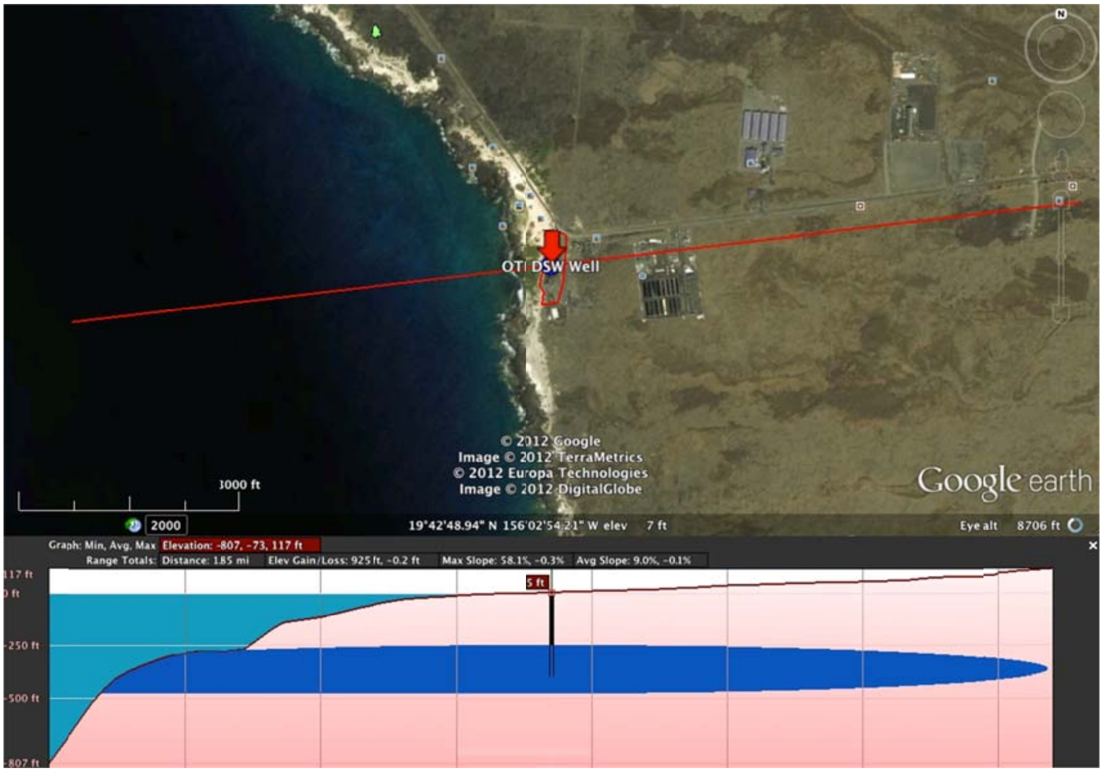

Figure 25 (bottom). Subsurface profile, showing the intermediate stage plume from DSW injection at -300 to -400 feet. Red line on the upper figure marks the surface intersection of the subsurface profile.

Cross-sectional views of the DSW and SSW plumes (Figures 23, 24) illustrate the previously described seepage fields, the interface of the plumes' seaward boundaries with the ocean floor. As noted, the seepage field for each plume occupies the depth ranges defined by the upper and lower margins of the plumes. Translated orthogonally, the plan view of the OTI OTEC DSW seepage field at an intermediate stage of plume development would appear as shown in Figure 27. Note that the region of ocean entry occurs at a depth and location far removed from both the warm water and deep water inlets of the NELHA 55-inch seawater system.

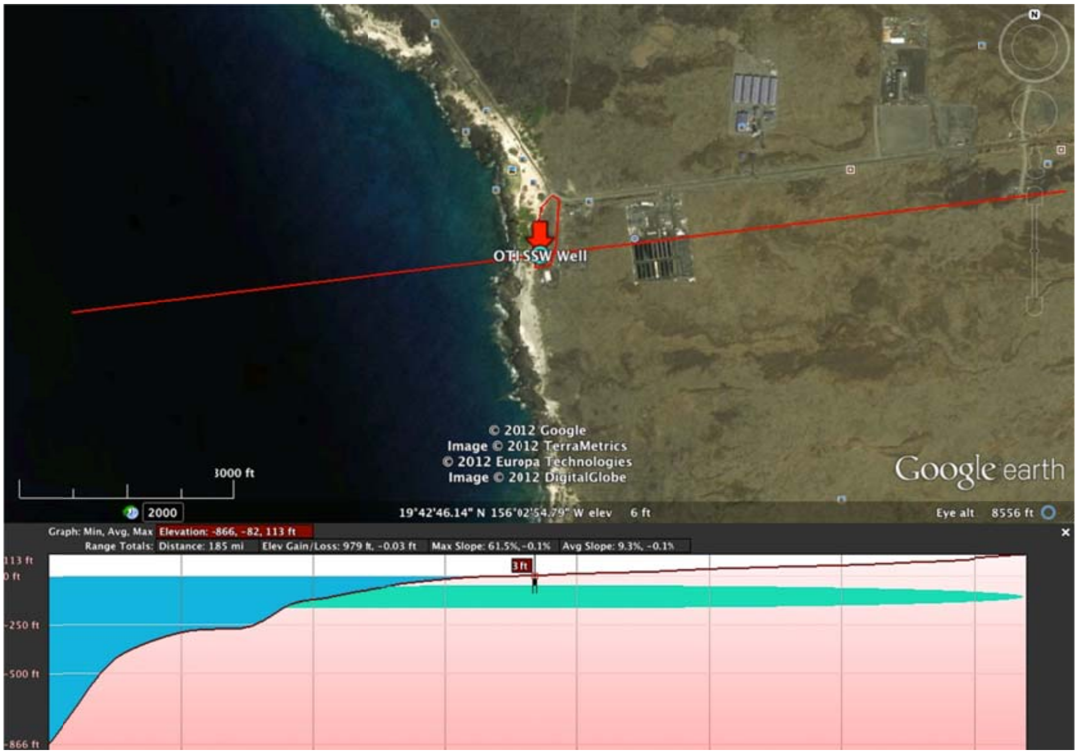

Figure 26 (bottom). Subsurface profile, showing the intermediate stage plume from SSW injection at -100 to -150 feet. Red line on the upper figure marks the surface intersection of the subsurface profile.

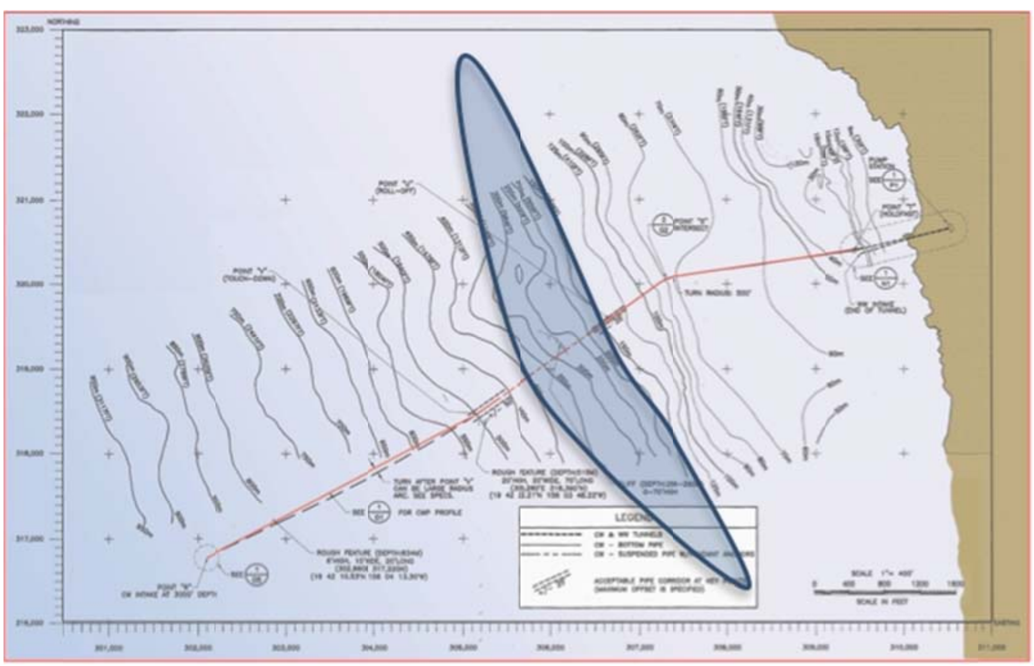

Figure 27. Schematic of the DSW bottom seepage area along the -300 to -400 foot bathymetric contours, intermediate stage plume development.

Mixing and water mass exchange in the region of the seawater return receiving waters is known to be vigorous (Bathen, 1975; Bretschneider, 1978; Dollar and Atkinson, 1992). Using data gathered by Noda (1986), Oceanit (1986) derived a mean depth integrated offshore current velocity of 1 foot/sec, leading to an average water residence time per coastal mile in the discharge region of about 1.5 hours.

As noted above, an analogous OTEC DSW return design was studied using model formulations and computer analyses (Dames and Moore, 1986) (See Appendix B). The study examined effluent plume behavior in a field of 4 wells, each 2 feet in diameter, with screened intervals between -300ft and -400ft. Solid casing prevented entry of the DSW above a depth of -300ft. Total well depth extended to at least -400 feet. The wells were located 250 feet from the shoreline, and the estimated capacity of each well was 8,000gpm, with 2 wells in active use at a time and the others in reserve for maintenance and surge purposes. Total pumping rate for the purposes of the model was 16,100gpm. Thus, the model assesses conditions that are quite similar in discharge rate and proximity to shoreline as those of the proposed action.

Model results from this design suggest that at equilibrium, 85% of the discharge of DSW would be distributed over a longitudinal distance of 30,000 feet at or below the 300 foot bathymetric contour, producing seepage rates ranging from 1.2 to 2.9gpd per square foot. Dames and Moore estimated the subsurface plume residence time of DSW discharged in this manner to be 87 days.

Using Oceanit's average water residence time of 1.5 hours per coastal mile, water overlying a 30,000 foot long seepage field would be fully replenished 2.8 times per day. Thus, dispersion of introduced DSW effluent by advection alone will prevent accumulation of redistributed properties of DSW within the regional vicinity of the HOST Park.

Potential static depth-integrated mixing and dilution for the DSW effluent entering the overlying ocean waters in this region is at least four to five orders of magnitude, based on the full water column dispersion of flows documented above. Using this dilution estimate we would expect the DSW nitrate concentration of 40µM diluted into the mean 0.25µM nitrate values of surface water to result in a final ambient nitrate concentration well within the observed variance range of regional oceanic surface water nitrate levels.

An alternate approach to estimating the rate of dilution incorporates water mass exchange and dynamic mixing as follows. Assume that a box model water mass with boundaries of 100m x 100m by 10,000m (=10^8 m^3) generally approximates the water column overlying the DSW seepage field. As previously noted, this water mass is replenished 2.8 times daily. At plume equilibrium, seepage will equal the full DSW daily discharge of 138,455 m^3. Factoring in the water mass exchanges and dividing the resulting input volume into the effective overlying water column results in the DSW effluent being diluted by a factor of roughly 1:40,000. Estimated in this way, the resulting dilution also is between four and five orders of magnitude, similar to the static estimate derived above.

Neither of these estimated dilution rates result in detectable increases in the ambient nitrate concentrations in the offshore marine environment. A similar conclusion can be reached for temperature. Ocean waters in the 300 to 500 foot depth average ~ 74°F. DSW is discharged from the facility at approximately 50°F. After approximately 87 days underground and mixing with other subsurface water before reaching the coastline, the temperature would be expected to be somewhat higher. Upon dilution and mixing into ambient seawater overlying at the ocean bottom, temperature differences would rapidly become indiscernible.

The SSW effluent discharges below the brackish groundwater lens and the greater density of the SSW will maintain the stratification of the effluent below the basal lens. Thus, the SSW plume does not interfere with the dynamic groundwater flux that sustains physical characteristics of anchialine ponds. In addition, the region of seepage of SSW effluent into the ocean is well beyond the sensitive nearshore and intertidal waters. The expected seepage field for returned SSW may be inferred from the seabed intersection of the SSW plume depicted in Figure 26, extending over a seabed depth range of roughly 120-170 feet and parallel to the shoreline. The region of discharge for SSW would be expected to smaller than that of DSW, therefore the dilution rate would be commensurately lower. If the shallow well discharge point were near 100 foot depth, the plume radius would be expected approximately 850 feet from shore. The SSW discharge does not contain elevated nutrient concentrations. Temperature depression of the SSW through the system is estimated to be 9°F (Table 8), making the SSW discharge in the range of ~69°F before dilution. Once again, upon dilution with ambient seawater, temperature differences are likely to be rapidly extinguished and undetectable, particularly in the higher water motion regimes closer to the coast. Note that temperatures of brackish basal water discharged at the shoreline fall in a similar range (Table 8), and equilibration to ambient conditions occurs within very short distances (Dollar, 2008).

A permit application for the injection wells has been prepared and will be submitted for approval to the Hawaii Department of Health Underground Injection Control Branch. OTI will comply with the terms and conditions of the UIC permit. Standard conditions include a requirement to properly close injection wells at such time as they cease being used for the intended purpose. Injection wells will be filled and plugged by method acceptable to the Department of Health when OTI ceases operations at NELHA, or when the injection wells are no longer used.

Based on previously accepted modeling results and physical data, the OTI seawater return system is designed to:

1) discharge the effluent into rapidly mixing and, transiting ocean water masses, spreading the effluent over as wide an area as possible, which ensures a high initial dilution at the point of effluent entry into the receiving waters, and;

2) avoid impacts to sensitive systems such as nearshore waters and anchialine ponds.

NELHA's previous analysis of various methods of seawater return identified deep injection wells as the method involving the least environmental impact (MCM Planning, 1987). In their section summarizing alternatives the EIS states: *As proposed, the deep injection wells would provide the greatest residence time for discharged waters, about three months, and would create seepage* *through the bottom between -300 and -400 feet depths. While this would avoid potential biostimulation at the shoreline it will come at a substantial additional cost.*

OTI has selected the deep injection well method as that which provides the greatest level of protection for NELHA's coastal and thermal resources. All other tenants are currently using shallow trench disposal systems.

4.2.3 Noise and Visual Impacts

The facility will generate noise from operating pumps and machinery, similar to noise levels currently generated by the 55" pumping station. The proposed OTEC facility is slightly closer to Wawaloli Beach Park than is the pump station and will therefore generate noise slightly in excess of the existing level. State of Hawaiʻi regulations specify that noise generation within the industrial zone shall not exceed 70 dB at the property line. The noise generation level by the OTI facility is estimated to be well below the regulatory limit. If noise is generated in excess of this limit, mitigation measures, such as sound insulation will be provided.

The OTI facility will stand 54 feet above ground level and will be within the view plane from OTEC access road. The facility is architecturally designed to be appropriate for the HOST Park, with a façade that is neutral colored. All machinery is shrouded from view by these facades. The facility will be maintained in an organized, workmanlike state and will not be cluttered with tanks, piping and other components of construction. The structures will be coated with flat textured paint and there will be no shiny surfaces larger than the head of a standard size fastener to reflect sunlight.

4.2.4 Hazardous Materials

The OTI RD&D facility will use and store both ammonia, the working fluid for thermal energy conversion, and chlorine gas or liquid for periodic removal of bacterial films which reduce the efficiency of heat exchange. During construction a large amount of polyester resin will be used for building a test tank. All of these compounds are considered hazardous materials in industrial quantities.

Ammonia will alternate between a liquid and gas inside the power block of the facility and a supplemental storage tank will be present. Under normal operations there will no perceptible release of ammonia to the water or atmosphere. If leaks occur in the heat exchangers of the facility ammonia will dissolve in seawater at concentrations that are commensurate with the volume of seawater and the volume of ammonia. A substantial ammonia leak of one gallon per minute to the SSW side of the heat exchanger would result in a concentration 17.8 parts per million (ppm) ammonia dissolved in seawater. At surface seawater temperature and atmospheric pressure that ammonia would tend to outgas if open to the atmosphere. However a leak inside the power block would not be exposed to the atmosphere. Seawater containing measurable amounts of ammonia would be diverted from other tenants and be injected to the ground between 100 feet and 150 feet below the groundwater surface. At that depth and pressure the vast majority of ammonia would remain in solution. This plume of ammonia contaminated water would be dispersed within the groundwater and diluted by several orders of magnitude before eventually entering the ocean. A leak into seawater in the heat exchanger is the most likely occurrence since the surface area of heat exchanger is quite large. Under this scenario it is unlikely that significant concentrations of ammonia would escape into the atmosphere. An ammonia leak in the turbine generators or other machinery outside of the heat exchangers is less likely because of design safety standards; however, pressurized ammonia leaking into air spaces would result in an airborne plume that may be hazardous. Internal spaces of the machine room will be monitored for ammonia during operation.

Ammonia gas is a respiratory tract irritant. It is noticeable by smell at 0.6 to 53 ppm. According to the Canadian Center for Occupational Health and Safety, irritating effects of ammonia vapor were noticeable in 5 of 10 volunteers at 72ppm, and in 10 of 10 volunteers at 134ppm. At 500ppm, immediate and severe irritation of the nose and throat occurs. Brief exposure to concentrations above 1500 ppm can cause pulmonary edema (Canadian Center for Occupational Health and Safety, 2012). The US EPA defines the toxic level for ammonia to be 200 ppm. Gaseous ammonia is lighter than air and tends to rise. Generic dispersion models for ammonia are dependent on the rate of release, temperature and wind conditions. These models show that dispersion in urban areas is considerably faster than in rural areas due to the dispersion effects of buildings and heat sources. HOST Park environmental conditions vary widely over a 24-hour cycle. The worst case scenario would be during a still night, where dispersion is slow. During daylight hours tradewinds and thermal eddies created by hot ground surface would tend to disperse the plume very rapidly.

The hazardous nature of ammonia makes strict safety precautions mandatory for OTEC. Should an accident occur, the risks are similar to those for other industrial applications involving these chemicals. Common applications involving ammonia include refrigeration systems for ice skating rinks. Early industrial refrigeration systems and icehouses also used ammonia as the refrigeration working fluid, and is currently the most common refrigerant used on ship-board refrigeration. A Risk Management Program and Emergency Management Plan which is compliant with US regulations will be developed, approved and implemented prior to delivery of ammonia.

At the outset, OTI does not anticipate using chemical methods for control of biological films that may potentially develop on heat exchanger surfaces. In the event that microbial films become evident in spite of other methods, low-level chemical treatment of the heat exchangers may be required. In the event that chlorine application is used, the biocide will be injected into the inlet stream of SSW and allowed to flow for a one-hour period daily. Neutralization of chlorine in the effluent is not anticipated to be necessary, due to the kinetics of reactivity of chlorine in seawater. Chlorination to protect the seawater side of evaporator surfaces from biofouling (OTC, 1984a) is considered a component of previous OTEC discharge waters. Effluent seawater from OTI's 1MWe RD&D facility will not be discharged directly to marine waters, but instead it will be directed to deep injection wells on land or routed to other downstream uses at the HOST Park. Because of the intermittence and reactivity of chlorine in seawater, residual chlorine is expected to be negligible at the time of discharge from the system. Effluent SSW is not expected to contain measurable chlorine residuals. If this effluent is determined to be unacceptable to potential downstream users, returned SSW following periodic application of normal operational levels of biocide will be routed to injection wells, with no anticipated adverse effects.

Most of the research on behavior of chlorine and its by-products in seawater has been performed in temperate waters. Sansone and Kearney (1985) suggest that results of temperate water studies of seawater-chlorine interactions are not necessarily transferable to subtropical and tropical waters. Furthermore, biofouling tests at the Natural Energy Laboratory of Hawai‘i demonstrated that microbial film production on heat exchanger surfaces is controlled by chlorination at levels roughly one order of magnitude lower than is required in temperate waters (Larsen-Basse and Daniel, 1983). Free and combined chlorine-produced oxidants are significantly more persistent in subtropical than in temperate waters (Sansone and Kearney, 1985), thus requiring a lower dosage to achieve the desired effects.

At the OTI 1MWe RD&D facility, SSW is expected to flow at an average rate of 34,800 gpm, resulting in flow rates through the evaporators of roughly 10 ft. sec^{-1}. Evaporator wall biofouling at these flow rates is expected to be minimal, and other proprietary control measures should prevent settling and accumulation of biota. If microbial film development is observed, present plans call for daily 1-hour applications to the evaporators only to achieve inlet solutions at a concentration of 0.07 mg 1^{-1} (70ppb). By comparison the federal drinking water standard for chlorine in drinking water is 4 ppm, nearly 60 times higher. After reaction with oxygen and organic materials the residual chlorine is expected to be negligible at the time of discharge from the system (Larsen-Basse, 1983). No interruption of seawater exiting the system for disposal or reuse is planned during the 1 hour chlorination period. Seawater containing residual chlorine will not affect or be detectable by downstream users.

Chlorine will be stored at the plant in one pressurized cylinders. To apply 70 ppb chlorine to the SSW stream for 1 hour per day the total demand for chlorine is 552 grams per day (1.2 pounds/day). A single 150 pound cylinder of chlorine gas would be expected to last for over 4 months. Spills or leaks of chlorine are most likely to occur during delivery or cylinder change. Unlike ammonia, chlorine gas is 2.5 times heavier than air and tends to accumulate in low spots or permeate into the ground. The chlorine cylinder will be covered in a shed which is separated from work spaces to reduce the risk to onsite personnel. In a worst case scenario Chlorine gas is not likely to represent a hazard to offsite personnel due to the limited quantities stored and characteristically slow dispersal.

Although chlorine is not flammable, it can combine with other substances, particularly gaseous ammonia, to cause fires or explosions (Sax, 1979).

OSHA and The EPA regulate worker exposure and recommend safety standards for storage of chlorine. A spill or leak of 4.54 kg or more over a 24-hr period must be reported to the EPA.

A large fiberglass tank which is similar to the cold water pipe for a commercial OTEC facility will be assembled onsite. The tank will be composed of fiberglass composite staves that are likely to be manufactured offsite and assembled onsite. Assembly will require use of polyester resins similar to surfboard resin for bonding the staves together. No air quality permitting is required for temporary use of these types of materials, but OSHA defines the maximum permissible exposure to workers. The concentrations of organic vapors are not expected to be near permissible limits to offsite personnel, but are likely to be noticeable depending on wind speed and direction, over approximately three weeks during the construction period for the tanks.

4.2.5 Emergency Management

OTI and all construction contractors will be responsible for maintaining compliance with federal state and local regulations and their individual Health and Safety Plans.

During start-up and operation, OTI will use approximately 50,000 lbs. of ammonia as its working fluid. Owners and operators of facilities containing over 10,000 lbs. of ammonia must comply with the United States Environmental Protection Agency's (EPA) Risk Management Program (RMP) regulations, 40 CFR Part 68, and the Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) Standard 29 CFR 1910.119.

OTI is preparing a comprehensive Risk Management Program to address both accidental and natural event scenarios that might result in ammonia or chlorine releases. The potential simultaneous release of ammonia and chlorine will be discussed in that plan, along with specific response protocols to minimize risks of human exposure. A Spill Prevention Control and Countermeasures Plan (SPCC) will be prepared if fuel storage capacity exceeds the minimum threshold of 1320 gallons.

This facility will require complete the Process safety Management (PSM) and a complete Risk Management Program (RMP) for compliance with these regulations. The RMP requires a facility to coordinate with the Local Emergency Planning Committee on emergency action planning in an effort to ensure the local responders can incorporate the regulated facility in their community action plan. In addition, all information in the RMP needs to be complete and a Risk Management *Plan* must be submitted to EPA prior to bringing ammonia on to the site. A responsible person will be designated to maintain the Emergency Management Plan and manage the RMP. Major components of the PSM/RMP program include:

1) <u>Process Hazard Analysis</u>. The Process Hazard Analysis is the basis for many of the decisions and procedures associated with an effective risk and safety program. It is a systematic effort to determine the potential hazards associated with the process and to evaluate mitigation alternatives including equipment modifications, procedural modifications, and training. An effective PHA considers and analyzes the potential consequences associated with a release of the hazardous material, including fires, explosions, and exposure of people to toxic materials. It focuses on equipment, instrumentation, utilities, human actions, facility siting, and external events.

2) <u>Hazard Assessment</u>. For compliance with the RMP, the “worst case” release will be modeled, as defined by EPA: “release of the largest quantity of a regulated substance from a vessel or process line failure that results in the greatest distance to an endpoint...”. This release must be modeled using pessimistic meteorological conditions.

3) <u>Risk Prevention Programs</u>. The necessary prevention programs for compliance with the PSM standard of the EPA RMP Program include requirements for:

- Employee Participation

- Process Safety Information
- Operating Procedures
- Employee Training
- Contractor Safety
- Pre-Startup Safety Reviews
- Mechanical Integrity
- Hot Work Permits
- Management of Change
- Incident Investigation
- Emergency Planning and Response , and
- Compliance Audits

4) Emergency Action Plan. The Emergency Action Plan contains the following information:

- The preferred means of reporting fires and other emergencies (including ammonia release) plan;
- Procedures for emergency evacuation, including type of evacuation and exit route assignments;
- Procedures to be followed by employees who remain to operate critical plant operations before an evacuation occurs;
- Procedures to account for all employees after emergency evacuation has been completed;
- Procedures to be followed by employees performing rescue or medical duties; and
- Names or regular job titles of persons or departments who can be contacted for further information or explanation of duties under the Plan.

5) Pre-Startup Safety Review. Pre-startup safety reviews are required by law for all new facilities, and for all modifications that result in a change to the process safety information. The aim of completing a pre-startup safety review is to reduce the likelihood of an ammonia release that could cause injuries or other damage on-site, and off-site consequences.

6) Documentation with the EPA and Local Emergency Planning Committee. The RMP encompasses all of the documentation requirements of the PSM regulation in addition to:

- Executive Summary
- Recordkeeping and Updates
- Management Programs
- RMP Certification

Analytic equipment for in-line detection and monitoring of chlorine and ammonia is being developed specifically for the OTI RD&D facility to provide for rapid response capability in the event of a significant leak. OTI anticipates that detection of ammonia in effluent seawater from the facility in excess of 70ppb will trigger a diversion of water to downstream tenant users. Details of the emergency response plan and shut down protocols will be made available for review.

4.2.6 Air Emissions

Ocean thermal energy technologies do not burn or convert solid organic matter into gasses. During normal operations ammonia is volatilized and condensed repeatedly but it is not released to the atmosphere. The primary air quality concern with respect to OTEC technologies is the potential release of carbon dioxide (CO_2) from the deep ocean waters. The world's oceans store much more CO_2 than its atmosphere, and over geological periods the oceans have the ability to compensate for fluctuations in the atmospheric CO_2 content, however the rate of change within the oceans is much slower.

The quantity of CO_2 dissolved in seawater is affected by a complex variety of factors including temperature, pH, salinity, and pressure. The carbonate buffering system in seawater is quite effective at managing variations in carbon content while maintaining a stable pH. Under normal sea surface conditions less than 5% of the total dissolved carbon is as CO_2 gas. Approximately 85% is stored as dissolved bicarbonate (HCO_3), and the remaining 10% is carbonic acid (CO_3^-). Due largely to decreased temperature, DSW contains up to 30% more CO2 than tropical SSW. The OTI facility will pump upwards of 34,000 gpm of DSW to a constant head tank atop its condensing heat exchanger. The tank will be closed, but vented to the atmosphere. DSW in the head tank will be at atmospheric pressure, turbulent and warming; all of which are conducive to a release of CO_2.

Krock (2009) reports that fears of large OTEC related carbon dioxide emissions are apparently based on misconceptions related to the carbon dioxide content of the cold water steam and the rate of gas exchange. While the total carbon dioxide content (including dissolved CO2**,** HCO3, and CO3) of the deep cold water is about 1/3 higher than that of the warm surface layer, it does not quickly exchange with the atmosphere. In the closed-cycle OTEC system, there is little free surface and the residence time in OTI's head tank is quite brief. Gas exchange occurs only at this location. In an open-cycle system, a far different design than the one proposed here, the time of exposure to partial vacuum conditions is too short for any significant switch from the bicarbonate form to the dissolved CO2 is exchanged. Unpublished data from the Open Cycle-OTEC test facility at Keahole Point indicate the maximum emission rate of carbon dioxide for open-cycle plants with direct contact condensers is about 4% of an equivalent oil fired plant (Krock 2009).

Another estimate of CO_2 out-gassing from the seawater used for the operating an OC-OTEC plant is less than 1 percent of the approximately 700 grams per kWh amount released by fuel oil plants. The value is even lower in the case of a CC-OTEC plant (Vega, 2012).

Green and Guenther estimated the carbon release footprint of an open-cycle OTEC facility would produce between 15 and 25 times less CO2 than a traditional fossil fuel plant (approximately 38 g-CO2/kWh). Closed-cycle OTEC, as proposed here was reported to produce no CO2 during operation (Green and Guenther, 1990).

A fourth estimate of CO_2 outgassing from an OTEC plant was found in the literature from Xenesys, Inc. Literature provided by this OTEC designer states "*OTEC emits extremely low CO2 in its whole lifecycle. (CO2 emission rate for 100 MW-class : 0.014 kg-CO2/kWh) Also, CO2* *fixation effects can be expected by diffusing the deep seawater after being used at OTEC system onto the surface layer of the sea, since marine plants grow well with the nutrient rich deep seawater"* (Xenesys, 2011).

Sovacool, 2010 published an estimate of the lifecycle greenhouse gas emissions for various power technologies. Lifecycle estimates include those generated during manufacture, transportation, assembly, operation and decommissioning (Table 9).

The Xenesys estimate clearly does not include lifecycle costs which push total CO_2 emissions from even non-emitting technologies into the whole numbers. From an examination of the estimates contained in Table 9 we may assume that the total CO2 emissions over the 20+ year life span including construction and demolition would probably lie between geothermal and nuclear energy.

Table 9: Lifecycle greenhouse gas emission estimates for electricity generators		
Technology	**Description**	**Estimate**
Wind	2.5 MW offshore	9
Hydroelectric	3.1 MW reservoir	10
Wind	1.5 MW onshore	10
Biogas	anaerobic digestion	11
Hydroelectric	300 kW run-of-river	13
Solar thermal	80 MW parabolic trough	13
Biomass	various	14-35
Solar PV	polycrystalline silicon	32
Geothermal	80 MW hot dry rock	38
Nuclear	various reactor types	66
Natural gas	various combined cycle turbines	443
Diesel	various generator and turbine types	778
Heavy oil	various generator and turbine types	778
Coal	various generator types with scrubbing	960
Coal	various generator types without scrubbing	1050

Source: Sovacool, 2010

Other literature recommends OTEC be funded using carbon credits. *"In economic terms, optimistic guesses at OTEC plant costs are in the range of a million dollars per MW. Since a kilowatt-hour (kWh) of electricity generated by coal produces about a kilogram of carbon dioxide, a carbon tax of one to two cents per kWh might cover the capital costs of an OTEC plant in carbon credits alone*" (Barry, 2008)

4.3 Socioeconomic Impacts and Mitigation

OTI's assessment of the economic potential of the proposed action stems from opportunities created in the capital development as well as operation and maintenance of the facility. In addition, OTI contemplates construction at two locations; first, the demonstration facility at the HOST Park on the Big Island, and second, following directly on the demonstration will be a commercial operating platform serving Oahu.

For the demonstration plant, the development period is anticipated to be approximately 2 years, and at least 25 years of operation. During the two years of development several professional, manufacturing and construction jobs will be created. OTI evaluated this job creation from an annual perspective, and estimates 210 job years will be created. The total number of jobs will exceed 100 but these will continue for less than one year as different disciplines are engaged so OTI aggregated the jobs into the job year concept.

OTI will engage professional engineers and consultants to perform the design and permitting for the facility, followed by considerable amount of manufacturing jobs for fabricating and assembling the intricate components of pumps, turbines and power generators, and finally construction jobs include, site management, operating engineers, concrete, steel erection, piping and equipment installation, and an independent building contractor to construct the office facility.

Lastly, OTI will employ 4 plant operators and maintenance staff, including one manager to run the facility. These jobs are clearly new and created by the completion of the demonstration plant. The development jobs also increase employment in Hawaii and would not be available without the development of the facility.

The positive impact of the proposed action includes local labor noted above and locally procured materials for the facility, which is estimated to exceed $10 million and will have a flow down effect on the local economy. Skilled workers will also be required from other locales. OTI intends to have a visitor facility that will explain OTEC and the activities of the facility, and will be available for scientific researchers, U.S. and foreign officials, educational groups, and the general public.

The proposed action is a required step toward development of a commercial-scale OTEC plant on Oahu. The commercial plant is estimated to generate nearly 5,000 job years for professional, consulting, manufacturing, installation and construction, and operation and maintenance managers and mechanics (Table 10). These jobs will not materialize unless the demonstration facility is developed since the demonstration facility will be used for "scale up" purposes as required by financial covenants.

Table 10: Estimated employment associated with OTEC demonstration and commercial development.

DEMONSTRATION PLANT	Duration (Years)	No. Jobs	Job years
Development and engineering	2	15	30
Equipment Manufacturing	2	15	30
Construction	2	25	50
Operations	25	4	100
G&A Staff	25	1	25
Total Proposed Action		60	235
COMMERCIAL PLANT			
Development and engineering	6	30	180
Equipment Manufacturing	4	200	800
Construction	3	150	450
Operations	30	100	3000
G&A Staff	30	15	450
Total Commercial Facility		495	4880

4.4 Community Impacts and Mitigation

The scheme and size of the proposed 1MW demonstration plant enables OTI to demonstrate not only the generation of electricity from a closed-loop OTEC cycle, but to validate the operations and maintenance ("O&M") concepts to be employed aboard floating OTEC plants. The design of the HX Towers provides the ability for the plant to continue to operate and generate electricity even during maintenance to repair or replace heat exchangers. The plant thus will be an excellent training facility for future workers to be deployed on the floating platforms.

The flexibility of OTI's project design at the HOST Park provides opportunities for collaboration and facilities sharing with the broader global OTEC community. This synergistic approach is intended both to maximize the value of the facility to OTI and to establish NELHA, the HOST Park, and Hawai‘i as the undeniably preeminent location for research, development and demonstration of OTEC technologies.

The development of a 1MW OTEC plant at the HOST Park would benefit society by furthering the development of renewable energy. The knowledge gained would be disseminated throughout the scientific and technical communities, and effects would be felt world wide. The demonstration plant can be used for educational purposes not only for scientists, but also school children and the local community.

Wawaloli Beach Park, located to the north and makai of the project site, includes a white sand beach, swimming area, picnic tables, barbecue pits, showers, and other public facilities. On-shore pole fishing is possible along the southern shore amidst the rocky shoreline. Both warm and cold seawater will be discharged in injection wells designed to prevent discharged water from impacting beach users or marine life (Section 4.2.2.1).

Temporary impacts resulting from construction of the facility include fugitive dust and noise. These impacts will be mitigated by best management practices during construction and will be limited to working hours for a period of no more than 1 year. Impacts resulting from facility operations may include pumping noise and the visual impact of the facility on shoreline users. Noise impacts will be minor and similar to the existing noises generated by the adjacent 55" pump station. Visual impacts on beach users will be partially mitigated by the design of the facility, which will shield noise and appear appropriate for its location.

Along the shoreline, there is an existing dirt 'jeep' trail that traverses near the makai border of the parcel and provides access to many small tide pools. There will be no disruption of the 'jeep' trail or shoreline access for the public.

4.5 Impacts and Mitigation to NELHA and Tenants

The proposed action will result in a number of positive impacts to NELHA and its tenants. Production of locally generated power will be sold to nearby tenants at a firm-fixed rate. Excess power is not generated in sufficient quantities for any other tenants to be entirely removed from the HELCO grid; however, if a significant amount of excess electrical power is provided, it will stabilize the rates for nearby tenants and reduce the demand of diesel power provided to the HOST Park.

OTI will replace the existing seawater pumps with new, larger capacity pumps, and will operate these pumps on power generated from OTI OTEC generators. This will substantially reduce the electricity charges that NELHA currently pays to the electric utility in excess of amounts that NELHA receives from State appropriations. OTI will also be developing land at the HOST Park that is not currently utilized.

OTI will increase the pumping rate for the existing 55" DSW pipe to at least its design capacity. Much of this seawater will be available for NELHA to provide to other tenants after use by OTI. NELHA will still own the water and collect revenue on this water but will have no electrical costs associated with pumping. Because the DSW is warmed by OTEC, the downstream aquaculture tenant will require less SSW for mixing thereby reducing the demand and increasing the available supply of SSW. Quite a large amount of DSW will be available for future tenants that wish to use the water after it has passed through OTEC heat exchangers. Traditional OTEC planning has included a significant value of post heat exchanger use by aquaculture and air conditioning users. These users may be encouraged by the availability of DSW provided from the OTI test facility. One such potential tenant is a CO_2 extraction system being developed to convert carbon dioxide into liquid fuels.

Fresh water is utilized by many of the algae tenants, limiting the availability of fresh water to other tenants. OTI will generate approximately 40,000 gallons of fresh water per day. OTI does not plan to further process the fresh water condensed from cold-water pipelines, and it will not be considered potable due to the lack of further treatment or testing. However, this fresh water will be available to distribute to other tenants for agricultural use.

The proposed action supports the central mission of NELHA, which is to develop natural energy sources from the ocean. Since its inception in 1974 the Natural Energy Laboratory has been at the forefront of OTEC research; however, the long hiatus created by inexpensive petroleum has impeded real advances in the technology and allowed foreign institutions in Japan, Korea and India to gain momentum in OTEC research. The proposed action will create the first megawatt-scale OTEC facility, the largest to date, and lead directly to commercial development of the technology with a 100MW floating plant to be based on the lessons learned from this demonstration. The benefits to NELHA and the State of Hawai'i accruing from being the leader in OTEC development are far greater than short-term gains resulting from the demonstration plant.

A final impact of the proposed action is to use the 55" pipe and pump station at its design capacity. Although planning for the proposed action allows for almost double the other existing use of DSW, any subsequent large-scale seawater users may be required to install another pipe and pump station. The 55" pipe was built with public funds to support an OTEC demonstration plant, planned in 1992, which never came to fruition. The proposed action will reach the goal of utilizing the 55" pipe as originally envisioned by the legislature. Successful demonstration of OTEC technologies may encourage additional investment in OTEC and the HOST Park due to its demonstrated cold-water resources and track record of success.

5. Alternatives to the Proposed Action

Hawai'i's energy costs, now based largely on diesel and other fossil fuels, are currently the highest in the United States (HCEI, 2010). The oil embargo of the 1970's and the threat of subsequent interruptions caused the State to establish the Natural Energy Laboratory for the primary purpose of developing ocean-related energy technologies. During the 1970s and 1980s NELH was used primarily for OTEC research and development of the required technologies to support ocean energy; however, the return of cheap oil and government austerity virtually stopped OTEC development for a period of more than 20 years. Once again the potential for OTEC development is recognized, and NELHA has maintained the infrastructure and permits necessary to support research and development.

5.1 Alternative Sites

Other than the HOST Park and other NELHA lands, there are no feasible sites within the State of Hawai'i for development of OTEC land-based demonstration facilities. Although proximity to deep water is available in various locations, the cost and environmental risks associated with installing a deep-water pipeline make developing a new site quite costly and time-consuming. OTI is considering a RD&D facility in New York State in association with industrial facilities that have a warm water resource. In this instance the cold-water source would be Lake Ontario, and the warm water would be effluent from an electric smelter. While the engineering principles can be demonstrated quite easily using the New York alternative, there are environmental data, and other benefits from establishing the RD&D facility near the proposed site of the commercial plant. Ocean thermal resources are primarily located in tropical oceans. Using a temperate location with larger and variable temperature differences for demonstrating the technology is judged to be less valuable than using the natural resource in the likely location of the first commercial facility. The New York alternative site is not attractive for development of an OTEC plant, as it would be using fresh water resources, which may be different in biofouling and corrosion.

Alternative sites considered also include Caribbean nations where a deep-water resource exists in close proximity to land. Countries including the Cayman Islands have expressed interest in pioneering the development of OTEC for the benefit of having a stable cheaper source of base load power. Caribbean governments have invited OTI to develop its technology on their shores. This alternative may require less up front planning and permitting than a US-based demonstration, but one of the purposes of the demonstration is to develop resources to respond to questions that will arise during the planning and permitting stage of commercial development.

OTI is an American company and would prefer to benefit Americans with reliable sources of power, and as well to contribute to the economic stimulus resulting from an American installation.

5.2 Alternative Technologies

Choosing which alternative energy technology to use in a specific location is challenging, because not all technologies are appropriate in every location, and cost-benefit analyses suffer from the inability to define the limits of the project impacts. Several comparative measures are useful in assessing the advantages of various technologies. Levelized energy cost (LEC) is a measure often used for financial analysis and project planning. LEC is the price at which electricity must be generated from a specific source to break even. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of money, and is very useful in calculating the costs of generation from different sources.

Typically LECs are calculated over different lifetimes depending on the useful life expectancy for a particular technology, and are given in the units of currency per megawatt-hour. Table 11 shows the anticipated cost of electricity during 2016 published by the US Energy Information Administration (US EIA, 2010).

Table 11: Levelized cost for various energy generators estimated for plants starting service in 2016. Costs are reported in dollars per Megawatt hour.

Plant Type	Total System Levelized costs ($/MWH)
Conventional Coal	94.8
Natural Gas combustion Turbine	124.0
Advanced Nuclear	114
Wind (on-shore)	97
Geothermal	101
Solar PV	211
Solar Thermal	311
Biomass	112
Hydro	86

Source: US Energy Information Administration Annual Report, December 2010.

LEC does not include lifecycle costs for environmental compliance or secondary costs of infrastructure and environmental degradation, nor does it include current tax incentives, or subsidies. Per the information above, OTEC compares quite favorably with other base-load technologies, mainly because there is no cost for fuel. It is worth noting that Hawai‘i’s primary energy source, diesel electric generation, is not common enough to be considered in the Energy Information Administration’s Annual Report. Current electric rates on Oahu are in the range of 32 - 35.1 cents per kWh for residential customers, an increase of 34.3% in the last 4 years.

Hawaiʻi's electric rates have now risen to the point where most alternative power methods are economically feasible. Unlike solar, and wind power, OTEC is firm power that can be used as base-load generation rather than peaking or intermittent sources. Unlike geothermal, one of the oldest alternative sources in Hawaiʻi, OTEC can be located near the demand in many locations around the state. Biomass and waste-to-energy facilities have been well demonstrated in Hawaiʻi from the sugar mills to H-Power, but these are not technologies that can be easily expanded to produce any significant fraction of our demand, and they come with an environmental cost. In Hawaiʻi, our primary asset is the Pacific Ocean. OTEC is an appropriate technology for Hawaiʻi as long as its construction and operation do not significantly damage our primary asset.

5.3 No Action Alternative

Under the No Action Alternative, the OTEC demonstration facility would not be constructed at the HOST Park. It is probable that OTI's commercial OTEC development would proceed on schedule, but at locations other than Hawaiʻi. The State may or may not be the initial site of commercial OTEC power generation, and the Natural Energy Laboratory would continue to be fueled principally on imported diesel fuel.. . The no action alternative maintains the existing condition and conserves irretrievable resources such as money and materials that would otherwise be used to build and operate the facility. The no action alternative does not meet the project objective of advancing the state of knowledge regarding ocean thermal energy conversion technology.

5.4 Selection of Project Alternative

Two alternative locations were reviewed. These are rejected for reasons discussed above. The no action alternative is rejected because it does not meet the project objectives or conform to the State and federal mandates to develop non-fossil fuels. Several alternative technologies were reviewed; however, OTEC is the appropriate technology for the HOST Park, and the proponent has expertise in development of OTEC. The HOST Park is currently the preeminent location for OTEC development, and the proposed action will maintain that position to the benefit of the consumers in Hawaiʻi. On this basis, the proposed alternative is selected and will be discussed further in this document.

6. Consistency with Public Policies and Objectives

6.1 Federal Policies Supporting Renewable Energy

Most energy policy incentives in the U.S. take the form of financial incentives. Examples of these include tax breaks, tax reductions, tax exemptions, rebates, loans, and specific funding. Throughout U.S. history there have been many incentives created through U.S. energy policy. Most recently the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and the Emergency Economic Stabilization Act of 2008 promote various energy efficiency improvements and encourage development of specific energy sources. U.S. Energy policy incentives can serve as a strategic means to develop certain industries that plan to reduce America's dependence on foreign petroleum products and create jobs and industries that boost the national economy. The ability to do this depends upon which industries and products the government chooses to subsidize. The federal government provided substantially larger subsidies to fossil fuels than to renewables in the period between 2002-2008. Subsidies to fossil fuels totaled approximately $72 billion over the study period, representing a direct cost to taxpayers. Subsidies for renewable fuels, totaled $29 billion over the same period (Environmental Law Institute, 2009).

The Energy Policy Act of 2005, signed into law by President George Bush on August 8, 2005 was the product of over four years of congressional consideration. Among the many provisions of the Energy Policy Act of 2005 are renewable energy production tax credits**.** The act provides tax credits for wind and biomass, which were extended for two years, and additional tax credits made available for other renewable energy sources including solar, geothermal, and ocean energy.

The energy policy of the Obama Administration lists the guiding principles of the administration regarding energy and the environment. They are: creating new clean energy jobs and technologies, making America more energy independent, and reducing carbon emissions. Many of the Obama Administration's initiatives were undertaken as a result of the American Recovery and Reinvestment Act of 2009, and many of those investments were specifically in clean energy. The White House website states that the Recovery Act provided over $80 billion in clean energy investments. The President and Congress have dramatically increased funding for the U.S. Department of Energy's wave and tidal technologies program. In addition, President Obama has advocated that by 2012, 10 percent of our domestic energy supply should come from renewable resources, increasing to 25 percent by 2025. Also, now that federal regulation of greenhouse gas emissions is increasingly likely, the focus is on reducing CO2 emissions through the renewable energy sector.

6.2 Hawai‘i State Policies Supporting Renewable Energy

Act 234, Session Laws of Hawai‘i 2007, established the State's policy framework and requirements to address Hawai‘i's greenhouse gas emissions, recognizing the potential adverse effects of recent climate change and global warming to Hawai‘i's economy, public health, natural resources, and environment (http://hawaii.gov/dbedt/info/energy/greenhouse/). The general purpose of Act 234 is to establish and to achieve State policy to reduce and limit greenhouse gas (GHG) emissions to levels at or below the best estimates and updates of the inventory of Hawaiʻi's greenhouse gas emissions estimates of 1990 emissions levels in a cost-effective manner by January 1, 2020.

Hawaiʻi's energy policies have gone through a major advance within the past 5 years. The Hawaiʻi Clean Energy Initiative (HCEI) has set the goal of transforming Hawaiʻi's energy use to 70% clean energy by 2030. Hawaiʻi's dependence on imported oil creates vulnerability for the state's economy, which is greatly affected by the price volatility of this finite energy source. Recognizing the detrimental effects this oil dependency has on Hawaiʻi's environment and local economy, the state signed a Memorandum of Understanding (Hawaiian Electric, 2008) with the U.S. Department of Energy (DOE) in January 2008, which established HCEI as a partnership bringing together local business leaders, policymakers, and industry experts to guide Hawaiʻi's transition to a clean energy economy.

The MOU states:

Signaling agreement on key actions, the Hawaiian Electric Co. (HECO) family of utilities voluntarily agreed to a number of actions after extensive discussions with DBEDT and the USDOE. In the Energy Agreement, HECO and the state agreed to move from central-station, oil-based power to a more renewable, distributed- and intermittent powered system while preserving the stability of the grid, minimizing disruption, and keeping the utilities financially sound.

The Energy Agreement includes the following significant goals:

- Increasing Renewable Portfolio Standard goals to 25% by 2020 and 70% by 2030.
- Developing an Energy Efficiency Portfolio Standard.
- Accelerated addition of clean energy resources on all islands.
- Laying an undersea cable linking Oahu and wind farms on Molokai and/or Lanai.
- Establishing feed-in tariffs to standardize rates for utilities' purchase of renewable power.
- Decoupling utility revenue from electricity sales.
- Removing system-wide caps on net energy metering.
- New programs for solar water heating and photovoltaics.
- Aggressively supporting alternative fuel and electric vehicles.
- Installation of advanced meters for customers who request them.

A significant piece of legislation was passed in 2009 under Act 190 that alters the state's permitting process. First, renewable energy facilities greater than 5 MW are now able to apply for the Renewable Energy Facility Siting (REFS) process from HB2971 HD1, a permitting and regulatory framework for the construction of renewable energy facilities in the state (this was formerly only offered to renewable energy facilities greater than 200 MW). Additionally, while the decision to award or deny permits is retained by the state or county agencies, new legislation allows the Energy Resource Coordinator in DBEDT to force a decision to either grant or deny permits by no later than 18 months after the approval of a complete permit application. A third step that was taken in the 2009 Legislature was the passage of Act 155, which requires DBEDT to identify Renewable Energy Zones (REZ)—areas that are rich in renewables, cost effective, and environmentally benign—and encourage development of these REZs for transmission of renewable energy. DBEDT is in the process of determining these zones, which will foster much quicker land-use permitting processes (DBEDT, 2010).

About 90% of Hawaiʻi's energy comes from crude oil and petroleum imports. Disruptions in the world oil market have considerable impact on Hawaiʻi's economy. Also, Hawaiʻi utilities do not have interconnections with utilities in other states and cannot rely on utilities from other states to provide back-up power to them when needed. Development of Integrated Resource Planning and Renewable Portfolio Standards (RPS) are thus important for Hawaiʻi in an effort to reduce oil imports, increase diversity of energy sources, and provide reliable electricity to end users.

In 2006 Act 162 granted the PUC authority to establish standards for each utility that prescribe what portion of the RPS shall be met by specific types of renewable electrical energy resources. RPS standards may be met through production of electricity using fuels as well as implementation of conservation measures that save energy.

To address these issues, the State of Hawaiʻi adopted four statutory energy objectives (HRS § 226-18a):

> *(1) Dependable, efficient, and economical statewide energy systems capable of supporting the needs of the people;*
> *(2) Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased;*
> *(3) Greater energy security in the face of threats to Hawaii's energy supplies and system, and;*
> *(4) Reduction, avoidance, or sequestration of greenhouse gas emissions from energy supply and use.*

The first Renewable Portfolio Standard (RPS) was enacted into law in Hawaiʻi in 2001 (Act 272). The RPS law establishes the percentage of electricity sales that should come from renewable energy sources. It established the goal of 7% of electricity sales from renewable energy sources by December 31, 2003, 8% by December 31, 2005, and 9% by December 31, 2010. The Hawaiʻi State Legislature revised the State's RPS law in 2004 with Act 95, which requires each electric utility company to establish a renewable energy portfolio standard of 10% of its net electricity sales by December 31, 2010; 15% by December 31, 2015; and 20% by December 31, 2020. The RPS law allows an electric utility company and its electric utility affiliates to aggregate their renewable portfolios in order to achieve the RPS.

6.3 County of Hawai‘i Policies Supporting Alternative Energy

The County of Hawai‘i has consistently supported the Natural Energy Laboratory since its inception.

The County of Hawai‘i’s Energy coordinator has contributed to the development of the County Energy Sustainability Plan. The Website lists its major policy objectives as:

1. To maximize the energy efficiency for all Hawai‘i Island energy systems.
2. To maximize the use of renewable energy for electrical energy generation and transportation on Hawai‘i Island.
3. To improve the County's energy emergency preparedness.

The County has adopted an Energy Sustainability Vision, which states:

- The County of Hawai‘i will lead by example to transform Hawai‘i Island from its current reliance on imported fossil fuels at the high level of 70% and expenditures exceeding $750 million dollars annually (2007) to a level where more than 70% of our electric generation and fuel resources are from renewable sources. Efficiency and conservation programs will be implemented continuously to provide the most cost-effective results.
- A transformation to Hawai‘i County's energy future will result in direct savings of energy dollars, increased sustainable economic development and new job creation. Concurrently, the Island's impact on a global scale will be a reduced Island GHG footprint with positive consequences for the environment.

The Vision’s current initiatives include:

- The Hawai‘i Clean Energy Initiative has embraced the initiatives of Hawai‘i County's Energy Plan. We are attending key meetings to determine how best to partner with our similar missions. National Renewable Energy Laboratory sent key personnel in engineering and finance to discuss how to leverage Hawai‘i Islands resources.

- The Department of Public Work policy is to include photovoltaic systems on all new construction and roof replacement bid specifications. This policy is optional, as some facilities lend themselves more readily to accommodate such systems and result in a higher cost/benefit ratio.

- The County's efforts to lead by example are expressed through initiatives such as the 100-kilowatt (kW) photovoltaic system that will be installed shortly as part of the renovations to the County Building in Hilo.

- A second major photovoltaic system has been installed on the new West Hawai‘i Civic Center. The 400kW system will provide nearly one-third of the building's power requirements and help to assure that the building meets the Leadership in Energy and Environmental Design (LEED) Silver of higher certification. The photovoltaic power would be supplied by a third party, thus eliminating the upfront costs estimated to be nearly $4 million dollars and resulting in an overall lower price per kilowatt-hour of power used. While contract terms are negotiated, discussions are ongoing with the utility to "net meter" the power generated on the weekends for credit to the County.

- $737,000 has been obtained to complete a detailed Energy Efficiency and Conservation Strategy (EECS) to include an audit of energy use throughout the County's buildings, equipment and transportation systems; development of policies and programs to rapidly move forward with the EECS; and retrofitting or installation of energy efficient systems such as street lights for immediate savings.
    - 400 street lights will be retrofitted with LED lamps in coordination with the traffic division.
    - Alex Woodbury will conduct an energy audit of multiple County buildings.
- The Kenoi Administration fully supported a recent initiative by the County Council to update the Model Energy Code. Changes to the Code will ensure that new construction of residences will employ energy efficient design and construction to minimize roof heat gain, create passive cooling systems, and provide for low-emissivity windows and doors. The small added cost for new construction is expected to result in significant cost savings over the life of the buildings.
- The County's newly formed Green Team consisting of County employees will take on sustainability issues as a means to save on energy costs for the County and lead by example within the community by adopting sustainable practices. Efforts will focus on collecting and analyzing data on energy, transportation, buildings and waste. Future steps will include development of policies to address reduction in our global footprint and to protect and conserve our environment.
- Efforts are proceeding to identify appropriate workforce development needs and opportunities in the area of green jobs. These include building design and construction, reuse and recovery of resources, renewable energy production, eco-tourism, creative digital media and fashion, holistic science and technology and through education and collective efforts to make all jobs "greener."
- Efforts are proceeding to develop a detailed website that residents and businesses may visit to secure answers to their energy related questions.

6.4 Consistency with Federal, State and County Coastal Zone Management Policies

The Coastal Zone Management Act (CZMA) was created in 1972 by the U.S. Congress to manage growth in coastal zones in the United States. The Act is administered by NOAA’s Office of Ocean and Coastal Resource Management (OCRM) to balance economic development with environmental concerns. The areas covered by this act are all lands of the State and the area extending seaward from the shoreline to the limit of the State's police power and management authority, including the United States territorial sea under the Submerged Lands Act (48 U.S.C. 1705, as applicable); The zone extends inland from the shorelines only to the extent necessary to control shore lands, the uses of which have a direct and significant impact on the coastal waters, and to control those geographical areas which are likely to be affected or vulnerable to sea level rise. (16 U.S.C. §1453 (section 304)) According to Hawaii Statutes **§205A-1**, the "shoreline" is defined as *the upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves.*

Section 205A-2 of the Hawaii Revised Statutes (HRS) outlines the Coastal zone management program policies and objectives. Consistency with the ten policies and objectives outlined in this statute are reviewed below.

1. **Recreational resources-** Recreational resources in proximity to the proposed action include Wawaloli Beach Park, shoreline areas, and a jeep trail used for access to shoreline areas. Wawaloli Beach park is located to the north and seaward of the proposed project. The park has picnic tables, barbecue pits, showers and bathroom facilities. Existing conditions include industrial facility noise from the 55" pump station, and aircraft noise from the Kona International Airport. Noise levels may increase temporarily during construction, and construction related traffic will increase along the jeep trail at certain times during the construction period. No operational impacts to the beach park or jeep trail were identified. Public access to shoreline areas and the jeep trail will be maintained.
2. **Historic resources-** The site has been subject to numerous archaeological surveys dating back to the 1940s. An anchialine pond and some archaeological findings surrounding it were re-discovered in a survey performed for this project. Documentation and recordation of the feature was completed in the 1950s. A management plan for the feature and its associated anchialine pond is in preparation and will be implemented prior to the start of site work. It is likely that the pond will be fenced off with a low rock wall to prevent any runoff from disturbing it and to protect the archaeological findings. To date, no evidence of human burials have been encountered, however if burial sites are inadvertently encountered during subsequent development or construction activities, such finds will be reported to DLNR-SHPD in accordance with HAR 13 §13-300-40. The proposed project and injection wells will be placed and designed not to impact the anchialine pond and the adjacent archaeological features.
3. **Scenic and open space resources-** The proposed project will be designed in accordance with the special management use permit #239 and its design manual. The facility will stand 54 feet above ground and will be in the view plane from OTEC access road. It will be architecturally designed to be appropriate for the HOST Park, and consistent with other structures in the area. The towers will be painted a neutral color with no reflective surfaces in accordance with FAA guidelines and to prevent significant visual impact. All machinery will be shrouded from view. Landscaping will be with native plants. Lighting on the project will be in accordance with Hawaii County's Lighting Ordinance Section 14-50.

4. **Coastal ecosystems-** During the construction phase, best management practices will be used to prevent surface water runoff and a NPDES construction stormwater permit will be obtained. Once the facility has been constructed and is running, a system of injection wells will dispose of the residual seawater that is not sent to other tenants. The deep seawater which is nutrient rich will be disposed in 400 foot wells that are cased to 300 feet to prevent dispersion at shallower levels. This will prevent the deep seawater from affecting shoreline ecosystems as it is expected to be widely disbursed and enter the ocean at depths greater than 300-400 feet. The surface seawater will be disposed in shallower wells but still below 100 feet below ground surface to prevent disruption of the brackish groundwater lens and impacts on the anchialine pond. This also alleviates potential impacts to shoreline biota including coral reefs as the surface seawater will enter the nearshore waters at depths greater than 100 feet and at a distance of approximately 600 feet from shore. Details of the injection well system are covered in section 4.2.2.1. No significant impacts to the coastal ecosystems are anticipated as a result of the injection well design. Ocean monitoring will continue with the CEMP program.
5. **Economic uses-** The proposed OTEC project is consistent with the primary objectives for the establishment of the Natural Energy Laboratory of Hawaii and Hawaii Ocean Science Technology Park which include research development and commercial application of activities for ocean thermal energy conversion and related activities that use ocean water as a resource. The proposed action represents the first step toward energy self-reliance for Hawaii. The location of the specific parcel for the proposed project is adjacent to the 55" pump station which provides access to the DSW and SSW needed for the 1 MW RD&D project. During construction and operation of the proposed project, jobs will be created for the local economy. There will be a visitor facility that will provide educational opportunities for scientists, U.S. and foreign officials, educational groups and the general public. The project will provide opportunities for collaboration and sharing with the broader OTEC community and furthers the State and County objectives for alternative energy and decreasing dependence on foreign oil. The proposed project and its facilities are behind the 40-foot setback and are designed to not impact the coastal zone.
6. **Coastal hazards-** The location on the parcel of the proposed OTEC project is located in zone X of the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map which is outside of the 100-year area for coastal flooding. (figure 11) The project is in the tsunami evacuation zone. (figure 12) A tsunami warning siren is located on the NELHA property and an emergency plan has been developed. Large swells and storm waves can impact the coastal environment and cause erosion, damage to coral ecosystems and coastal inundation. Significant blocking and reduction of nearshore waves occurs from the other 7 Main Hawaiian Islands that are located to the northwest of the Island of Hawaii. The proposed project is well behind the 40-foot shoreline setback. Appropriate best management techniques will be used in the construction period to prevent stormwater runoff, silt and dust from impacting the shoreline in any way.

7. **Managing development-** NELHA and HOST Park have several existing master permits and environmental impact statements that are described in sections 1.4.1, 1.4.2, and appendix A. There are several special management area (SMA) use permits, #26, 77, and 239. OTI and its consultants have examined the documents and permits associated with NELHA and HOST Park's existing and planned operations. The proposed project is consistent with the guidelines and existing land use permits. This environmental assessment is to provide a comprehensive reference document for public disclosure of the full extent of the proposed activities and their expected environmental impacts and mitigation. All other appropriate building, construction and operating permits are in process.
8. **Public participation-** This document and meetings with stakeholders are designed to encourage public participation in the proposed action.
9. **Beach protection-** The proposed action does not involve construction in the shoreline area. Access to Wawaloli Beach Park will be maintained without disruption or significant impact. Appropriate best management techniques will be used during the construction and operating processes to prevent any degradation of the beaches and nearshore waters. All construction, buildings and injections wells for the proposed project will be mauka of the 40-foot shoreline setback. Native plants will be used in landscaping within the parcel which will be fenced to prevent any impingement on shoreline access or use.
10. **Marine resources-** The proposed project is consistent with Federal, State and local policy for the development of alternative energy sources to decrease Hawaii's dependence on foreign oil. In addition, the 1 MW RD&D OTEC plant provides an opportunity for research and further development of ocean thermal energy technology and research to contribute to the potential development of commercial applications which is consistent with NELHA and HOST Park mission statements. Research on potential impacts will be ongoing during operation of the proposed projects and continued monitoring of the ocean environment will occur with the CEMP process.

Pursuant to §205-21 of Hawaii Revised Statutes, Hawaii legislature has determined that *"special controls on developments within an area along the shoreline are necessary to avoid permanent losses of valuable resources and the foreclosure of management options, and to ensure that adequate access, by dedication or other means, to public owned or used beaches, recreation areas, and natural reserves is provided."* §205A-22 defines the special management area as the land that extends inland from the shoreline as delineated by maps filed. In the case of NELHA/HOST Park, the special management area extends from the shoreline to Queen Ka'ahumanu Highway. Special management area use permits are needed for developments with a valuation exceeding $500,000 or which may have substantial adverse environmental or ecological effect. The proposed project is located in the special management area of HOST Park behind the 40 foot shoreline setback. NELHA/HOST Park has SMA Use Permit 239 which covers the area of the proposed project. This permit was approved June 4, 1986 *to allow the development of the Hawaii Ocean Science and Technology (HOST) Park Subdivision and related improvements, including all future improvements and structures at Ooma 1st and 2nd, North Kona,* *Hawaii.* The location of the proposed project is within the HOST Park and part of Ooma 1st as designated in SMA maps. (http://www.hawaiicounty.gov/tax-maps/current/zone-7/section-3/)

The conditions that are applicable to the proposed project and must be upheld according to the SMA use permit 239 include:

- Architecture, setbacks, ground cover, etc. must conform to the standards and guidelines of the Development Design Manual
- Method of sewage disposal shall meet with regulations
- Plans must be submitted to the Planning department for Plan Approval review
- Shoreline Management Plan
- Archaeological salvage/historic preservation shall be conducted prior to construction of any sites to remove scientific information
- Unanticipated archaeological sites or features addressed in accordance with SHPD (previously, the Planning Director was the authority)

No structural improvements will be constructed within the 40-foot setback.

Off-shore water quality monitoring data shall be submitted annually to the Planning Department. The proposed OTEC facility is within the area covered by SMA 239 and meets all of the conditions specified therein.

7. Anticipated Finding of No Significant Impact

In determining whether an action may have a significant effect on the environment under HRS 11-200, the proponent must consider every phase of a proposed action, the expected consequences, both primary and secondary, and the cumulative as well as the short-term and long-term effects of the action.

An action shall be determined to have a significant effect on the environment if it:

1. Involves an irrevocable commitment to loss or destruction of any natural or cultural resource;
2. Curtails the range of beneficial uses of the environment;
3. Conflicts with the state's long-term environmental policies or goals and guidelines as expressed in chapter 344, HRS, and any revisions thereof and amendments thereto, court decisions, or executive orders;
4. Substantially affects the economic welfare, social welfare, and cultural practices of the community or State;
5. Substantially affects public health;
6. Involves substantial secondary impacts, such as population changes or effects on public facilities;
7. Involves a substantial degradation of environmental quality;
8. Is individually limited but cumulatively has considerable effect upon the environment or involves a commitment for larger actions;
9. Substantially affects a rare, threatened, or endangered species, or its habitat;
10. Detrimentally affects air or water quality or ambient noise levels;
11. Affects or is likely to suffer damage by being located in an environmentally sensitive area such as a flood plain, tsunami zone, beach, erosion-prone area, geologically hazardous land, estuary, fresh water, or coastal waters;
12. Substantially affects scenic vistas and view planes identified in county or state plans or studies, or;
13. Requires substantial energy consumption.

Based on analysis of the 13 significance criteria listed above, the proposed action is not expected to result in significant adverse environmental impacts when conducted within the constraints of the required plans and permits. Pending comments received from the public and various agencies during this DEA review period, the Board of Directors of the Natural Energy Laboratory of Hawaiʻi Authority (approving agency) anticipates a Finding of No Significant Impacts (FONSI).

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The proponent also wishes to thank **The Natural Energy Laboratory of Hawai‘i Authority** for providing information and assistance with preparation of this assessment. The efforts of the following NELHA members are recognized:

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Greg Barbour, Executive Director
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Appendix A

Compliance with Hawaii Environmental Protection Act (HEPA) and Land-use Regulations

Environmental Compliance Requirements for the Proposed OTEC International, LLC OTEC Research Facility at the Natural Energy Laboratory of Hawai‘i Authority (NELHA), Keahole, North Kona, Hawai‘i

Introduction

OTEC International, LLC (OTI) intends to construct an OTEC test facility at a site within the Natural Energy Laboratory of Hawai‘i Authority (NELHA). The facility will be designed and operated by OTI to demonstrate their capability to build and operate larger commercial scale facilities. This test platform will be used initially to perform a 1000-hour test of the heat exchangers and power systems, with subsequent application as a testing and development platform for evolving OTEC technology. It is expected to produce 1 MWe of electric power, which may be used to supplement the electrical demand at NELHA.

OTI and its consultants have reviewed accepted Statements prepared pursuant to Chapter 343, HRS along with land use permits issued to NELHA. In our opinion the full extent of OTI’s proposed activities fall within the scope of actions described in existing EIS documents. In addition, we find that CDUA permits currently in place comprehensively encompass the full scope of the intended actions. This paper documents compliance of the OTI actions with Chapters 183C and 343, HRS and with Titles 11-200 and 13-5, HAR.

Prior Environmental Review at Keahole Point

Hawai‘i Revised Statutes (HRS) Chapter 343 provides for systematic, public disclosure and review of proposed actions that fall within specific categories, or “triggers”, as defined in HRS §343-5. The environmental review system ensures that “environmental concerns are given appropriate consideration in decision making along with economic and technical considerations” [HRS §343-1]. The EIS law also provides that “a statement that is accepted with respect to a particular action shall satisfy the requirements of [HRS 343], and no other statement for the proposed action shall be required” [HRS §343-5(g)]. Regulatory guidance regarding the sufficiency of an accepted statement for the purposes of compliance with provisions of Chapter 343 HRS appears in Title 11 Chapter 200 Section 26 Hawai‘i Administrative Rules (HAR) which states, “as long as there is no change in a proposed action resulting in individual or cumulative impacts not originally disclosed, the statement associated with that action shall be deemed to comply with [HRS 343].”

The following four accepted Environmental Impact Statements (EIS) relating to proposed actions at the NELHA facility were prepared pursuant to Hawai‘i environmental law (HRS 343):

1) 1976 Final Environmental Impact Statement (FEIS): Environmental Impact Statement for Natural Energy Laboratory of Hawaiʻi, Keʻahole, Hawaiʻi (Phase I), prepared for the Research Corporation of the University of Hawaiʻi (RCUH) by R. M. Towill Corporation, accepted by Governor George Ariyoshi in February 1977;

2) 1985 Final Environmental Impact Statement (FEIS): Development Plan for the Hawaiʻi Ocean Science and Technology Park and Expansion of the Natural Energy Laboratory of Hawaiʻi, Keʻahole, North Kona, Hawaiʻi, prepared for the Hawaiʻi High Technology Development Corporation (HTDC) by The Traverse Group for the Hawaiʻi High Technology Development Corporation (HTDC), accepted by Governor John Waihee in September 1985;

3) 1987 Final Supplemental Environmental Impact Statement (FSEIS): Alternative Methods of Seawater Return Flow Disposal, prepared by MCM Planning, Honolulu, Hawaiʻi for the State of Hawaiʻi Natural Energy Laboratory of Hawaiʻi (NELH), accepted by Governor John Waihee in March 1987, and;

4) 1992 Final Supplemental Environmental Impact Statement (FSEIS): Development of Land Exchange Parcel, prepared for the Natural Energy Laboratory of Hawaiʻi Authority (NELHA), by GK & Associates for NELHA, accepted by Governor John Waihee in September 1992.

Actions described in these documents reflect both research and business development goals for the Keahole facility. In addition, these Statements comprehensively assess the significance of anticipated impacts resulting from the evolution of intended projects at NELHA, resulting in concrete recommendations for acceptable operating practices relevant to all facets of NELHA activities. Because Chapter 343 stipulates that "acceptance of a required final statement shall be a condition precedent to implementation of the proposed action" [HRS §343-5(b)], information presented in EIS documents forms the basis for established permit parameters that have subsequently been granted to operations at the facility. In particular, conditions delineated in the principal State land use permits granted to NELHA through the Conservation District Use Permit (CDUP) process administered by the Department of Land and Natural Resources [*ref.* HRS 183C-6(a)] directly reflect stated operating parameters described in the series of Statements listed above.

After review, we find that the proposed OTI OTEC 1MWe demonstration facility at NELHA comprehensively complies with statutory and regulatory provisions for environmental review and permitting arises from comparing elements of the intended action with provisions and operating parameters specified in the previously accepted Statements and in existing permits. The remainder of this paper highlights the correspondences between the components and operating parameters of the OTI proposal and specific discussions and provisions of existing Statements and permits.

Project Overview

The demonstration OTEC plant that OTI will install at NELHA will be comprised of the systems, subsystems and components that will exist on its floating plants and configured to simulate the fluid flow through and emulate the operation of such plants. The shore-based pilot OTEC plant will produce 1MWe (nominal value), which may be supplied to NELHA to offset its costs of operation and support.

OTEC has always been central to the purpose and intent of the NELHA mission. The original 1976 FEIS stated:

> *The basic purpose of the NELH is to provide the essential support facilities for future energy programs and to interest research organizations in using these facilities. By providing a centralized location with favorable conditions, it is hoped that research groups examining alternative sources of energy will select Hawaii as the location for their research and test facilities* (Towill, 1976, p. II-2).

This FEIS identified OTEC as the Laboratory's principal project, implemented through a "phased research and development program" beginning with "small-scale experiments in existing facilities" and ultimately developing to "a scaled prototype operation" (Towill, 1976, p. II-4). More specific description of the envisioned OTEC proof-of-concept appears in Appendix A, where a likely prototype of between 1 and 5 MWe in size uses ammonia as a working fluid and pumps between 250 and 1000 cubic feet per second each of deep sea and surface ocean water (Towill, 1976, p. A-2). Some discussion of potential environmental impacts of such a facility appeared in this EIS, but it mostly addressed the basic infrastructure of roads, potable water and power. Although deep and surface sea water systems were envisioned, they were only discussed in general terms.

Subsequent Statements also placed principal emphasis on the centrality of OTEC to the mission and objectives of research and commercial development at the Keahole facility. A second FEIS, prepared for construction and operation of the Hawai‘i Ocean Science and Technology (HOST) Park and expansion of NELH, more explicitly addressed operational parameters anticipated at the facility (Traverse Group, 1985). Among the actions assessed in this document was the pumping of 42,000 gallons/minute (gpm) from OTEC and mariculture operations at NELH and 100,000gpm from commercial operations at the HOST Park. Various seawater management methods were considered, and the preferred method selected for seawater disposal was on-site trenches. The 1985 FEIS also assessed a mixed seawater return pipeline, and this alternative was judged to be feasible and environmentally benign, but not cost effective.

The purpose of the third Statement (MCM Planning, 1987) was to assess best methods of seawater return. Alternatives included deep injection wells, direct surface discharge through a holding pond and into coastal waters, and the trench method of disposal. Although direct discharge of mixed seawater was most cost effective, it was determined to be infeasible due to the size of the pond required to return discharged seawater to ambient ocean temperatures. Deep injection was judged to be the most environmentally benign of the considered methods of seawater disposal due to the extended residence time (3 and 4 months) of the return water. This alternative also was rejected due to its high cost. The 1987 FSEIS concluded that the use of a shallow disposal trench installed parallel and makai of the NELHA access road is the best method for OTEC seawater return. The trench would be approximately 250 feet from the shoreline at its closest point and contain a perforated distribution pipe beneath backfill materials to prevent biofouling. The flows discussed were up to 42,000gpm of mixed OC OTEC discharge and mariculture effluents (MCM Planning, 1987 Appendix C). The document observes:

> *"A cost effective disposal technique may make the difference between success and failure of the fledgling state-of-the-art businesses."*

Principal mitigation recommended in the 1987 Statement to address potential impacts of seawater discharge was a comprehensive Environmental Monitoring Plan (CEMP) established to monitor potential impacts resulting from the return flow. According to Dames and Moore (MCM Planning, 1987 Appendix C Addendum 1 pg. 3), the anchialine ponds to the south of the proposed development would not be within the area of influence of the discharge flow net for a 42,000gpm mixed discharge trench located in an area similar to the one proposed.

In the most recently prepared FSEIS (GK & Associates, 1992), one of the primary activities assessed was an OTEC facility generating 1MWe gross power using an ammonia-based closed cycle heat engine powered by cold deep sea water (DSW) and warm surface sea water (SSW). The OTEC plant would supply DSW and SSW to an Ocean Science Center, Lobster farm and other NELHA tenants. Seawater return flow was to be disposed in 2 shallow trenches near the current site of the 55" pumping station.

Empirical OTEC-related development at NELHA generally has followed the phased implementation model expounded in the original plans. Initial successful testing of heat exchanger components led to a growing understanding of both materials and operating performance characteristics. During the mid-90s, an experimental open-cycle OTEC apparatus successfully produced up to a maximum of 103 (net) kW of electricity, along with up to 6 gallons per minute of desalinated seawater. Testing of OTEC components continues to this day, with ongoing heat exchanger evaluations presently being conducted by Lockheed Martin and Makai Ocean Engineering. However, developing and implementing a commercial-scale pilot OTEC facility has from the outset been an NELH objective, repeatedly and explicitly referenced in all of the planning documents generated to guide the facility's evolution.

With completion of the proposed OTI demonstration facility, the founding premise of viable OTEC at NELHA will become an accomplished fact.

The proposed location of the facility will be the 2.5-acre site adjacent to the pumping station for the 55" SSW and DSW pipes on Lot 87. This lot, shown in the map in Figure 1, is on land zoned in the Urban district, and designated for industrial usage.

Figure 1. Tax Map, Plat 43; Lot 87 is at the bend in OTEC Road.

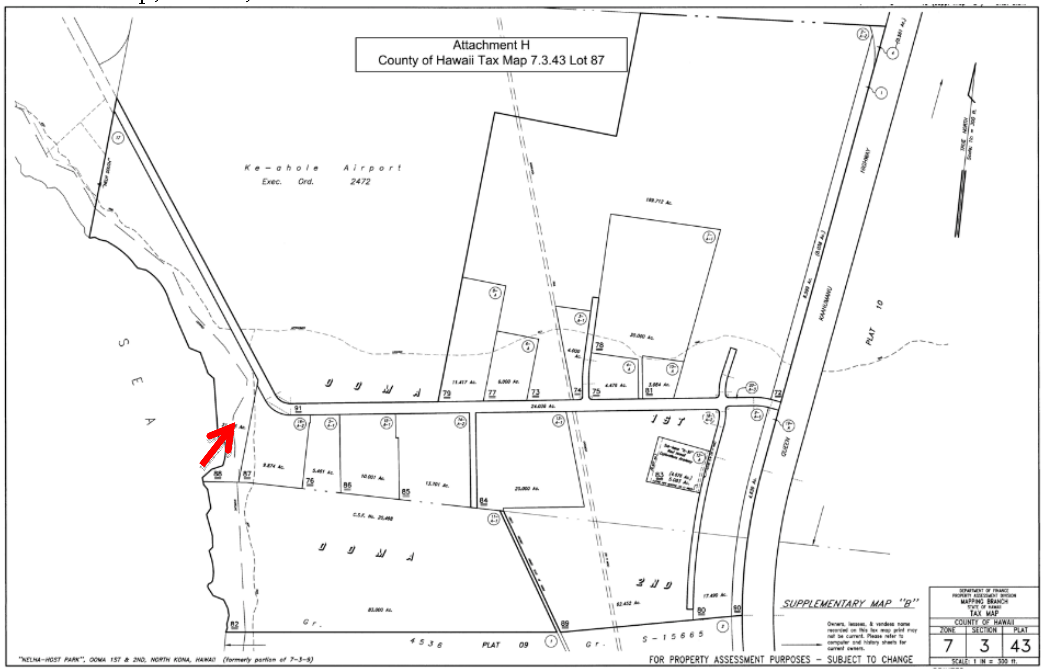

Figure 2. Aerial photo of the 2.5-acre lot allocated for the OTI RD&D Facility; NELHA 55-inch Pump Station is south of the OTI lot.

An aerial image of the pumping Station and location of the proposed OTI 1MWe OTEC plant is shown in Figure 2.

OTI will supply NELHA with variable speed drive pumps with capacity of 40,800gpm for SSW and 30,000gpm for DSW. This will provide the capacity needed to meet existing NELHA demand as well as to achieve an electricity output of 1MWe or more from the OTI OTEC plant. Innovative technologies allow the SSW and DSW water to pass through the aluminum heat exchangers of the OTI OTEC plant without chemical treatment. The water discharged by the OTI OTEC plant will be plumbed to go either back into the NELHA facility distribution piping, to a system of discharge injection wells, or to a combination of these. The OTEC process will elevate the DSW temperature and lower the SSW temperature by 3 to 5 degrees C. Discharged water is considered single-pass non-contact cooling water. With the exception of minor temperature changes, there are no detectable differences in SSW or DSW as a result of its use. OTI would be willing to distribute SSW and DSW to other NELHA tenants for their use provided certain requirements for indemnity are met. Reuse of seawater by other tenants should prove to be a desired benefit for all parties. OTI will not utilize all of the available seawater available to NELHA. Even if there is no reuse of OTI's effluent, NELHA maintains a sufficient volume of SSW and DSW to satisfy the demands of current and future tenants.

OTI plans to perform a 1000-hour operation test for which the plant must run continuously for at least 1000 hours with uninterrupted 1MWe output. This test will utilize as much as 3.61 billion gallons of combined surface and deep seawater (see appendix 3). In addition to the 1000-hour operation test, water must be pumped at operational capacity for start-up and shut down testing. In all, OTI estimates that by the conclusion of the 1000-hour test, at least 4 billion gallons of pumped seawater will be processed through the 1MWe OTEC plant.

The OTI OTEC plant will be a fully operational and compliant power plant with four sets of turbine-generators, machinery controls, transformers and a switchyard to generate and transmit 1MWe at 69kV. OTI will ensure that the electricity generation subsystem will control and regulate the frequency to be fully compatible with the needs of NELHA.

OTI plans to continue to perform OTEC research and development at its plant at NELHA for decades to come with a multi-generation development plan already begun. Future generations of development include pumps, motors, generators, heat exchangers, control systems to produce potable water and other co-products. For example, as part of a Navy Cooperative Research and Development Agreement (CRADA) MELE Associates (MELE) is working with Naval Research Laboratory (NRL) on research and development for later commercialization of a seawater carbon dioxide (CO2) extraction process. MELE Associates, Abell Foundation (OTI), and NRL have performed joint projects in the past. The OTI OTEC plant at NELHA would provide a possible platform and electrical supply for the seawater CO2 extraction. If OTI locates a 1 MWe OTEC plant at NELHA, MELE-NRL would perform research activities with the seawater CO2 extraction unit and develop a scaled up version of the CO2 extraction skid. MELE's objective is to develop commercial-scale seawater CO2 extraction technology within six years.

Correspondence of Project Elements with Existing Permits

As the foregoing overview notes, installation and operation of a commercial-scale OTEC facility at NELHA would bring to fruition one of the fundamental purposes for which the Laboratory was conceived. The advantages of the Keahole location for such research and development are well recognized, and have been cited repeatedly (e.g., Towill, 1976; Traverse Group, 1985; MCM Planning, 1987; GK & Associates, 1992). OTEC's known demands for seawater supply and disposal also have been fully appreciated and discussed, leading to the NELHA operating parameter recommendations previously cited. Following procedures discussed above, operational and mitigation recommendations developed in accepted Statements have been incorporated into conditioned authorizations granted to NELHA by duly designated approval authorities.

The Keahole facility has secured four Conservation District Use Permits (CDUP) and permit amendments, which regulate the use of lands within the Conservation District including both onshore and offshore lands included in the existing NELHA lease. Following acceptance of the first Statement in 1976, NELH submitted a Conservation District Use Application (CDUA) to the State Board of Land and Natural Resources pursuant to provisions of Chapters 183C HRS. The original CDUP for NELH allowed ocean research and baseline data collection activities within conservation land areas at Keahole Point, North Kona, Hawai‘i, portions of TMKs 7-3-43:3, 4, 5 and adjacent coastal water and submerged lands. These authorizations were for temporary use only. Projects lasting more than one year were to obtain annual variances. The document also conditionally approved later phases of the NELH program.

Authorized actions in CDUP HA-879, approved on February 11, 1977 included: conducting research and data collection related to weather conditions, ocean currents and temperature, solar and wave energy, ocean bottom geology, biofouling effects, biological and corrosion tests, etc. It created a research corridor 1,000' wide by 800' onshore and 1,000' wide by 1 mile offshore as measured from the existing lighthouse and centered on Keahole Point.

With proposed activities and seawater pumping needs identified and discussed in the 1985 Statement, NELH submitted a more comprehensive CDUA in anticipation of expanded OTEC and mariculture research and development (see appendix 2). Approved on July 31, 1986, CDUP HA-1862 allowed the use of approximately 2,940 acres of ocean waters and submerged lands for temporary and permanent ocean research, alternative energy and mariculture research, commercial mariculture, and energy-related activities and facilities. HA-1862 provided approval for immediate construction of 3 pipelines, use of 2 parcels of land for pipeline and utility easements, pump stations and road improvements and maintenance activities.

As noted earlier, anticipated seawater demand for full-development activities at NELH reached a total of 142,000gpm, with recommended disposal via a system of trenches at various locations throughout the leased properties. Rather than the total proposed seawater-pumping rate, the BLNR decided to approve a slightly reduced rate of

126,000gpm, but the Board left open the option for intake of an additional 16,000gpm upon approval of “an acceptable seawater disposal system” (CDUP HA-1862, p. 3, Condition 8, 1986). Other authorized actions include: approval for 15 additional pipelines in the expanded corridor (Condition 9); construction of the beach park facilities (Condition 11); public use of the shoreline area at night (Condition 13), and; expanded requirements for the Cooperative Environmental Monitoring Program (CEMP) to include NELH/HOST anchialine ponds and establishment of long-term sampling to monitor impacts to fish eggs, larvae and juveniles (Conditions 15 and 19). This CDUP also specified that return seawater be warmed to a temperature acceptable to the DLNR (Condition 14), it imposed a number of restrictions on blasting (Conditions 18, 20, and 21), and it required alternative methods of seawater return if the anchialine ponds become adversely affected (Condition 16).

Due to growing awareness of the need for more efficient and capacious seawater delivery, NELHA in early 1994 sought a simple amendment to CDUP HA-1862 to remove the 48” diameter size limit of installed seawater pipelines in the Ocean Research Corridor, and this request was approved on February 11, 1994. The approval recapitulated the existing cap on permitted pumping volume for the facility of 126,000gpm.

Plans to acquire an adjacent parcel for the purpose of expanding available land at NELHA for commercial development led to the completion of the 1992 FSEIS. With the acceptance of that Statement, NELHA again submitted an application to amend CDUP HA-1862 on April 5, 1994 seeking the addition of roughly 350 acres of offshore ocean area and an additional 82.21 acres of land to the area on which research and commercialization activities might be allowed. CDUP HA-1862A was approved by the BLNR on September 23, 1994 and remains in effect today, incorporating all previously approved conditions, and adding the requested additional land and ocean areas (see appendix 2).

The previous section identified surface and deep seawater needs anticipated by OTI to meet the requirements of the 1000-hour test. Preliminary engineering estimates of heat exchanger efficiency and power cycle dynamics in the OTI demonstration facility suggest that the desired 1MWe output of the plant will be achieved with a continuous pumping rate of 60,200gpm of surface and deep seawater. The total volume pumped during the actual test then will comprise 47.8% of the permitted maximum pumping rate provided under CDUP HA-1862A (see appendix 3).

The OTI test facility will be constructed on urban-zoned land designated for industrial use. OTI will exercise due diligence to ensure that the structure meets all design criteria and height limitations specific to the site. All of the needed surface and deep seawater for the 1000-hour test will be supplied using NELHA pipelines and pumping facilities covered under the existing CDUP. Seawater return facilities constructed for both surface and deep seawater that is not distributed to other NELHA tenants will conform to methods assessed and recommended in accepted EIS documents as noted above. No seawater return systems will be constructed on land zoned Conservation, and no actions will be undertaken within the shoreline setback area. Proposed sites for construction of the OTI facility and associated discharge systems do not include any sites identified as having historic significance.

The foregoing discussion highlights analyses of the proposed OTI action at NELHA in the context of statutory and regulatory provisions for environmental compliance under HRS 343 and HRS 183C. Summarizing, we find that development of a 1 MWe (net) OTEC demonstration facility at NELHA conforms to both intended and specifically described actions considered in accepted Statements prepared pursuant to Chapter 343, HRS. We further find that operational parameters of the proposed OTEC facility fall within conditions specified in applicable permits granted to NELHA pursuant to Chapter 183C, HRS for ongoing research activities, and that proposed methods for management of seawater streams conform to recommended procedures incorporated into existing permit structures.

Appendix A-1

Triggers for the Hawai‘i Environmental Protection Act (HRS 343).

A description of the project follows in the context of the 9 triggers discussed in HAR 11-200 and elsewhere.

HRS §343-5(a)(1). Use of state or county lands or the use of state or county funds…

The project is located on public land; however, previous Environmental Impact Statements and Supplemental Environmental Impact Statements have assessed a comprehensive range of actions, disclosed their potential impacts and discussed mitigation measures as appropriate and feasible. To the extent that these actions and impacts are not altered by the present project, the accepted EISs remain valid, and are incorporated into the planning and design of the proposed OTI facility.

Previous EIS documents covering the range of actions proposed by OTI include:
- NELH EIS 1977,
- HOST Park EIS 1985,
- Seawater Disposal Final Supplemental EIS 1987, and
- Land Exchange Final Supplemental EIS 1992.

The proposed project does not utilize any public funding.

HRS §343-5(a)(2). Use of land in the State Conservation District…

The proposed OTEC demonstration facility is located in the Urban District on land zoned for industrial use. Seawater disposal trenches are either in the industrial zone or in a previously approved easement through the conservation district. Pumping volumes are limited to those previously approved under CDUA HA-1862A.

HRS §343-5(a)(3). Use within the Shoreline setback...

None of the proposed project lands are within the shoreline setback.

HRS §343-5(a)(4). Use of any historic site of district...

The proposed project site is not within a recognized historic district or known historic site.

HRS §343-5(a)(5). Use within the Waikiki District…

The site is not within the Waikiki special Design district.

HRS §343-5(a)(6). Requires amendment to the General Plan…

The proposed action is consistent with The County of Hawai‘i General Plan.

HRS §343-5(a)(7). Reclassification of Conservation district Lands…

The proposed action will not seek to reclassify lands within the Conservation District.

HRS §343-5(a)(8). Proposed helicopter facilities…

OTI does not intend to purchase or operate a helicopter.

HRS §343-5(a)(9). Propose any:

(a) *Wastewater facilities…* The proposed action does not treat any water or wastewater.
(b) *Waste-to Energy Facility…* The proposed action does not collect or use any waste for generating energy.
(c) *Landfill…*The proposed action is not a landfill, and will utilize licensed waste management services to properly dispose of any waste generated at the site.
(d) *Oil refinery…* The proposed action is not an oil refinery and will reduce our dependence on those that now exist.
(e) *Power generating facility…* The definition of a power generating facility contained in HRS 343 specifies fossil fuel driven power generators in excess of 5 Megawatts. The proposed action will generate approximately 1 MW at peak performance. The generating unit will be driven by thermal gradients between layers of ocean water. With the exception of lubrication, no fossil fuels will be used.

We will be happy to provide additional information or clarification of this information on request. The proposed action is similar in appearance and operation to current and previous OTEC test platforms including:

- OC-OTEC facility built in 1989;
- The proposed KAD-OTEC facility, and;
- The current Lockheed- Martin platform.

None of the current or previous OTEC demonstrations required additional assessment under HRS 343.

Appendix A-2

Conservation District Use Permit HA-1862A

JOHN WAIHEE
GOVERNOR OF HAWAII

KEITH W. AHUE, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

DEPUTIES
JOHN P. KEPPELER, II
DONA L. HANAIKE

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

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

REF:OCEA:BKW

SEP 29 1994

FILE NO.: HA-1862A
Acceptance Date. 4/5/94
180-Day Exp. Date: 10/2/94
DOC. NO.: 4951

EXHIBIT 7 IS ORIGINAL CDUA HA-1862

RECEIVED
SEP 30 1994
NELHA

Mr. Robert K.U. Kihune, Executive Director
Natural Energy Laboratory of Hawaii Authority
P.O. Box 1749
Kailua-Kona, Hawaii 96745

Dear Mr. Kihune:

Subject: Conservation District Use Application for Ocean Research, Alternative Energy and Mariculture Research, and Commercial Mariculture and Energy Facilities, at Keahole Point, North Kona, Hawaii

We are pleased to inform you that your Conservation District Use Application for use of approximately 350 acres of ocean waters and submerged lands in the vicinity of Keahole Point, Hawaii for temporary and permanent ocean research, alternative energy and mariculture research and commercial mariculture and energy activities and facilities; and for pipeline and utility easements, construction and maintenance of pumps, and other related maintenance activities on and offshore of Keahole Point, Hawaii; use of one parcel of land, TMK: 7-3-09: 23 for the establishment of aquacultural activities and its related facilities and uses was approved on September 23, 1994, subject to the following conditions:

1. The applicant shall comply with all applicable statutes, ordinances, rules and regulations of the Federal, State and County governments, and applicable parts of Section 13-2-21, Administrative Rules, as amended;

2. The applicant, its successors and assigns, shall indemnify and hold the State of Hawaii harmless from and against any loss, liability, claim or demand for property damage, personal injury and death arising out of any act or omission of the applicant, its successors, assigns, officers, employees, contractors and agents under this permit or relating to or connected with the granting of this permit;

3. Since this approval is for use of conservation lands only, the applicant shall obtain appropriate authorization through the Division of Land Management, State Department of Land and Natural Resources for the occupancy of State lands;

4. The applicant shall comply with all applicable Department of Health Administrative Rules;

5. Before proceeding with any work authorized by the Board, the applicant shall submit four (4) copies of the construction plans and specifications to the Chairperson or his authorized representative for approval for consistency with the conditions of the permit and the declarations set forth in the permit application. Three (3) of the copies will be returned to the applicant. Plan approval by the Chairperson does not infer approval required of other agencies. Compliance with Condition 1 remains the responsibility of the applicant;

6. Any work or construction to be done on the land shall be initiated within one (1) year of the approval of such use, and all work and construction must be completed within three (3) years of the approval of such use;

7. The applicant shall notify the Department in writing when construction activity is initiated and when it is completed;

8. That the applicant shall comply with all applicable conditions of Conservation District Permit #HA-1862 and its previous amendments;

9. That precautions shall be taken during development activities to prevent construction materials, petroleum products debris and other potential contaminants from entering the anchialine ponds or nearshore waters;

10. That the applicant shall be required to construct, maintain and replace as required, stiles or similar devices to facilitate crossing over pipelines and structures that may impede or appear to impede lateral access along the shoreline;

11. That a corridor with a buffer along the coastline allowing for coastal lateral access shall be left undeveloped by the applicant for the long-term protection of coastal resources;

12. That in issuing this permit, the Department and Board has relied on the information and data which the permittee has provided in connection with his permit application. If, subsequent to the issuance of this permit, such information and data prove to be false, incomplete or inaccurate, this permit may be modified, suspended or revoked, in whole or in part, and/or the Department may, in addition, institute appropriate legal proceedings;

13. That all representation relative to mitigation set forth in the accepted application for this proposed use are hereby incorporated as conditions of this approval;

14. That failure to comply with any of these conditions shall render this Conservation District Land Use application null and void; and

15. Other terms and conditions as prescribed by the Chairperson.

Please acknowledge receipt of this permit, with the above noted conditions, within thirty (30) days, in the space provided below. Please sign two copies. Retain one and return the other within thirty (30) days.

Should you have any questions on any of these conditions, please feel free to contact our Office of Conservation and Environmental Affairs staff at 587-0377.

Very truly yours,

KEITH W. AHUE

Receipt acknowledged

Applicant's Signature

Date 3 OCT 94

cc: Hawaii Board Member
Hawaii Land Agent
Hawaii County Planning Department
Hawaii DP&R, DWS
DOH/OHA/OSP/DOT

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

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

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES

EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
AQUACULTURE DEVELOPMENT PROGRAM
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CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

RECEIVED
JUL 01 1986
NELH

JUL 31 1986

FILE NO.: HA-1/24/86-1862
180-Day Exp. Date: 7/23/86
DOCUMENT NO.: 1414

Natural Energy Laboratory of Hawaii (NELH)
High Technology Development Corporation (HTDC)
P.O. Box 2359
Honolulu, Hawaii 96804

Gentlemen:

Conservation District Use Application for Use of Approximately 2940 Acres of Ocean Waters and Submerged Lands in the Vicinity of Keahole Point, Hawaii for Temporary and Permanent Ocean Research, Alternative Energy and Mariculture Research and Commercial Mariculture and Energy Activities and Facilities; Approval for Immediate Construction and Development of Three Ocean Water Pipelines; Use of Portions of Two Parcels of Land for Pipeline and Utility Easements, Pump Stations and Road Improvement and Maintenance Activities; and Consideration and Approval of a Process for "Expedient Approval" of Future Projects on and Offshore of Keahole Point, Hawaii

We are pleased to inform you that your Conservation District Use Application for Use of Approximately 2940 Acres of Ocean Waters and Submerged Lands in the Vicinity of Keahole Point, Hawaii for Temporary and Permanent Ocean Research, Alternative Energy and Marciculture Research and Commercial Mariculture and Energy Activities and Facilities; Immediate Construction and Development of Three Ocean Water Pipelines and Use of Portions of Two Parcels of Land for Pipeline and Utility Easements, Pump Stations and Road Improvement and Maintenance Activities on and Offshore of Keahole Point, Hawaii was approved on July 11, 1986, subject to the following conditions:

1. The applicant shall comply with all applicable statutes, ordinances, rules and regulations of the Federal, State and County governments, and applicable parts of Section 13-2-21, Administrative Rules, as amended;

2. The applicant, its successors and assigns, shall indemnify and hold the State of Hawaii harmless from and against any loss, liability, claim or demand for property damage, personal injury and death arising out of any act or omission of the applicant, its successors, assigns, officers, employees, contractors and agents under this permit or relating to or connected with the granting of this permit;

3. Since this approval is for use of conservation lands only, the applicant shall obtain appropriate authorization through the Division of Land Management, State Department of Land and Natural Resources for the occupancy of State lands;

4. If any unanticipated sites or remains of historic or prehistoric interest (such as shell, bone or charcoal deposits, human burials, rock or coral alignments, paving, or walls) are encountered during construction, the applicant shall stop work and contact the Historic Preservation Office at 548-7460 or 548-6408 immediately;

5. The applicant shall comply with all applicable Public Health Regulations;

6. The construction, alteration, moving, demolition and repair of any building or other improvement on lands within the Conservation District shall be subject to the building and grading codes of the respective counties in which the lands are located; provided that prior to the commencement of any construction, alteration, or repair of any building or other improvement, four (4) copies each of the final location map, plans, and specifications shall be submitted to the Chairperson, or his authorized representative, for approval of which three (3) copies will be returned;

7. Other terms and conditions as prescribed by the Chairperson;

8. That the applicant's maximum intake of seawater be limited to 126,000 gpm until such time as an acceptable seawater disposal system for the remaining ±16,000 gpm of seawater is approved;

9. That this approval allow for the installation of fifteen (15) additional pipelines, within the established corridor, with a maximum size of 48";

10. That prior to construction of each pipeline, the applicant obtain approval from this Department on the actual alignment;

11. That within one year from the start of actual construction on the HOST/NELH projects, the applicant start construction on the permanent public recreational facilities proposed within their project site;

12. That the final Conceptual Shoreline Management Plan be approved by this Department prior to implementation;

13. That the provision for public night use of the shoreline area be implemented by November 1987;

14. The return seawater be warmed to ambient water temperature acceptable to this Department;

15. The monitoring program include anchialine ponds at the NELH/HOST Park site. The monitoring program should describe the existing conditions at these sites in terms of water quality and endemic aquatic fauna, and the program should last a minimum of 10 years. This program should be coordinated with this Department and the appropriate Federal, State and County Agencies;

16. Should the long-term studies indicate that the anchialine ponds at the NELH/HOST Park are being adversely affected by the seawater plume, the NELH and HOST Park shall take the necessary mitigative measures to alleviate these effects which may include the installation of an ocean outfall for the disposal of return seawater;

17. Trenching spoils shall not be stockpiled in the water. Trenching spoils not used for backfill will be removed from the water and stored on land at an acceptable site;

18. If blasting is required for the trenching of the pipelines, details must be thoroughly coordinated with the National Marine Fisheries Service and the Division of Aquatic Resources;

19. A long-term monitoring/sampling program to determine the impacts of impingement and entrainment on fish eggs, larvae, and juveniles be conducted. These studies should be coordinated with the National Marine Fisheries Service, the Division of Aquatic Resources, and the U.S. Fish and Wildlife Service;

20. If blasting is necessary it should occur only between May and November to limit impacts adverse to the Hawaiian Humpback Whale, and a pre-blast visual inspection should be made for marine mammals and sea turtles, withholding detonation until these protected species are clear of danger;

21. If blasting is required, shaped explosive charges should be used to the extent feasible and limited to 100 lbs. per microsecond delay or less or as approved by the Department to minimize fish kills and excessive destruction of other marine organisms. Additional mitigation measures such as sandbagging the charges might also be employed; and

22. Precautions should be taken during onshore activities to keep construction materials, petroleum products and debris from blowing, falling, flowing or leaching excessively into the marine environment.

Please acknowledge receipt of this permit with the above noted conditions in the space provided below. Please sign two copies. Retain one and return the other.

Should you have questions on any of these conditions, please feel free to contact our Office of Conservation and Environmental Affairs staff at 548-7837.

Very truly yours,

SUSUMU ONO, Chairperson
Board of Land and Natural Resources

Receipt acknowledged:

Applicant's Signature

cc: Hawaii County Board Member
Hawaii Land Agent
Hawaii County Planning Dept.
Hawaii County Dept. of Public Works
Hawaii County Dept. of Parks and Recreation
DOH/OEQC/EC/DPED/OHA/DOT-Airports
U.S. Coast Guard
U.S. Corps of Engineers
National Marine Fisheries Service
U.S. Fish & Wildlife Service
The Traverse Group, Inc.
P.O. Box 27506
Honolulu, Hawaii 96827

Appendix A-3

Seawater pumping calculations for OTI OTEC 1000-hour test

Maximum Permitted Annual Flow Rate:

126,000gpm x 60 x 24 x 365 = 6.62 E10 gallons per year
60,200gpm / 126,000gpm x 100 = 47.8 (percent of maximum permitted SW pumping)

1000-hour test at 60,200gpm combined SSW and DSW flow rate:

60,200gpm x 60 m = 3.61 E06 gallons per hour

60,200gpm x 60 m x 24 = 8.67 E07 gallons per day

60,200gpm x 60 m x 1000 = 3.61 E09 gallons total pumped during 1000-hour test

3.61 E09 / 6.62 E10 x 100 = 5.5 (percent maximum permitted annual SW pumping)

Appendix B

Analysis of Seawater Return Systems

Analysis of Proposed OTEC Seawater Return Systems;
OTI 1 MWe OTEC Demonstration, NELHA, Keahole, Hawai‘i

1/21/12

Introduction

This White Paper discusses environmental management factors contingent on the problem of discharging large volumes of deep and surface seawater used in the proposed OTEC demonstration facility at NELHA. The overall intent of the report is to better understand environmental concerns that must be addressed in any discharge design and to highlight subject areas in which our existing understanding is imperfect. Some effort will go towards distinguishing between knowledge deficiencies that are readily resolvable and those for which only empirical results can produce reliable answers. Ultimately, the context provided by this discussion should promote a better ability to appreciate advantages and disadvantages of discharge variants, thereby improving the quality of decision-making.

Structurally, the analysis is divided into 5 sections, starting with general descriptions of the amount and quality of effluent water from proposed OTI actions at NELHA. Section 2 describes environmental characteristics of coastal waters near NELHA, including a summary of regulatory policies applicable to these waters and the relationship between ocean management policies and seawater return options. The third section examines characteristics of the onshore environment, with particular attention to subsurface hydrogeology, including a consideration of terrestrial management policies and their application to the proposed OTI OTEC demonstration project. Section 4 recapitulates and summarizes physical determinants of effluent management, and the final section sets out the design objectives for effluent return, along with individual descriptions of discharge options and their advantages and disadvantages. Each section begins with an abstract.

Section 1. Description of the Proposed Discharge

Abstract
Single-pass, contact thermal exchange seawater will energize the proposed OTEC demonstration facility. Full operational capacity will require 27,000gpm of deep seawater and 40,800gpm of surface seawater for a total pumped volume of 67,800gpm. Five methods of seawater return to the environment have been considered in the course of prior environmental review at NELHA, of which two are in current use. At present, NELHA uses up to roughly 14,000gpm for ongoing research and commercial activities. At full OTEC development and including seawater utilization projections of other NELHA tenants, OTI anticipates total seawater pumping at NELHA may amount to as much as 99,300gpm, well within the permitted NELHA seawater utilization limit of 126,000gpm.

OTEC International, LLC (OTI) intends to construct a 1MWe OTEC demonstration and testing facility at a site within the Natural Energy Laboratory of Hawai‘i Authority (NELHA). The shore-based OTEC plant that OTI will install at NELHA will be comprised of the systems, subsystems and components that will exist on its floating plants and configured to simulate the fluid flow through and emulate the operation of such plants.

To accomplish performance objectives, the demonstration facility requires withdrawal of 27,000gpm of cold deep-sea water and 40,800gpm of warm surface water from adjacent ocean resources. As planned, both surface seawater (SSW) and deep-sea water (DSW) will be supplied to the plant through existing NELHA facilities.

Warm and cold seawater respectively provide a thermal energy source and sink integral to the OTEC process. Heat exchangers transfer energy in a one-pass, non-contact process that is designed to produce effluent water with no process contamination and at temperatures about 10°F warmer and colder than the cold and warm source seawater streams. Water utilized in the OTEC heat exchangers will either be distributed to other NELHA tenants for subsequent research or commercial applications or returned to the environment. Water directed to ancillary applications must conform to the resource needs of the downstream applications in quantity and quality. Seawater returned to the environment must conform to both NELHA facility disposal guidelines and water quality standards established in State regulations.

A number of detailed studies have examined alternative methods of seawater return at NELHA (e.g., Towill, 1976; Traverse Group, 1985; MCM Planning, 1987; GK & Assoc., 1992). The range of considered seawater disposal options includes one offshore alternative, construction of a discharge pipe to deep water, and five variants of onshore seawater return:

1. Direct disposal through a canal to the shoreline;

2. Disposal into an open trench and percolation to the water table;
3. Disposal through perforated pipe into a closed trench;
4. A hybrid of perforated pipe and deep wells, and;
5. Disposal through a manifold into a deep well field.

Existing regulatory constraints preclude direct disposal of OTEC effluent seawater through a direct channel through the shoreline, thereby eliminating discharge method 1 from further consideration. Presently, seawater return at NELHA occurs via a combination of methods 2 and 3, with various facilities, mostly constructed and maintained by individual tenants at their respective sites of operation. Total seawater return flow at this time is variable, ranging up to around 14,000gpm (J. War, pers. comm.).

OTI proposes to develop additional pumping capacity for both SSW and DSW through existing 55" pipes near the southern boundary of the Ocean Research Corridor (see Figure 1). As noted above, projected flows of SSW and DSW will energize the OTEC demonstration facility. Added to existing demand at NELHA, the OTEC flows will raise the total seawater pumping capacity at NELHA to about 99,300gpm. Pursuant to terms of existing permit conditions (CDUP 1862A), seawater pumping in excess of 126,000gpm would require implementation of an "acceptable disposal system".

Figure 1 – NELHA Offshore Intakes and Distribution Pipelines

Section 2. Environmental Quality of Keahole Point Coastal Waters

Abstract
Extensive environmental research and review has led to a broad understanding of the physical and biological oceanography of waters adjacent to NELHA. Prior studies complemented by ongoing monitoring conducted through the CEMP and additional coastal work at a site adjacent to NELHA provide insight into near-shore mixing and dispersion of high-nutrient low salinity groundwater that flows into the ocean. Nutrients associated with groundwater are elevated close to shore, while temperature and salinity are depressed. However, natural mixing returns all values to near ambient oceanic levels within about 50m of the shoreline in an unaltered coastal environment. Coastal ocean water quality is regulated through water quality standards (WQS) implemented and enforced by the Hawai'i Department of Health. The DOH establishes both water quality criteria and protocols for sampling and evaluation of coastal waters. To allow for natural seepage of high-nutrient groundwater, two methods of assessing sample compliance with established standards reflect differing analytic approaches that apply under normal and low-salinity coastal regions. Since standards for groundwater-influenced coastal waters are much less stringent, the choice of a deep seawater disposal method that preserves the natural brackish basal lens flow would lessen the chance of a regulatory violation due to OTEC effluent discharge. In addition, protection of the coastal ecosystem and compliance with WQS is favored by DSW discharge methods that provide for effluent entry to the ocean through seepage into deeper, offshore ocean bottom areas.

The coastal waters off Keahole Point are well characterized. The following description of general conditions in waters adjacent to NELHA is taken from the 1985 Final Environmental Impact Statement (FEIS) (Traverse Group, 1985):

Water depth increases rapidly with distance from the shore off Keahole Point, with depths of 2,000 feet within a mile of the coast. Between the 500 and 2,500 feet depths, the bottom slope is approximately 30 degrees. Shallower than 500 feet, the slope angle decreases. Passages of white sand up to 30 feet wide occur between basalt outcrops running perpendicular to the shoreline. Lava from the 1801 Hualalai flow is present in beds up to 20 feet thick, down to depths of 420 feet.

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 ¾ to 1 knot. Tidal currents may be obscured for extended periods by large-scale eddies propagated from the Alenuihaha Channel. An eddy off leeward Hawai'i persisted and was tracked for 2 months (Lobel and Robinson, 1985).

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).

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 Hawai'i over the past 20-year period was 25.5 feet (Towill, 1976).

Sea surface temperatures inn Hawai'i vary relatively little annually or diurnally, ranging between 23 – 28.5 degrees C (Gunderson, 1974). The wind-mixed surface layer extends 50-100 meters deep; the bottom of the thermocline may extend to 150 meters.

Scalar (non-directional) irradiance in the photosynthetically active wavelengths (400-700nm) has been measured through the water column off shore 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 near-shore 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).

PH is maximal at the surface of the ocean 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 minimum (1.0 ml/l) occurs between 450 and 900 meters (Noda, 1980).

Three distinct nutrient layers have been identified in offshore depth profiles (Noda, 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 near-shore salinities are lowest, nutrients are highest, clearly reflecting shoreline seepage of nutrient-rich, brackish basal water.

The baseline studies underlying the foregoing description have been followed by ongoing monitoring of ocean water quality through the Comprehensive Environmental Monitoring Program (CEMP) implemented at NELHA in conformance with provisions of regulatory permits. The CEMP data offer long-term records of conditions in both coastal waters and in water from sample wells scattered throughout NELHA. All of these data are helpful both as indicators of regional water quality and as avenues for detection of incipient water quality problems that may develop as a result of activities at NELHA.

Although monitoring of water quality has been performed regularly through the CEMP at NELHA, the design of the monitoring program does not lend itself to a definitive description of near-shore mixing and dispersion regimes along the Keahole coastline. Near-shore sampling since 2007 has conformed to Department of Health regulatory guidelines (*ref.* ***§11-54-6(d)(1)(iii)*** *HAR*), and the requisite spacing of sample station locations is too broad to develop a well-defined gradient in parameters as a function of distance from the shoreline.

A more comprehensive data set exists for the coastal region immediately to the south of the NELHA site, where Dollar (2008) has sampled three transects over a period of 14 years, most recently in 2006 (Figure 2). The purpose of this study was "to determine the contribution of groundwater to the marine environments" and "to evaluate the effects that this input has on water quality". The work was performed prior to any alteration or development on coastal land adjacent to the shoreline, and thus it offers a long-term, comprehensive assessment of natural conditions in an area immediately adjacent to the coastline along which OTEC-related discharges may occur. Estimated groundwater flow into the ocean in this area is 3mgd per mile (Oki et al., 1999).

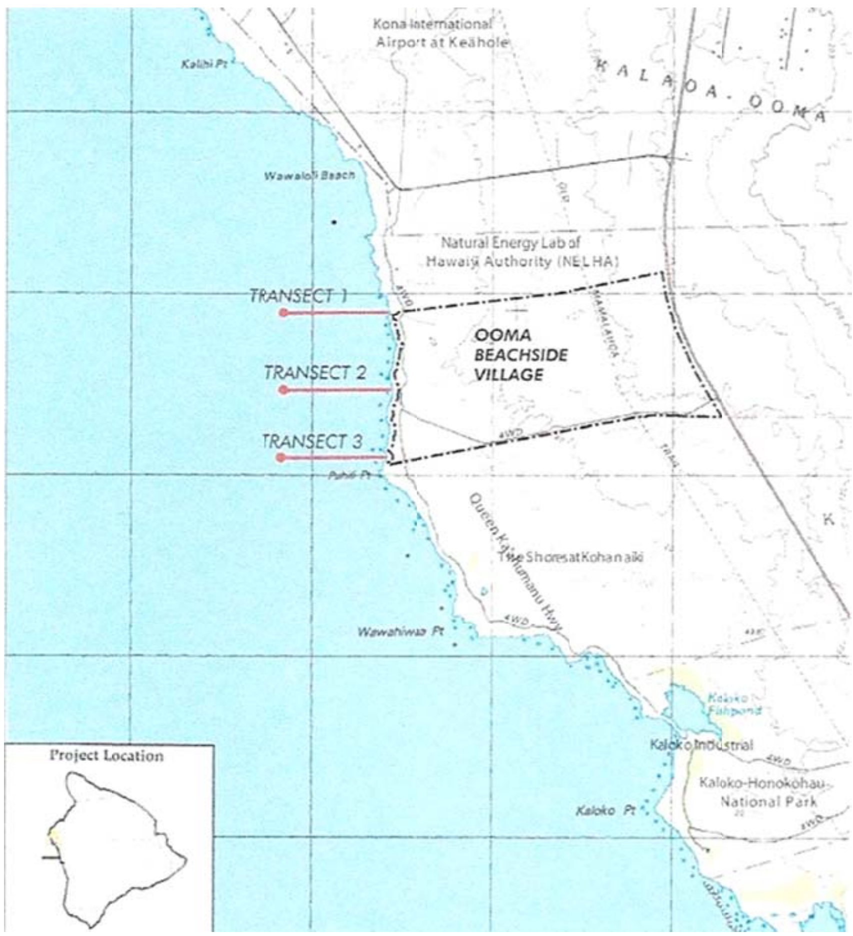

Figure 2. Map of North Kona showing location of O'oma Beachside Village and three water quality monitoring transects located offshore of the property. The Natural Energy Laboratory of Hawai'i is to the north of the O'oma site (Dollar, 2008).

Expanding on the CEMP sampling design, this methodology offers insight into near-shore mixing and dispersion of terrigenous groundwater inputs in the coastal region. Figures 3 and 4 show plots of concentrations of both nutrients and physical parameters as a function of distance from shore. For dissolved nutrients most closely associated with groundwater input (Silicate, Nitrate, and Total Nitrogen), concentrations are distinctly elevated within 30m of the shoreline, falling off to stable oceanic levels by about 50m offshore. Chlorophyll a similarly becomes elevated close to shore, and declines as distance from the coast increases. Salinity and temperature, not surprisingly, show an inverse trend, being depressed by groundwater input close to shore and rising to equilibrium with the ocean at 50m. In contrast, parameters that are not components of groundwater (Ammonium, Dissolved Organic Nitrogen and Phosphorus) show no consistent pattern, but vary widely along the horizontal axes.

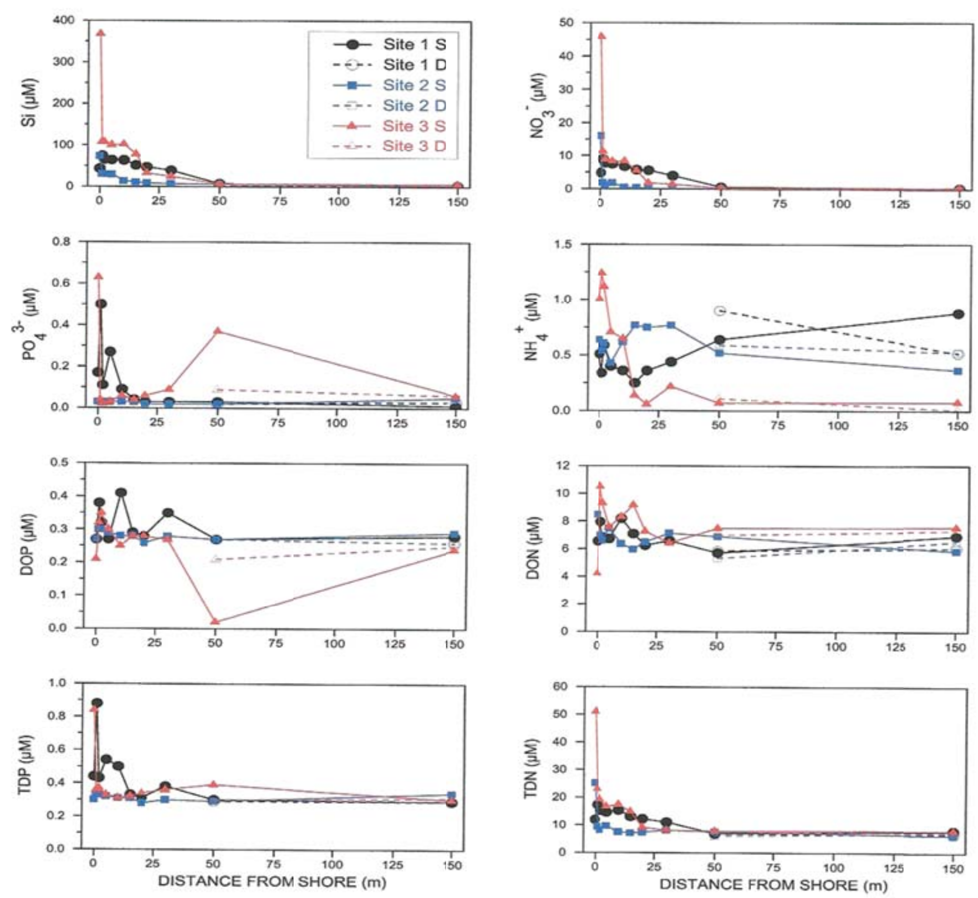

Figure 3. Plots of dissolved nutrients in surface (S) and deep (D) samples collected along transects offshore of the O‘oma Beachside Village project on November 3, 2006 as a function of distance from the shoreline (Dollar, 2008).

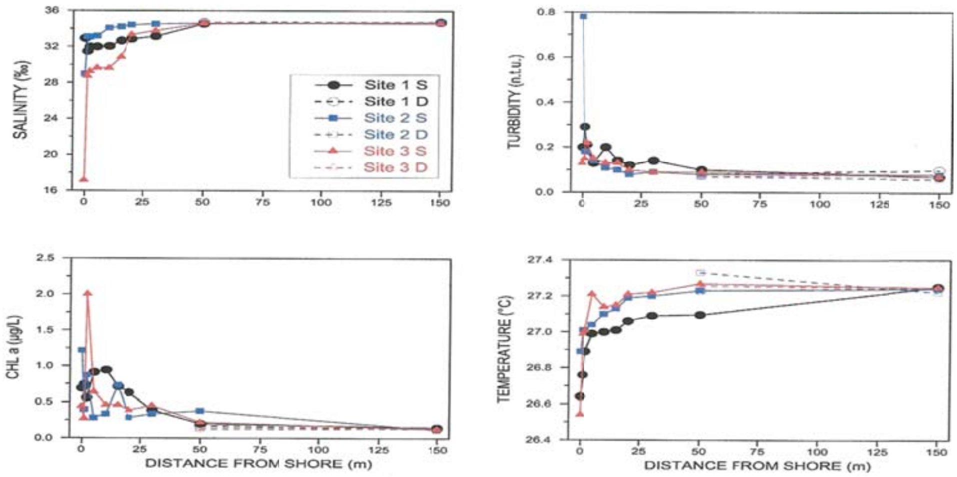

Figure 4. Plots of water chemistry constituents in surface (S) and deep (D) samples collected along three transects of the O‘oma Beachside Village project on November 3, 2006 as a function of distance from shoreline (Dollar, 2008).

Viewing these plots, the evident conclusion is that mixing and dispersion effectively resolve perturbations of seawater components due to groundwater input at the shoreline, and virtually all of the parameters are in equilibrium with more oceanic levels by a distance of 50m offshore. Although there was some variability between transects, the prevailing trends held consistently for those parameters most closely associated with groundwater. Analyses of samples along identical transects collected during 1991-1992 gave comparable results (Dollar, 2008), indicating an absence of any long-term changes in natural coastal water quality.

Section 2.1. Policy Framework Governing Coastal Waters

Ultimate authority for regulation of effluent disposal into the environment rests with the Federal government, and the principal framework for that regulation is the Federal Water Pollution Control Act, more commonly known as the Clean Water Act (CWA) [**33 U.S.C. §1251 et seq. (1972)**]. However, the CWA delegates implementation of its provisions to the States, and the immediate regulatory authority in Hawai‘i is established under Chapter 342D, Hawai‘i Revised Statutes (HRS). HRS 342D designates the State Department of Health (DOH) as the implementing authority, and its substantive elements are implemented pursuant to DOH regulations found in Hawai‘i Administrative Rules **(HAR) Title 11 Chapter 54.**

In general, regulatory limits relevant to OTEC disposal at NELHA are imposed in reference to Water Quality Standards (WQS) established under **§11-54-6(d)** HAR. Coastal waters in the region surrounding most of the Big Island are designated Class AA and extend to the limit of “open coastal waters”, which are defined in HAR **§11-54-6(b)(1)** as, “marine waters bounded by the 183-meter or 600-foot (100-fathom) depth contour and the shoreline.” The region offshore of Keahole Point is more narrowly defined in **§11-54-6(d)(1)** to include "all areas from the shoreline at mean lower low water to a distance 1000 m seaward." Thus, the extent of Class AA waters off of NELHA is determined by the absolute distance from the shoreline, rather than the 100-fathom depth contour. In practice, this reduces the distance to Class A waters somewhat in the Keahole Point region.

Section **11-54-6(d)(1)(i)** establishes water quality criteria for waters having a salinity greater than 32.00 parts per thousand (ppt), including a table of geometric mean criteria values that define the acceptable concentrations of regulated parameters (Total Dissolved Nitrogen, Ammonia Nitrogen, Nitrate + Nitrite, Total Dissolved Phosphorus, Phosphate, Chlorophyll a, and Turbidity. Limits are defined for each parameter as acceptable geometric mean concentrations or units.

A different method, defined in **§11-54-6(d)(1)(ii)**, establishes water quality criteria for regions where near-shore marine waters having a salinity *less than or equal to* 32.00 ppt. In these waters, nutrient parameters (with the exception of ammonia nitrogen) are defined in relation to salinity, based on the linear least squares regression:

$$Y = MX + B$$

where:
Y = parameter concentration in μg/l,
X = salinity in ppt,
M = regression coefficient or slope and,
B = the Y intercept.

For each nutrient parameter, the absolute value of the upper 95% confidence interval for the calculated sample regression coefficient must not exceed given values.

Section **11-54-6(d)(1)(iii)** provides an explicit sampling design for collecting water samples to be employed in the determination of measured water quality, involving transects established from the shoreline sampling location. Samples collected at specified distances from shore, within one meter from the surface, are to be filtered and analyzed following standard seawater chemistry protocols, and replicate samples must be taken not less than three times over a period not to exceed 14 days. The geometric means of sample measurements from corresponding offshore stations are to be used for regression calculations.

Other regulated parameters include pH (no more than 0.5 units from a value of 8.1, unless depressed by groundwater flow); dissolved oxygen (not less than 75% saturation, corrected for temperature); temperature (no variance greater than 1°C from ambient conditions), and; salinity (no more than 10% variance from natural or seasonal changes, taking hydrologic input into consideration).

The intent of the modified water quality criteria as applied to Keahole Point coastal waters is to recognize and accommodate the natural condition of high rates of groundwater entry at the coastline. By using a hydrographic mixing model regression to establish a baseline, naturally occurring high concentrations of dissolved nitrate and phosphate theoretically would not lead to violations of established standards in the absence of anthropogenic influences. In practice, many researchers have noted that the criteria as implemented are not fully effective, and excessively high nutrient levels are measured even in regions where natural conditions prevail (Olsen, 2010; Dollar, 2008; Traverse Group, 1985; Towill, 1982; WRRC, 1980).

Section 2.2. Implications of Ocean Management Policies to the Proposed Action

As established under DOH regulations, Class AA water standards in the region of NELHA apply to a distance of 1000m from the shoreline. For near-shore monitoring, sampling protocols specified in the regulations confine collection of water quality samples to sites located 1, 10, 50, 100, and 500 meters from the shoreline sampling location and within one meter of the air/water interface. Different protocols apply to point-source outfalls and other waste discharge structures, but routine monitoring for regulatory compliance of onshore discharges of OTEC effluent will fall under the provisions of **§11-54-6(d)** HAR as noted above.

Groundwater entry along the Kona coast contributes a consistent signal of high nutrient, low salinity source water to shoreline communities. The transects established and monitored by Dollar (2008) (Figures1-3) offer clear evidence of both groundwater input adjacent to an undeveloped region and rapid natural mixing and dispersion of introduced physical and chemical signals within a short distance from the shoreline. Additional studies (Dollar and Atkinson, 1992) have demonstrated the influence of coastal morphology on nutrient flux and ecosystem response, leading to an understanding of the greater mixing and dispersion potential of open coastal as opposed to embayment systems. The high-energy environment in the region of Keahole Point noted in the earlier discussion of offshore current and eddy systems, contributes to a very dynamic region with characteristically low ocean water residence times.

It is evident from the sampling design that the monitoring regime established under the DOH regulations has a distinct near-shore emphasis. Pragmatically, this reflects the tendency for human impacts to the marine realm to be most concentrated at the shoreline, but it also recognizes the higher sensitivity of shoreline and intertidal ecosystems. Various stresses are manifest at the land-sea interface, including significant excursions of salinity and temperature, aerial exposure, physical forces and abrasion in turbulent conditions, and access by coastal predators. In designing standards to calibrate and measure quality that meets the statutory goal of "water quality which provides for the protection and propagation of fish, shellfish and wildlife" and for the maintenance of "balanced indigenous populations" (*ref*. **33 U.S.C. 1251 *et seq*.**), the DOH chose an analytic model, described previously, that appears successful in most instances.

Dollar reported results of water quality samples from the O'oma transects in tabular form (Table 1), with values that exceeded the geometric mean water quality criteria shaded blue. Clearly, the high frequency of exceedances underscores the problem created by groundwater seepage at the coastline. However, once he applied the DOH least squares regression procedure, only nitrate measurements in one of the three transects exceeded the upper 95% confidence limit standard (Table 2). Thus, although not perfect, the method did accommodate much of the natural nutrient variability that exists in this region.

Close examination of Dollar's findings in the light of the nominal DOH sampling design reveals some interesting observations. Plots of concentration against distance from the shoreline reveal that most of the change in concentration occurs within a very short distance from shore. Over the first 10 meters, most of the nutrient signals show a significant decline, and by 50 meters out, most of the conservative parameters (temperature, salinity, silica and nitrate) are at oceanic levels. Dollar achieves substantial resolution of the mixing process because his experimental design goes far beyond that proposed by DOH. Over the initial 50 meters from shore, Dollar collects nine samples, where DOH only calls for 3. It's not at all clear that a reliable regression slope will emerge from sparse samples taken in what appears to be a highly variable system.

TRANSECT SITE	STA. NO.	DFS (m)	PO_4^{3-} (µg/L)	NO_3^- (µg/L)	NH_4^+ (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (NTU)	SAL (ppt)	CHL a (µg/L)	TEMP (deg.C)	O2 (%sat)	pH
OOMA 1	1S	0	5.27	67.76	7.14	1,231	8.37	91.70	13.64	166.60	0.20	32.917	0.69	26.64	106.4	8.25
	2S	1	15.50	125.30	4.76	2,105	11.78	111.30	27.28	241.36	0.29	31.482	0.74	26.76	105.3	8.27
	3S	2	3.41	109.34	8.26	1,850	9.92	96.04	13.33	213.64	0.21	31.952	0.56	26.89	107.0	8.27
	4S	5	8.37	104.72	5.60	1,810	8.37	94.22	16.74	204.54	0.13	31.987	0.91	26.99	107.5	8.27
	5S	10	2.79	94.64	5.04	1,792	12.71	114.80	15.50	214.48	0.20	32.048	0.94	27.00	106.4	8.26
	6S	15	1.24	80.36	3.50	1,451	8.99	99.26	10.23	183.12	0.14	32.655	0.71	27.01	104.3	8.25
	7S	20	0.93	78.26	5.04	1,324	8.68	87.50	9.61	170.80	0.12	32.839	0.63	27.06	104.8	8.24
	8S	30	0.93	56.00	6.16	1,091	10.85	92.40	11.78	154.56	0.14	33.147	0.39	27.09	103.5	8.22
	9S	50	0.93	8.12	8.96	199	8.37	80.08	9.30	97.16	0.10	34.548	0.20	27.10	108.1	8.16
	9D	50	0.62	BDL	12.60	83	8.37	82.04	8.99	94.64	0.08	34.721	0.17	27.23	107.2	8.15
	10S	150	0.31	3.08	12.32	70	8.68	96.46	8.99	111.86	0.07	34.727	0.15	27.25	105.1	8.15
	10D	150	0.93	4.20	7.28	59	8.06	84.00	8.99	95.48	0.10	34.758	0.14	27.24	105.2	8.16
OOMA 2	1S	0	0.93	224.56	8.96	2,061	8.37	118.86	9.30	352.38	0.78	28.977	1.22	26.89	105.2	8.07
	2S	1	0.93	26.88	7.56	861	9.30	97.86	10.23	132.30	0.18	33.123	0.40	27.01	105.8	8.26
	3S	2	0.93	15.12	8.54	854	9.30	92.82	10.23	116.48	0.18	33.064	0.87	27.01	104.6	8.33
	4S	5	0.93	25.48	6.02	858	8.99	104.86	9.92	136.36	0.14	33.205	0.28	27.04	106.3	8.24
	5S	10	0.93	7.56	8.68	401	8.68	89.18	9.61	105.42	0.11	34.081	0.34	27.10	104.5	8.23
	6S	15	0.93	5.74	10.78	325	8.68	83.58	9.61	100.10	0.10	34.233	0.73	27.13	105.5	8.22
	7S	20	0.62	2.52	10.50	249	8.06	91.00	8.68	104.02	0.08	34.408	0.28	27.19	106.4	8.21
	8S	30	0.62	2.94	10.78	205	8.68	99.96	9.30	113.68	0.09	34.521	0.34	27.20	101.2	8.18
	9S	50	0.62	2.66	7.28	168	8.37	96.60	8.99	106.54	0.08	34.605	0.38	27.23	104.5	8.18
	9D	50	0.93	2.10	8.26	82	8.37	74.62	9.30	84.98	0.07	34.720	0.13	27.33	102.2	8.16
	10S	150	1.55	1.96	5.18	74	8.99	81.34	10.54	88.48	0.08	34.729	0.12	27.24	105.5	8.16
	10D	150	0.93	1.68	7.42	55	8.06	90.72	8.99	99.82	0.06	34.781	0.14	27.22	104.3	8.16
OOMA 3	1S	0	19.53	642.18	14.14	10,342	6.51	59.36	26.04	715.68	0.13	17.149	0.44	26.54	107.4	8.18
	2S	1	1.24	159.04	17.36	3,051	9.92	147.56	11.16	323.96	0.15	28.751	0.27	26.99	105.5	8.28
	3S	2	0.62	124.04	15.68	3,024	10.85	130.90	11.47	270.62	0.22	29.265	2.00	27.01	104.8	8.31
	4S	5	0.93	116.90	9.94	2,838	9.30	106.12	10.23	232.96	0.15	29.642	0.64	27.21	106.3	8.32
	5S	10	1.86	118.02	9.10	2,872	7.75	116.62	9.61	243.74	0.13	29.618	0.46	27.14	105.3	8.32
	6S	15	1.24	77.70	1.96	2,220	8.68	128.38	9.92	208.04	0.13	30.853	0.46	27.15	108.4	8.34
	7S	20	1.86	25.76	0.84	926	8.68	101.92	10.54	128.52	0.10	33.332	0.39	27.21	103.1	8.29
	8S	30	2.79	21.00	3.08	698	8.37	90.02	11.16	114.10	0.09	33.777	0.45	27.22	104.3	8.26
	9S	50	11.47	4.76	0.98	185	0.62	105.00	12.09	110.74	0.09	34.595	0.22	27.27	108.8	8.19
	9D	50	2.79	3.08	1.54	119	6.51	98.00	9.30	102.62	0.07	34.720	0.13	27.26	107.6	8.17
	10S	150	1.86	6.30	1.12	189	7.44	105.56	9.30	112.98	0.07	34.575	0.13	27.25	105.8	8.14
	10D	150	1.86	2.10	BDL	106	7.75	102.20	9.61	104.30	0.08	34.700	0.15	27.24	105.7	8.15
W HI WQS (GEO MEAN)			5.00	4.50	2.50				12.50	100.00	0.10	*	0.30	**	***	****
ANCHIALINE POOL			205.84	1,492	8.96	28,170	9.92	582.40	215.76	2,083.20	0.12	15.02	0.27			7.74

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary more than one degree Celsius from ambient conditions.
*** Dissolved oxygen shall not be less than 75% saturation.
****pH shall not deviate more than 0.5 units from a value of 8.1.

Table 1. Water chemistry measurements from ocean samples collected along three transects off the O'oma Beachside Village project site on November 3, 2006. Also shown are the State of Hawai'i Department of Health (DOH) area-specific geometric mean criteria for the Kona coast of the Island of Hawai'i. Shaded and boxed values exceed geometric mean criteria for waters and salinity greater than 32 ppt. Red line separates samples with salinities less than 32 ppt.

NUTRIENT	DOH	TRANSECT 1			TRANSECT 2			TRANSECT 3		
	SLOPE	SLOPE	LOWER CI	UPPER CI	SLOPE	LOWER CI	UPPER CI	SLOPE	LOWER CI	UPPER CI
NO_3^-	-31.92	-37.48	-40.41	<u>-34.55</u>	-38.67	-47.06	-30.28	-36.31	-41.50	-31.12
TDN	-40.35	-41.64	-47.58	-35.70	-43.86	-53.11	-34.62	-35.25	-38.43	-32.06
PO_4^{3-}	-3.22	-2.87	-5.58	-0.16	-0.01	-0.14	0.12	-0.77	-1.54	-0.01
TDP	-2.86	-3.63	-6.50	-0.76	0.00	-0.28	0.29	-0.85	-1.23	-0.46

Table 2. Slopes of linear regressions of nutrient concentrations as functions of salinity for surface samples on three transects offshore of O'oma Beachside Village. Also shown are DOH compliance slopes. Underlined values indicate absolute value of upper confidence limit exceeding DOH compliance slope.

As noted above, applying the DOH regression model to Dollar's data produces one false nitrate violation in a natural system; the chances are good that the higher variability inherent in the sparser DOH statistical universe will lead to larger 95% confidence intervals, so one would expect a greater range for regression coefficients. In other words, for purposes of compliance with WQS it may be an advantage to take fewer samples in a highly variable system.

Another implication of the DOH WQS compliance system underscores the importance of avoiding displacement of the groundwater lens. The regression coefficient model applies to water in which salinity values are less than 32.00 ppt, i.e., influenced by an influx of brackish groundwater. We earlier noted the high frequency of standards violations in nutrient and other parameter levels measured against the geometric mean (GM) criteria established by DOH for Kona coast Class AA water (see Table 1). However, because low salinity measurements were common near the shoreline, the regression model applied, rather than the GM model. By the latter standards, only a single violation was noted. By implication, if a method of OTEC effluent discharge is employed that results in displacement of the groundwater flow at the coastline, salinities will not fall below 32 ppt, resulting in less permissive standards being applied.

We further note that the DOH standards require all samples to be taken within 1 meter of the surface. Particularly as OTEC effluents follow deeper substrata to enter the ocean further offshore, initial dilution and turbulent mixing with overlying ocean waters will attenuate nutrient signals and prevent bio-stimulation and ecosystem perturbation. Thus, sampling at the more offshore stations (100 and 500 meters from the coast) will be unlikely to reflect the denser, colder layer of seepage from the ocean bottom.

Having considered both the structure and the process of sampling for compliance with prevailing WQS and further taking into account initial dilution, advection and dispersion in coastal waters more removed from the immediate shoreline, it is evident that in addition to posing less risk of harm to the ecosystem, entry of OTEC effluent through steady seepage into deeper waters further offshore offers significant compliance advantages.

Section 3. Environmental Characteristics of the Terrestrial Discharge Region

Abstract

Subsurface basalts in the Keahole region are highly permeable, with an average hydraulic conductivity of ~5,000ft/day. Variable formation composition leads to considerable local departures in permeability from the regional average value. Various hydrologic studies indicate a moderate groundwater flow with high-nutrient, low temperature water entering coastal waters at an average rate of 3mgd/mile. Deep ocean water circulation inland at depth exerts considerable influence on basal groundwater through an unknown mechanism, contributing to low temperatures in the basal lens. OTI is mindful of various regulatory frameworks applicable to effluent discharges onshore

and is structuring its approach to operational design to comprehensively comply with all permit and policy provisions. Extensive modeling of NELHA seawater return discharge into surface trenches and deep injection wells provides some insight into regional discharge plume behavior, but site-specific data collection will be required for seawater return systems engineering. Plume trajectories dictate the extent and rate of effluent entry into coastal waters, and different discharge designs may be engineered to achieve a suitable distribution of the SSW and DSW effluents.

At a regional scale, the terrestrial setting in the vicinity of Keahole Point is well defined, primarily consisting of geologically recent, primitive basalts of the Hualalai volcanic series (Dames and Moore, 1985; 1986). Olivine basalts of this series are poorly layered and heterogeneous, comprised of a‘a, clinker and pahoehoe, with individual units extending laterally no more than several hundred feet and vertically less that 100 feet. Average flow thickness is about 10 feet, and in the region of NELHA, there are no known vertical intrusions. The lavas are poorly weathered, and surface flows are transected by extensive and irregular vertical fractures. Flank inclination near the coastline is less than 5 degrees, and lava tubes are common, some with collapsed surface openings and others at subsurface depths. These conditions are known to be favorable for highly permeable aquifers, but both lateral and vertical porosity varies at a local scale.

A thin Ghyben-Herzberg lens of brackish basal groundwater with a thickness of less than 125 feet floats on the seawater that permeates subsurface strata. From the coastal region to a distance of about three miles inland, the groundwater is non-potable, discharging in a narrow band within the coastal intertidal zone. Estimates of hydraulic conductivity in the area range from 2,000 to 10,000 feet per day, with an average value of 5,000 ft/day, and effective porosity of the conductive substrata is estimated to be 0.1 (Mink, 1992). Water samples from coastal and inland wells in the region indicate a feeble gradient of 0.8ft. / 5,000ft.

Much of the information on regional geohydrology is derived from monitoring well samples in the area, including the 34 wells on the NELHA property. In addition to data available through the CEMP at NELHA, comprehensive data also have been reported from sites immediately to the south of the prospective OTEC site. Nance (2008) summarizes his findings as follows:

Salinity, temperature, water level and water quality data from basal wells in the area all indicate that the flow rate is low compared to areas north of Keahole Point and south of Kailua Bay, that salt water circulation at depth exerts considerable influence on temperature in the basal lens, and that formation permeabilities are exceptionally high.

Measured tidal variation in wells 450 feet and 5,500 feet from the shoreline provides insight into the high permeability of the coastal formations. Both wells reflect considerable tidal influence, with the more coastal well showing a water level variation of about 75% of the ocean, and lagging it in time by about a half hour. Water levels in the more inland well vary by 45% of oceanic levels, and the time lag at a mile inland is about 1.4 hours (see Figure 5).

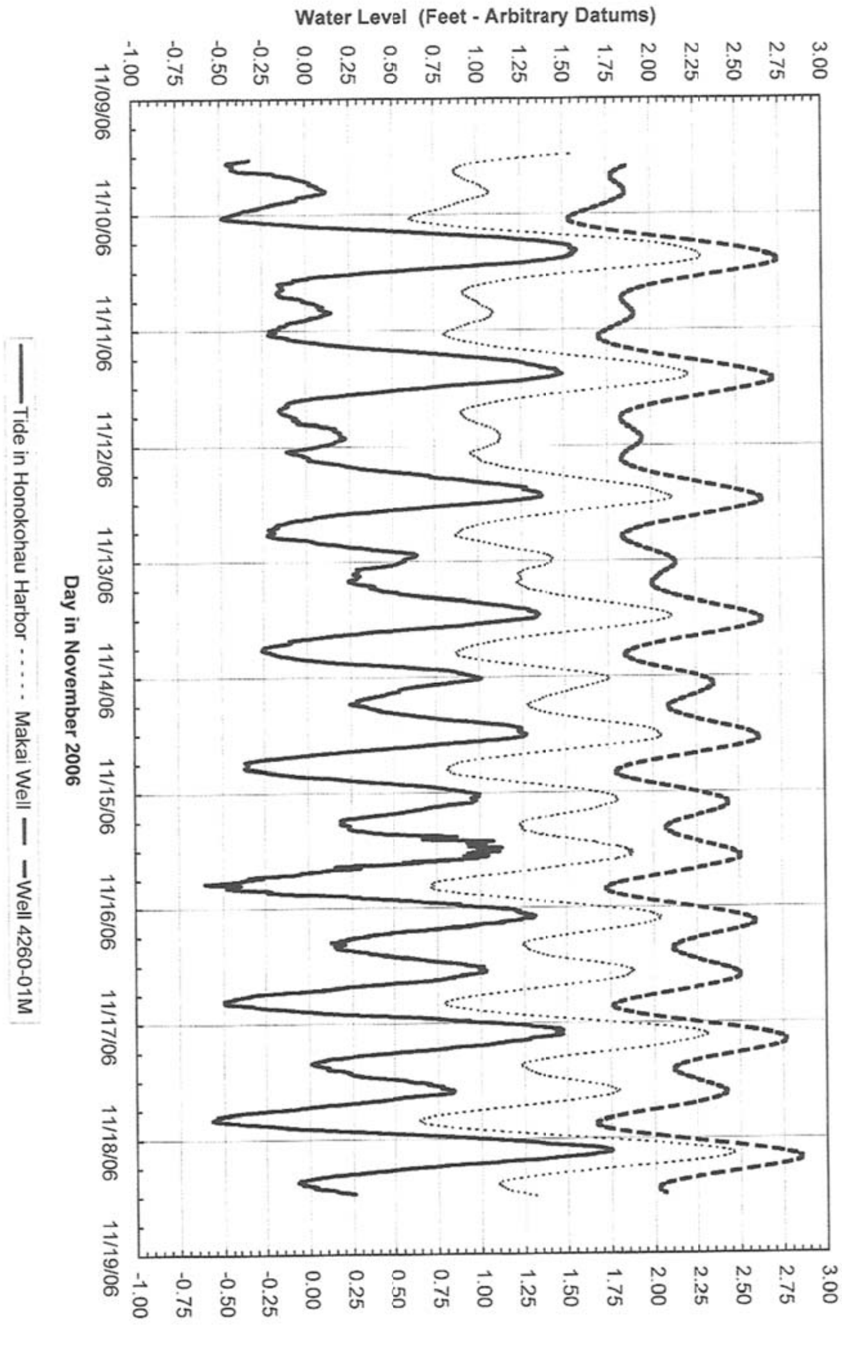

Figure 5. Tidal influence shown by water levels in inland and makai wells immediately south of NELHA.

Figure 6 shows salinity profiles of the two wells. Salinity in the upper 10 feet of the inland well is about 20% of ambient surface seawater. As the figure shows, the lens close to the coast is much thinner. Salinity, lens thickness, and the breadth of the transition zone suggest a moderate groundwater flow rate (Nance, 2008). As noted earlier, the best estimate of groundwater emergence at the coast in this region is 3mgd/mile (Oki, et al., 1999).

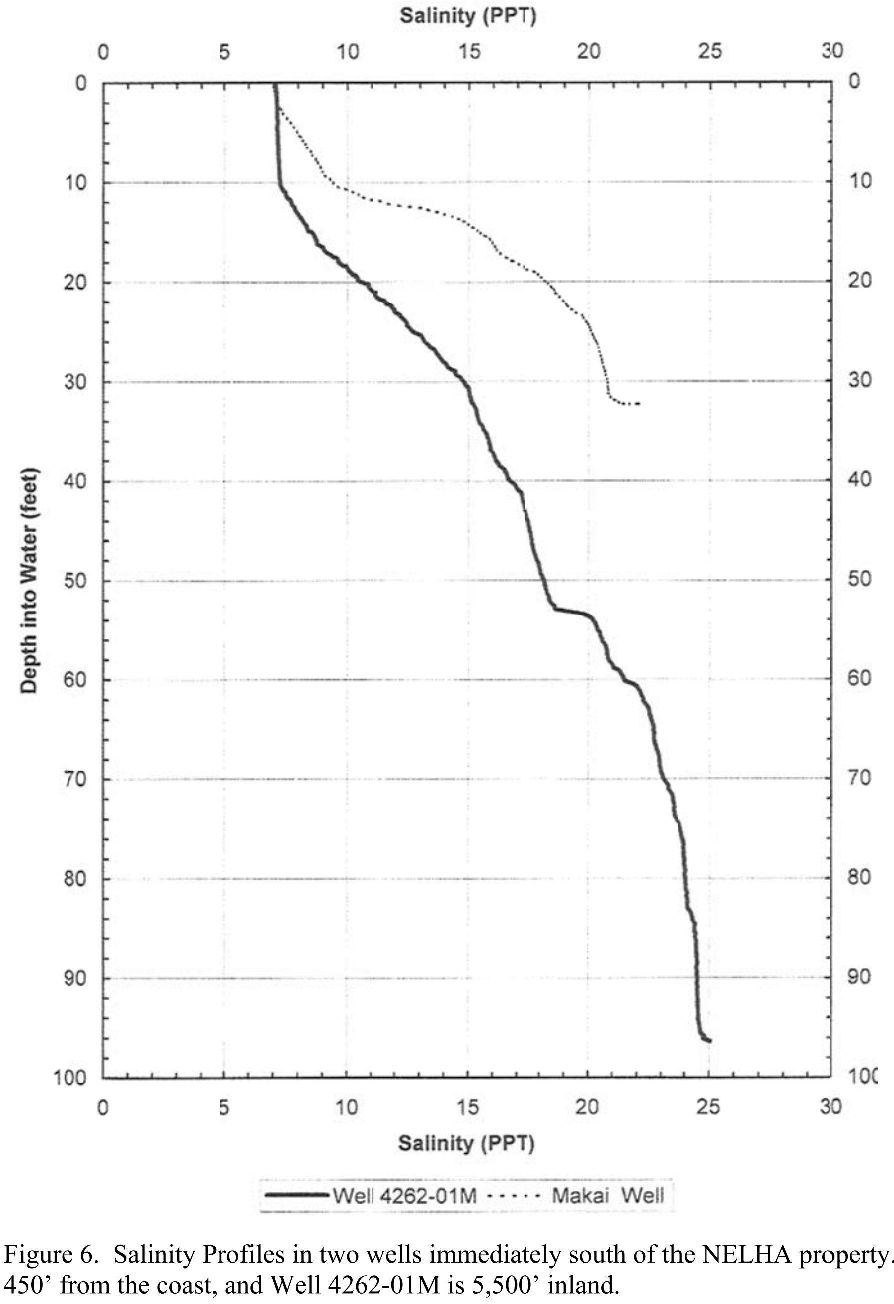

Figure 6. Salinity Profiles in two wells immediately south of the NELHA property. The Makai well is 450' from the coast, and Well 4262-01M is 5,500' inland.

Figure 7 shows the temperature/depth profiles of the inland and coastal wells. Nance notes that these temperatures are unusually cold, some 5 to 10 degrees colder than that of the high level groundwater that is the source of the basal lens in this region. Evidently, seawater mixing with high-level groundwater to form the basal brackish layer must be in communication with cold seawater at offshore depths of 700' or more (Figure 8). The mechanism of landward deep seawater flow mixing and coupled to seaward basal water movement is not understood, and the low temperatures of basal groundwater are unique to this region (Nance, 2008).

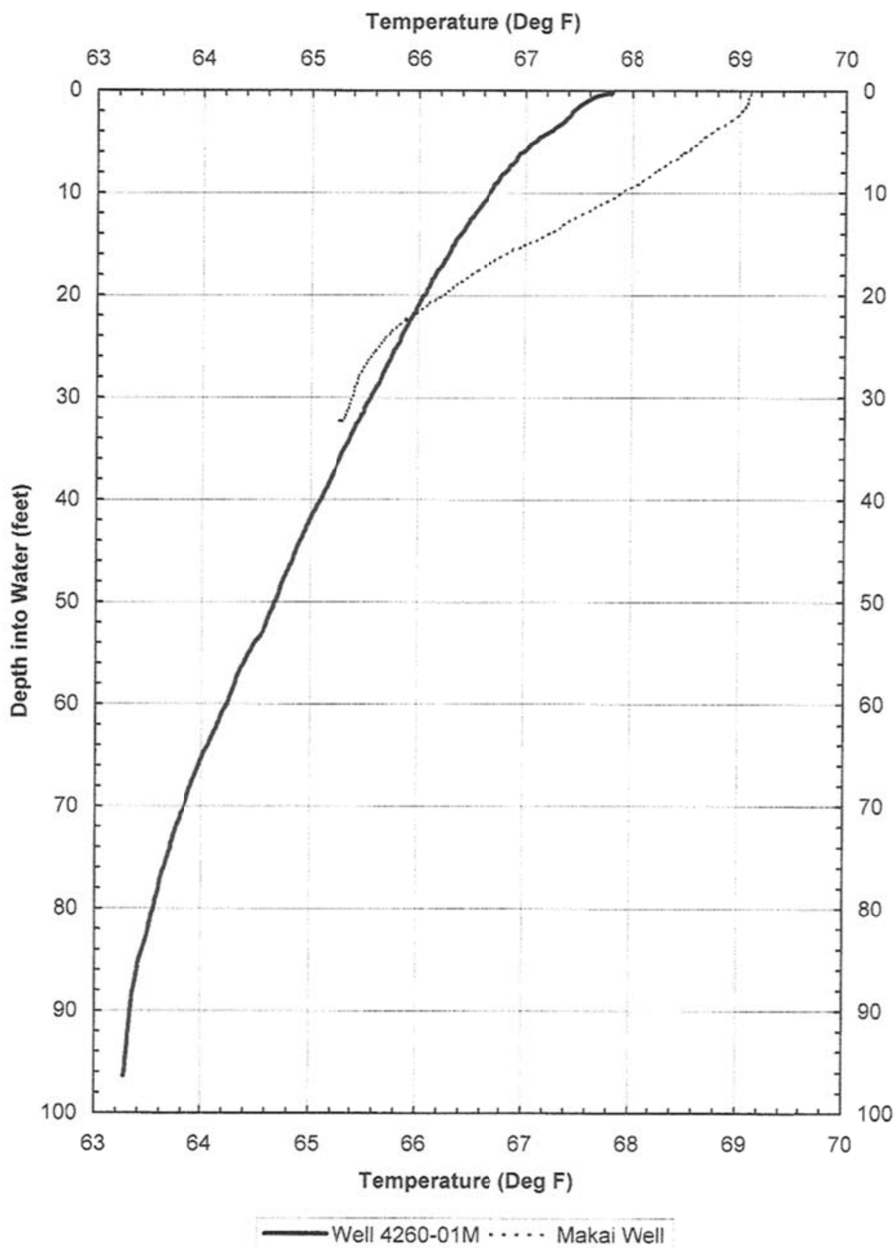

Figure 7. Temperature profiles in the inland and makai wells south of NELHA.

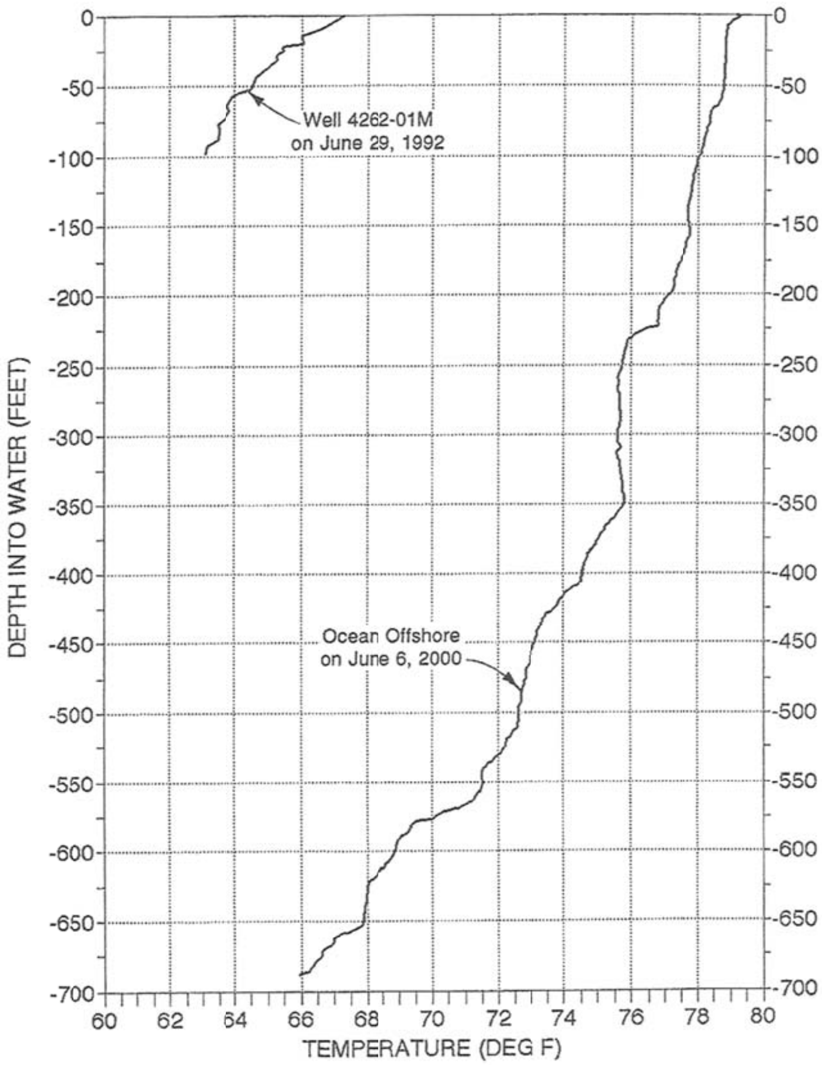

Figure 8. Temperature profile in inland well south of NELHA and offshore ocean waters.

Assessing the effects of different methods of effluent seawater return requires an understanding of conditions at the locations of discharge and in the region of mixing and dispersion of the effluent in receiving coastal waters. A separate examination of the hydrologic characteristics of the West Hawaiʻi region has been prepared (NSC OTI 06-3011) that more comprehensively describes research results in the area over the past 60 years, but the following brief summary provides a summary description. Hydrologic reports previously cited (Dames and Moore, 1985; 1986; Mink, 1992; Oki et al, 1999; Nance, 2008) offer insights suggesting that the regional substratum at Keahole is highly heterogeneous with regard to permeability. Additional evidence of the variable geologic features characteristic of lava at Keahole point comes from drilling records collected in the course of monitoring well construction. For example, Figure 9 is a boring log for a well in the vicinity of the NELHA 55” pump station, showing layers of basalt and clinker gravel with varying degrees of both porosity and hardness, interspersed with voids, and cavities. Note that at this location, a continuous layer of clinker gravel and sand extends from a depth of 30' to the bottom of the core at 55'. Locally, layers such as this provide

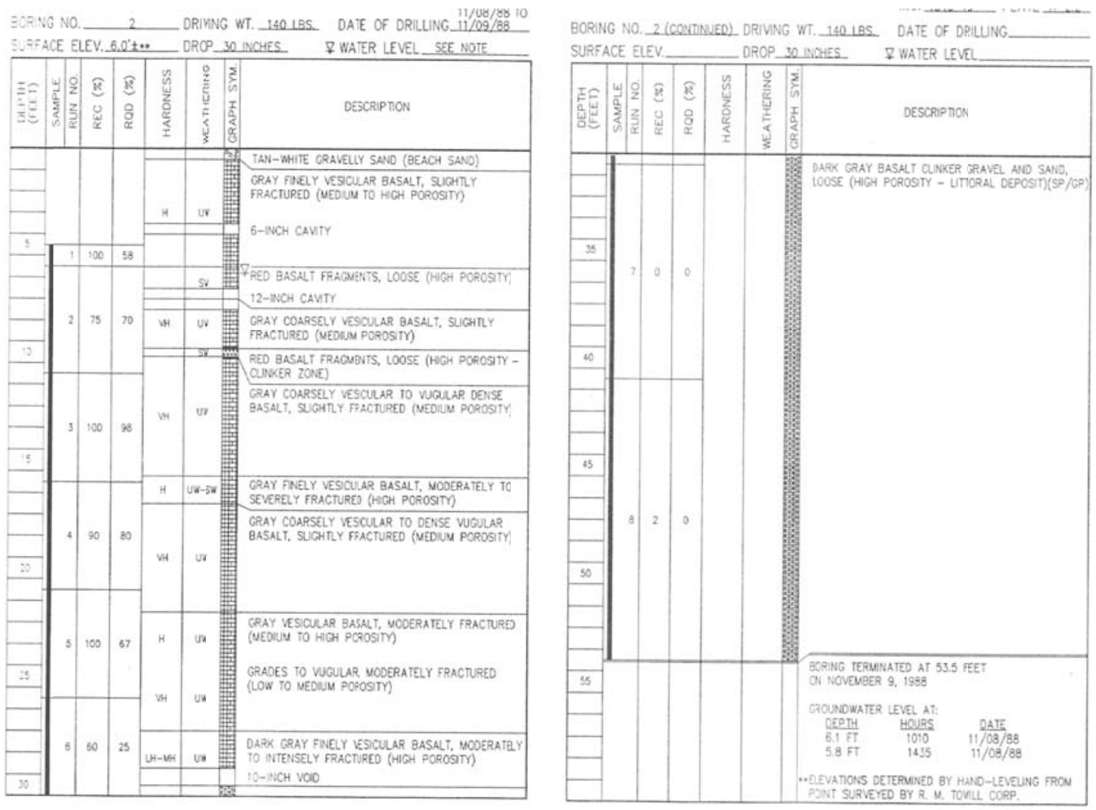

Figure 9. Geolabs-Hawaii boring log, monitoring well W-2, NELHA.

channels for high rates of subsurface water flow. Drilling records like this offer the only practical means of collecting site-specific information needed to make engineering assessments on which to base reliable designs for subsurface seawater return systems.

Three studies have directly considered seawater discharges from NELHA into trenches in lava (Dames and Moore, 1985; 1986; Mink, 1992.) Although the models differ in the degree to which infused effluents permeate downward into lower ground strata, they generally agree that seawater delivered to the trenches will arrive at the shoreline in a time frame proportional to the distance of the trench from the coast. For a trench 250' from the shoreline, Dames and Moore estimates a residence time of 1-2 days. Mink suggests that it will take about 2-2.25 days for water disposed in a trench 400' from the coast to reach the shoreline. Both hydrologists predict trench effluent seawater dispersion will laterally displace ambient groundwater flow, and the highest rate of effluent delivery to the ocean will occur along the most direct route to the coast from the trench.

Additional insight into the fate of deep ocean water discharged into an onshore trench emerges from reported attempts to trace water flow from the trench in the NELHA

Research Park by introducing 25 pounds of Fluorescein dye into the trench while a high rate (16,000gpm) of seawater was also being pumped. Monitoring of adjacent coastal waters from both the air and in the water failed to detect any evidence of the dye, but traces of it appeared a week later in one of the CEMP monitoring wells within the Research Park (J. War, pers. comm.). Apparently, mixed DSW and SSW returned to onshore trenches has a lengthy residence time and tends to disperse over distance in the groundwater underlying NELHA to a degree exceeding literature detection limits for the dye (~1ppt using tunable laser spectrophotometric detectors; Imasaka, et al., 1977).

Section 3.1. Policy Framework Governing Discharge to the Terrestrial Region

Policies related to construction and management of seawater return systems at NELHA are addressed in the NELHA Seawater Return System Management Recommendations (NELHA, 2001). As noted in §2.1 of those guidelines,

No single set of regulations governs the existing seawater return system at the NELH. In part, this is due to the way in which the system has been developed over the years; in part it is due to the system's decentralized nature.

Applicable regulatory authorities and provisions are summarized in Table 2-1 of the NELHA Recommendations reproduced below. As indicated, oversight accrues to various agencies at State and County levels, mostly relating to the Conservation District Use Permit (CDUP) administered by the State Board of Land and Natural Resources (BLNR), Special Management Area (SMA) use permits administered by the County of Hawai‘i, and an Underground Injection Control (UIC) permit under the purview of the State of Hawai‘i Department of Health (DOH). The latter (UIC) permit specifically applies to any well, defined in **HAR §11-23-3** as "a bored, drilled or driven shaft, or a dug hole, whose depth is greater than its widest surface dimension."

The 1987 Seawater Return FSEIS noted that discharge into a trench onshore, as implemented frequently at NELHA does not require any environmental permit. However, the document goes on to note,

…Section 33 of Chapter 342, [HRS] contains a general prohibition against the discharge of any pollutant into state waters, which by definition include groundwater. 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.

Proposed actions in Hawai‘i are subject to review under the State's Environmental Impact Statement Law, Chapter 343, HRS. Applicability of this law to the OTI OTEC demonstration project was the subject of a separate White Paper (NSC OTI 03-2011). Findings of that analysis led to the conclusion that development of a 1 MWe OTEC demonstration facility at NELHA conforms to both intended and specifically described actions considered in accepted Statements prepared pursuant to Chapter 343, HRS. Review of relevant Court opinions similarly concluded that existing environmental review prepared pursuant to Chapter 343 remains valid, and no further review pursuant to this law is required for the actions proposed by OTI.

The NELHA Recommendations note an additional requirement for tenants to comply with the Comprehensive Environmental Monitoring Program (CEMP) to ensure that responsibilities of sampling and analyses are fulfilled. OTI will comply with all monitoring requirements established pursuant to the CEMP and other permitting conditions presently in effect at NELHA.

Table 2-1. List of NELH and HOST Park Permits With Provisions Applicable to Seawater Return System.

Permit	*Agency*	*Applicant*	*Types of Applicable Conditions*
NELH/HOST Master leases	BLNR	NELH	
Exchange Deed & Agreement 1986	State BLNR	NELHA	Seawater return system facilities and activities cannot interfere with use of Mamalahoa Trail.
CDUP 1862	State BLNR	NELHA and HOST Park	Must monitor water quality & endemic aquatic fauna in anchialine ponds min. of 10 years.
CDUP 1994 Amendments	State BLNR	NELHA and HOST Park	Pipelines and facilities must be designed so as not to impede lateral access along the shoreline.
SMA Use No. 77	Hawaii County Plan. Dept.	NELHA	Monitor quality of ground-water and offshore waters.
SMA Use No. 239	Hawaii County Plan. Dept.	Host Park	Various design requirements, most having little influence on seawater system.
UIC No. UH 1378	State Dept. Of Health	NELHA	Continuously monitor effluent flow rate into Pit B (to 3000 gpd)
Species Importation Permit	State Department of Agriculture	NELHA	Chapter 150 HRS and Title 4-71 HRS establish a species importation permit process and specifies the procedures for introduction and transfer of organisms and the specific conditions for culture (e.g. containment of species and disposal of water). NELHA's Aquatic Species Health Management Program is a means of coordinating implementation of this requirement.
Source: Natural Energy Laboratory of Hawaii Authority.			

Section 3.2. Implications of Policies and Terrestrial Setting to Effluent Discharge

Policy frameworks discussed in the preceding section will apply in varying degrees to different configurations of effluent discharge under consideration by OTI. However, in view of cost and time constraints, a central focus of OTI planning is to streamline and simplify procedural compliance requirements wherever feasible under guidance of a clear understanding of permitting requirements. OTI is attentive to elements of regulatory policies, and while every regulatory requirement will be met comprehensively, avoiding unnecessary delays is of paramount importance.

Thorough review of the evolution and applicability of the NELHA CDUP (HA-1862A) to the OTI OTEC Demonstration project was addressed in a previous White Paper (Environmental Compliance Requirements for the Proposed OTEC International LLC OTEC Research Facility at the Natural Energy Research Laboratory of Hawai‘i Authority (NELHA), Keahole, North Kona, Hawai‘i [NSC-OTI 03-2011]). OTI has carefully chosen alternatives for siting and configuring the discharge system to ensure full compliance with existing permit provisions. As noted in NSC OTI 03-2011,

The OTI test facility will be constructed on urban-zoned land designated for industrial use. OTI will exercise due diligence to ensure that the structure meets all design criteria and height limitations specific to the site. All of the needed surface and deep seawater for the 1000-hour test will be supplied using NELHA pipelines and pumping facilities covered under the existing CDUP. Seawater return facilities constructed for both surface and deep seawater that is not distributed to other NELHA tenants will conform to methods assessed and recommended in accepted EIS documents as noted above. No seawater return trenches and percolation systems will be constructed on land zoned Conservation, and no actions will be undertaken within the shoreline setback area. Proposed sites for construction of the OTI facility and associated discharge systems do not include any sites identified as having historic significance.

The placement of discharge pipelines and infiltration systems within the NELHA Access Road and utility right of way is one of the options considered by OTI. Use of this corridor conforms to a previously recommended preferred alternative discharge method (MCM Planning, 1987), and it offers advantages in addition to avoidance of use of Conservation lands. Ease of access for installation and maintenance will help to minimize costs, and the location is readily accessible to discharge distribution infrastructure that OTI will need to install.

As noted above, any discharge design that includes wells or pits with depths greater than their diameter will require approval under the DOH UIC permit process. However, NELHA facilities overlie an exempted aquifer area designated as unsuitable as an underground source of drinking water, and any injection well design that is part of the selected OTI discharge system will be in full compliance with the DOH/UIC regulations.

Similarly, OTI anticipates working closely with the NELHA and the CEMP to ensure that all requirements for sampling and analyses to meet monitoring objectives are fully met.

In developing a strategy for effective, compliant discharge of the substantial volumes of seawater entailed in an OTEC process, the OTI team has sought the best information available on the terrestrial environment and the behavior of effluents discharged via different methods. Although preceding sections have summarized our findings relating to geology and hydrologic features at Keahole Point, some additional review of prior modeling work performed at NELHA will help inform analysis of the advantages and disadvantages of disposal options under consideration.

The brackish basal groundwater lens described earlier flows moderately seaward, separated from underlying seawater due to its lower density. However, in the absence of geological barriers in the form of vertical intrusions of denser, less permeable rock, the aquifer is laterally unconfined and therefore subject to displacement. Model simulations of discharges of large volumes of DSW and SSW into pits or trenches created in the lava surface agree that the continuous flow of effluent seawater will create a spreading plume that displaces the brackish groundwater both upstream and downstream of the trench (Dames and Moore, 1985; 1986; Mink, 1992). However, these models rely to varying degrees on assumptions of isotropic flow through the lava substrata, and they treat their respective solutions regionally in order to resolve the anomalies introduced by the inherent heterogeneity of the terrestrial volcanic basalt. While these assumptions allow for a regional solution, local behavior of effluent plumes is expected to differ in practice.

From a regional perspective, model simulations produce hemispherical plumes radiating in all directions. More locally, in the case of trenches or injection well arrays parallel and in relatively close proximity to the coastline, a half-cylinder geometry may be more appropriate (Mink, 1992). Although trenches may penetrate the substratum below the level of the water table, lateral movement of effluent through the trench walls will create an expanding plume that overcomes the relatively weak flow of the brackish basal lens, and the effluent seawater will travel as an expanding plume surrounded by a zone of diffusion (Dames and Moore, 1985; 1986). As either a hemispheric or half-cylindrical structure, the plume will intersect the coastline, entering the coastal waters both along the linear shoreline interface and via seepage through the ocean bottom at a distance from the shoreline determined by the geometry of the plume in its transmission through subsurface geologic layers. Thus, detectable signals of physical and chemical parameters characteristic of the plume will appear in shoreline waters in proportion to the partitioning of the plume as a function of its geometry.

Model simulations of seawater effluent delivered through a system of deep injection wells are less well developed due to the nature of model assumptions and to the greater pragmatic need to address the trench disposal method most widely in service at NELHA. Two reports (Dames and Moore 1985; 1986) have described simulations of injection well performance at NELHA. Appendix C of the HTDC FEIS (1985) discusses scenarios for three configurations of discharges employing arrays of wells 2 feet in diameter with depths of 100 feet. Well casings described in the assumed configurations are slotted, with allowable permeation at all levels within the wells. Under these conditions, discharge plumes are assumed to displace the existing brackish basal lens in much the same way as expected in the case of trench discharges. However, deeper injection results in a greater lateral transport of effluents through deeper substrata, resulting in a more effective delivery of effluent to offshore regions through seepage through the bottom.

The three configurations examined include discharges of, a) 14,000gpm into a well field 2,000 feet from the shoreline; b) 100,000gpm into a well field 2,000 feet from the shoreline, and; c) 27,000gpm into a well field 1,000 feet from the shoreline. For a), the model predicts that it would require between 187 days and 3.6 years for the discharge to reach the shoreline, depending on variations in the presumed aquifer anisotropy. At the higher level of discharge b), the residence time would be reduced to between 26 and 144 days. The third case, c), results in plume arrival at the shoreline in between 12 and 80 days.

Based on regional hydraulic conductivity, the 1985 model also calculates the times required under different discharge scenarios for the plume to reach a collection of anchialine ponds located 1.5 miles from the more inland well field. For a), the arrival would occur at between 32 and 216 years, and for b) it would take between 4.4 and 30 years to get there. In all cases, the discharge would arrive at the closest coastal region at higher rates than at points further up and down the coast. The linear expanse of coastline intersected by the plumes would range from a minimum of 8,000 feet to 16,000 feet, depending on the configuration of the discharges.

A subsequent addendum by Dames and Moore (1986) modeled performance of an alternate well disposal system designed to distribute 16,100gpm of DSW to an ocean bottom seepage field below the ocean thermocline. This well system was comprised of 4 wells approximately 2' in diameter and drilled to at least 400', with casing installed to prevent injection above the 300' level. The wells each were estimated to handle about 8,000gpm, with two wells active and the others reserved for maintenance and surge purposes, and they were located at the Research Park, roughly 250' from the shoreline. Thus, both the DSW effluent design objective and the volume flow rate of this modeled injection well field are useful analogs to the anticipated OTI OTEC RD&D DSW effluent dimensions.

In evaluating plume dynamics for these conditions, Dames and Moore used the This non-equilibrium equation, incorporating the following assumptions:

1. The regional hydraulic conductivity K is assumed to be 5000 ft./d. (Kanehiro and Peterson 1977);
2. The effective porosity of lava is 0.1;
3. The effective aquifer thickness in the vicinity of the well is 100ft.;
4. The effluent ocean water will be relatively free of solids, and;
5. The assumed anisotropy of the lava is 5:1 horizontal to vertical flow (based on geologic description of the area from Stearns and MacDonald, 1946).

The This non-equilibrium equation formulation used for deep injection well disposal evaluation was:

$$h_0 - h = \frac{Q}{4\pi T}\int_{u}^{\infty}\frac{e^{-u}}{u}\,du ,$$

with parameters assigned as follows:

h_0 - h = drawdown or buildup of water level in a well
Q = disposal rate
T = 3,740,000gpd/foot (coefficient of transmissibility)
U = a dimensionless constant derived from the equation:

$r^2S_1/4Tt$

where,

S_1 = 0.1 (coefficient of storage)
r = radial distance from well
t = time since disposal started

Residence time was calculated using a derivation of the expanding cylinder model:

$$t = [n - z\,(\pi r^2)]/Q$$

where,

t = residence time
n = effective porosity = 0.1
z = aquifer thickness = 150 feet for a flow distance of 750 feet to the shoreline
π = 3.1416
r = distance to shoreline
Q = constant rate of disposal

Results of model runs indicated that 85% of the discharge would occur over a distance of 30,000 feet along the -300 to -400 foot bathymetric contour, located 800 feet offshore, and the associated seepage would be 1.2 to 2.9gpd/ft^2 of ocean bottom (Dames and Moore 1987). The minimum residence time calculated for a discharge of 16,100gpm was approximately three months.

Ultimately, the subsurface flow of injected effluent is driven by gravity. Within the relatively porous matrix of lava, a combination of dynamic head at the injection site and differences in specific gravity between the ambient groundwater and the injected effluent will produce the expanding plume. The boundaries of the plume at equilibrium will depend on variations in the hydraulic conductivity of the lava, the relative densities of the groundwater and the intrusive effluent, and the balance between injection input and seepage output flows. Interpreting the results of computer simulations, Dames and Moore proposed that because of *"higher density due to lower temperature and relatively close proximity to the shoreline, the injected OTEC discharges were modeled based on flow 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."*

Dames and Moore note that even though resistance to vertical flow is five times greater than in a horizontal vector, hydraulic head increases due to injection have a tendency to cause seawater injected at depth to rise in the vicinity of the well. However, the greater density of the injected effluent relative to ambient groundwater, due principally to its much lower temperature, will oppose this tendency. Figure 10 illustrates cylindrical plume behaviors in injection fields with and without density differences between introduced and ambient fluids.

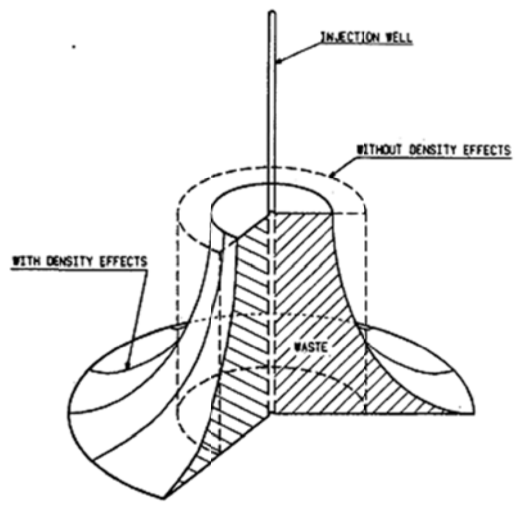

Figure 10. Ideal injection plume geometry with and without density effects. (From Miller, 1986)

As with all models, these results presume ideal conditions that greatly simplify the reality of the natural world they simulate. Two important considerations to bear in mind are 1) the heterogeneity of geologic formations in terms of porosity and permeability, including high degrees of known variability in vertical as opposed to lateral hydraulic properties, and 2) an underlying assumption in the Dames and Moore formulations that the density of the disposed water is "about the same" as "the bulk of the groundwater to be displaced" (Dames and Moore, 1985). In addition, the design of the injection wells considered in these models varies levels of infusion within the wells. We further discuss these considerations in Section 5.3 below.

Section 4. Physical Determinants of Effluent Management

Abstract

Effective management of OTEC seawater return flows requires incorporating understanding of local subsurface conditions into the engineering process. Hydraulic conductivity, particularly as mediated by the presence of highly porous regions, will govern the rate and vectors of discharge plume expansion. Drilling records for newly-constructed discharge structures will provide stratigraphic, tidal, salinity, and temperature profiles that are needed to design appropriate discharge structures. Understanding these parameters will lead to a design solution that avoids sensitive areas such as anchialine ponds, while directing effluent flows to appropriate points of entry into the coastal ocean waters.

As we move into a more focused discussion of effluent discharge methods and configurations under consideration, a recapitulation of important factors that affect management of a seawater return design relevant to planning for the OTI OTEC demonstration facility is useful.

In the geological realm, hydraulic properties in substrata encountered by returning seawater will govern the rate and distribution of the effluent. Prior work has identified a high degree of variability in formation porosity and permeability over relatively short distances. In particular, prediction of effluent plume behavior in the vicinity of the discharge requires reliable values for both lateral and vertical permeability in order to allocate vectors of transmission for design purposes.

A related geologic factor needed for design calculations is the depth and nature of successive strata underlying the discharge sites, along with information on the degree and local variation of inclination of the strata in the seaward direction. Knowledge of these values will allow better resolution of plume trajectory and probable regions of intersection with the sea bottom for seepage discharge into overlying waters. A key subset of this area of inquiry is the occurrence and distribution of subsurface lava tubes or other coherent regions of high porosity. In view of their potential as avenues of rapid effluent offshore transport, information relating to their existence is extremely important.

While a brackish basal lens is known to underlie the surface lavas of the region, an understanding of its salinity, temperature, and water quality constituents as a function of depth will be needed in order to predict interactions that will occur with the introduced seawater discharges. As previously noted, engineering an effective discharge method requires reliable understanding of both the density profile of the groundwater in the discharge region and the local subsurface permeability horizons in order to discern plume behavior in relation to the lower density basal lens.

A related concern is the presence and proximity of existing anchialine ponds that might be subject to the influence of a spreading seawater effluent plume. Management of water quality in these ponds is a priority under the HDOH regulatory framework, and seawater discharge must be engineered to avoid unwanted influence on them.

Ultimately, both DSW and SSW processed through the OTEC facility will find its way to the adjoining coastal waters, where it will be mixed, diluted, and dispersed. Turbulent mixing, along with tidal and other current structures will serve to accomplish the dispersion of the seawater effluent, and effective management of coastal water quality requires an understanding of the dynamics of ocean water masses over hourly, daily, and longer-term intervals. Various studies have described near-shore and offshore currents off of Keahole point (e.g., Bathen, 1975; Bretschneider, 1979; Lobel and Robinson, 1985; Noda, 1985), and regional scale dispersion and mixing characteristics of open coastal regions of west Hawaiʻi likewise are well documented (Dollar and Atkinson, 1992). Ensuring maintenance of the high quality of the coastal water ecosystem as required under Class AA designation will be achieved by engineering a broad, diffuse input of the discharged DSW into ocean waters where initial dilution and mixing quickly return concentrations of nutrients and water temperatures to ambient oceanic levels.

Section 5. Key Objectives of Effluent Return Design and Alternative Onshore Discharge Methods

Abstract
In order to protect both coastal water ecosystems and the ocean water resources on which NELHA relies, OTEC effluents must either be isolated from sensitive receiving waters or distributed in such a manner as to promote very high rates of dilution and dispersion. A percolation trench method offers advantages of amenability to engineering based on well-understood design parameters. A proposed infiltration trench route along the mauka side of the NELHA access road was considered for both DSW and SSW disposal. Concerns regarding displacement of the brackish basal groundwater lens by DSW and subsequent appearance of unacceptable levels of nutrients along the shoreline led to rejection of this method for DSW and SSW return. A hybrid option incorporating elements of both percolation and injection was proposed, but proved problematic again as a consequence of concerns for near-shore nutrient contamination. A deep well injection design appears to be superior to other options for effective transmission of DSW and SSW to offshore bathymetric profiles suitable for the desired initial dilution and mixing characteristics while isolating it from entry into shoreline waters.

Redistribution of oceanic properties is among the most challenging concerns confronting commercial implementation of OTEC. In particular, the high volume flow of deep seawater poses a potential threat to ecosystem stability of shallow, productive surface waters, due to the elevated concentrations of dissolved nutrients in DSW (see Table 3). Principal goals for a successful seawater return design may be summarized into two main elements: 1) protect the pristine quality of the coastal ocean environment and other protected waters, and 2) avoid thermal or nutrient contamination of ocean water resources on which NELHA depends for its research and commercial operations. The NELHA Seawater Return System Management Recommendations emphasize these goals explicitly:

It is critically important to offshore ecosystems and facilities uses that discharges from tenant operations not degrade the quality of coastal waters.

To avoid degradation of the receiving waters, a successful seawater return system must be engineered to: 1) direct the effluent into rapidly mixing, transiting ocean water masses; 2) spread the effluent over as wide an area as possible, which ensures a high initial dilution at the point of effluent entry into the receiving waters, and; 3) avoid discharge into sensitive systems such as intertidal and anchialine pond waters.

Unlike many past and ongoing activities at NELHA, the OTI OTEC demonstration facility entails a use of deep and surface ocean waters that largely avoids changes to constituent properties of the inlet streams. The SSW and DSW temperatures will be cooled and warmed respectively by no more than 10ºF, and under normal operating conditions, no chemicals will be added or removed. Unlike mariculture operations, the OTEC process will not produce any biological or organic byproduct that becomes a component of the effluent. Of the two contact thermal transfer streams,

	NO3	PO4	Temperature
DSW effluent	~40 µM	~3µM	53-56°F
SSW effluent	~0.25µM	~0.1µM	65-73°F
Brackish Basal Water	~80µM	~4µM	65-69°F
Coastal Ocean Water	~0.25µM	~0.1µM	75-83ºF

Table 3. Comparative water quality parameters of OTEC effluents, groundwater, and open coastal ocean water at NELHA.

the SSW will be returned to coastal waters in a form virtually indistinguishable in all parameters except temperature from the near-shore waters (Table 3). The major concerns with regard to coastal water contamination by OTEC discharge streams are the temperatures of both SSW and DSW effluents and the elevated nutrient concentrations of the DSW effluent. While the nutrient and temperature differences of effluents and coastal waters are significant, and although the rate of seawater disposal is great, the volume of the receiving ocean is virtually infinite, and mixing, dilution and dispersion in open coastal waters are vigorous. All of the elements comprising the principal goals of successful seawater return are achievable by one of two design principles: physical isolation of the discharge from sensitive coastal waters, and distribution of the discharge so that it is diluted and dispersed at a broad area of entry into well-mixed coastal waters.

OTI has conducted exhaustive research into the feasibility and cost effectiveness of constructing an effluent discharge pipeline system that would accomplish the physical isolation of OTEC effluent from Class AA waters adjacent to the NELHA facility. Despite the evident advantages of such a system, the burdens of high construction costs and the extended time required for environmental review places this option beyond our practical reach. Therefore, our present area of consideration for OTEC effluent seawater return focuses exclusively on onshore disposal options that result in wide distribution of DSW effluent into a region of rapid oceanic mixing and dilution.

5.1. Percolation Trench

The preferred alternative for seawater return selected in the 1987 FSEIS (MCM Planning, 1987) and widely implemented at NELHA is disposal into trench structures excavated down to below the water table underlying the lava. Permeability calculations based on infiltration models provide guidance to the dimensions necessary to accommodate required discharge flows, allowing for reasonable engineering certainty of trench capacity. Structures designed along these lines remain in use at the present time. Figure 11 illustrates a variant of the infiltration trench recommended for installation in the right of way along the makai side of the NELHA access road and designed to accept 25,900gpm of mariculture effluent.

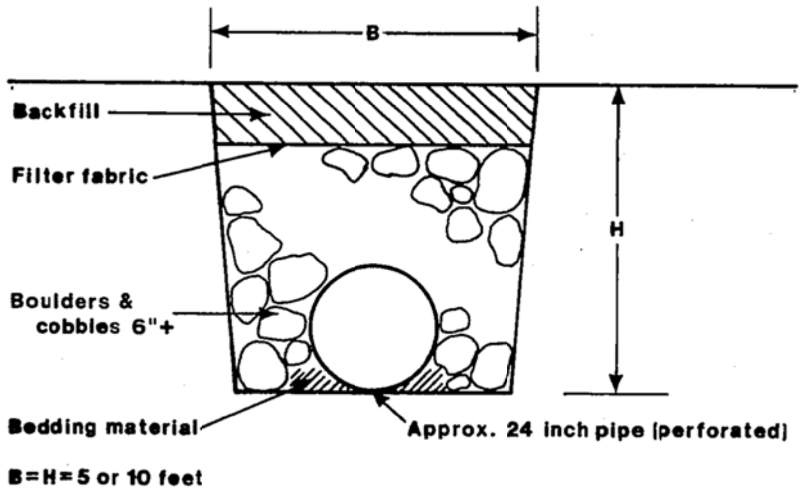

Figure 11. Cross-section of 25,900gpm percolation trench schematic as depicted by MCM Planning (1987). Dimensions of OTI infiltration trench will be sufficient to accommodate 63,000gpm.

At the outset of effluent design planning, OTI considered a percolation trench option, appropriately sized to manage either a discrete DSW effluent flow or a mixed effluent discharge of both DSW and SSW. As recommended in the 1987 review, the trench was located along the makai side of the access road where an existing utility right of way extends to the boundary of the plot intended as the site of the OTEC demonstration facility. As originally conceived, the covered percolation trench was proposed to extend mauka of Wawaloli Beach Park, terminating near the north end of the area's parking lot.

Upon review of the predicted plume trajectory for DSW effluent from this proposed configuration, concerns arose regarding efflux of high-nutrient cold water into the near-shore waters at the beach park. Although a cold brackish water seep already is known to emerge in this region, the temperature of the discharged water would be noticeably colder and might raise concerns among beachgoers. As a result, a modified design evolved in which a solid pipe section transits the beach park area, and the infiltration portion of the system is located to the north, past the parking area (Figure 12). Perforated pipe sections originally considered posed problems in the sizes required for higher flow rates, and subsequent versions of the design utilize commercially available storm water drain infiltration modules (*e.g.* Contech ChamberMaxx), which are more easily shipped and assembled.

Figure 12. OTI Percolation Trench proposed route. Yellow polygon is the OTI OTEC site; Dark blue line is solid pipe to transfer DSW past Wawaloli Beach Park. Light blue line is the infiltration section.

A major advantage of the percolation trench concept is that the system is amenable to engineering using permeability coefficients that have empirical basis in prior trench experiences at NELHA. Because no additional data collection is needed, there are lower costs involved in final design work, and the sufficiency of the system may be assured by designing an excess capacity. Models of plume behavior as discussed earlier offer insight into the dispersion dynamics of the effluent, and the half-cylinder model suggests that much of the vertically distributed effluent will enter the ocean over a broad area some distance offshore as seepage through the seabed, where it will be subject to extremely high rates of initial dilution. In addition, costs of construction are lower than those of other alternatives, and the design is entirely compatible both with NELHA guidelines and with existing environmental review.

For all its advantages, the percolation trench design has one major drawback. Plume model simulations for trench disposal methods agree that the brackish basal lens will be widely displaced by the effluent flow, and discharged DSW will enter the ocean at the shoreline along an extent considerably wider than the length of the trench. Highest rates of shoreline entry will occur at the shoreline's closest approach to the discharge point, and as the brackish lens no longer will be entering the ocean, salinity measurements in the shoreline will rise to oceanic levels greater than 32.00 ppt. In earlier discussion of the regulatory framework governing coastal water quality, we noted the different criteria applied when salinity was 32.00ppt or lower, and we showed that the application of the regression line criteria mostly compensated for the elevated levels of nutrients delivered by brackish groundwater. With that salinity signal extinguished, the more restrictive geometric mean standards promulgated by the DOH would apply, and the elevated levels of nutrients in a DSW or Mixed Effluent Discharge (MED) plume would be certain to exceed levels of compliance, based on Dollar's (2008) findings shown in Table 1. As a result, Class AA WQS would not be met under the seawater return flow necessary to conduct the OTEC demonstration program, and facing a regulatory violation, the plant would be required to shut down. Thus use of a percolation trench system is not recommended for DSW or MED discharge. However, because properties of SSW effluent from the OTEC facility are for the most part indistinguishable from ambient coastal ocean conditions (see Table 3), this option might be a viable alternative for disposal of SSW.

5.2. Hybrid Discharge System

Figure 13 illustrates conceptual elements of an alternate method of seawater disposal that incorporates both percolation and injection methods, comprising a hybrid discharge system. As shown, this configuration includes both SSW and DSW effluents, which are conveyed through a perforated pipe along an infiltration trench set slightly below the water table, with lined injection pits penetrating several substrata installed at roughly 200' intervals. Being below the water table, the perforated pipe would fill with seawater at ambient conditions, and the MED would entrain an initial dilution in its transit through the system. At full operational discharge, it is unclear whether the MED flow rate would overcome ambient seawater infiltration, due to uncertainties regarding permeability of injection pits. As initially conceived, the hybrid system incorporated perforated transmission pipe for its full length, including the section immediately inland of the beach park. Concerns similar to those raised in the percolation trench scheme regarding efflux of cold water into the shoreline at the beach park led to a modified design in which a solid pipe manifold connecting the initial injection pits extends through the beach park region, becoming perforated as the system proceeds to the north. The route and general description is illustrated in Figure 14.

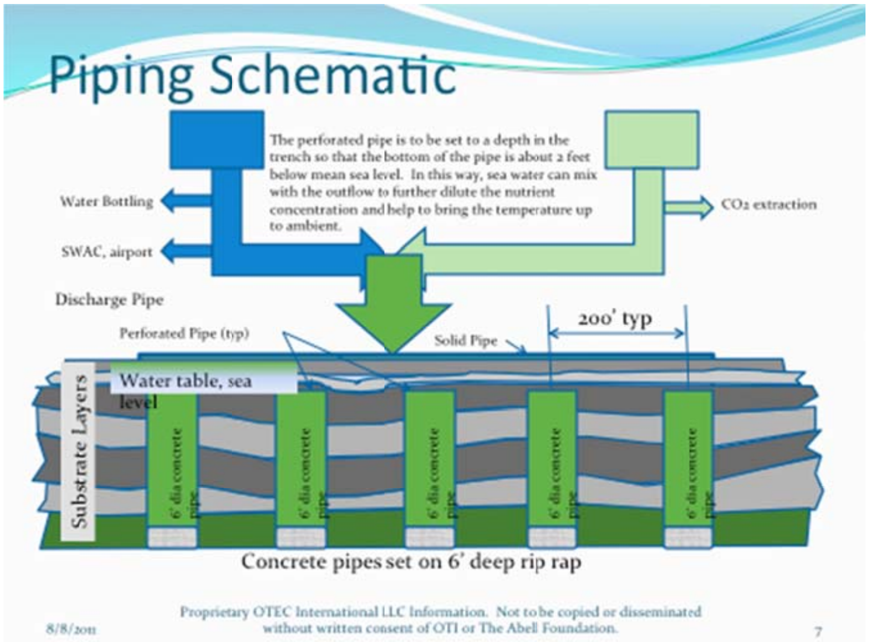

Figure 13. Schematic of OTI Hybrid Discharge System.

The principal advantage of the hybrid discharge concept lies in the injection of effluent into deeper layers of the subsurface lava, below the brackish basal lens. DSW or MED inserted at depth would be expected to enhance downward development of the plume, promoting allocation of a greater portion of the discharge to enter the ocean via seepage through the sea floor at a greater distance from the shoreline. This addresses the objectives of spreading the effluent entry over a wide area and ensuring that the region of contact with ambient ocean water provides for a high rate of initial dilution. Both percolation and injection infiltration systems conform to NELHA guidelines for seawater disposal, and both methods have been thoroughly described and recognized as acceptable in prior environmental review documents. Although more costly to construct than a simple percolation system, the hybrid system is less expensive than an offshore disposal system and, depending on permeability data that remain to be gathered, likely less expensive than an injection well field. At least in the region where a solid pipe manifold overlies injection pits, effluent will be isolated from the basal lens, thereby reducing the likelihood of WQS violations being detected in that region of the shoreline in the course of CEMP sampling.

The major concern surrounding the hybrid concept is the same problem confronting the percolation trench in relation to displacement of the groundwater lens. For the region in which surface infiltration will occur, hydrologic models suggest that the basal lens will be pushed aside by the expanding effluent plume. As this part of the plume intersects the coastline, salinity in that region will rise to oceanic levels, and the concern regarding violation of WQS again will raise the prospect of forced operational shutdown. For this reason use of the hybrid model for DSW or MED effluent is not presently recommended.

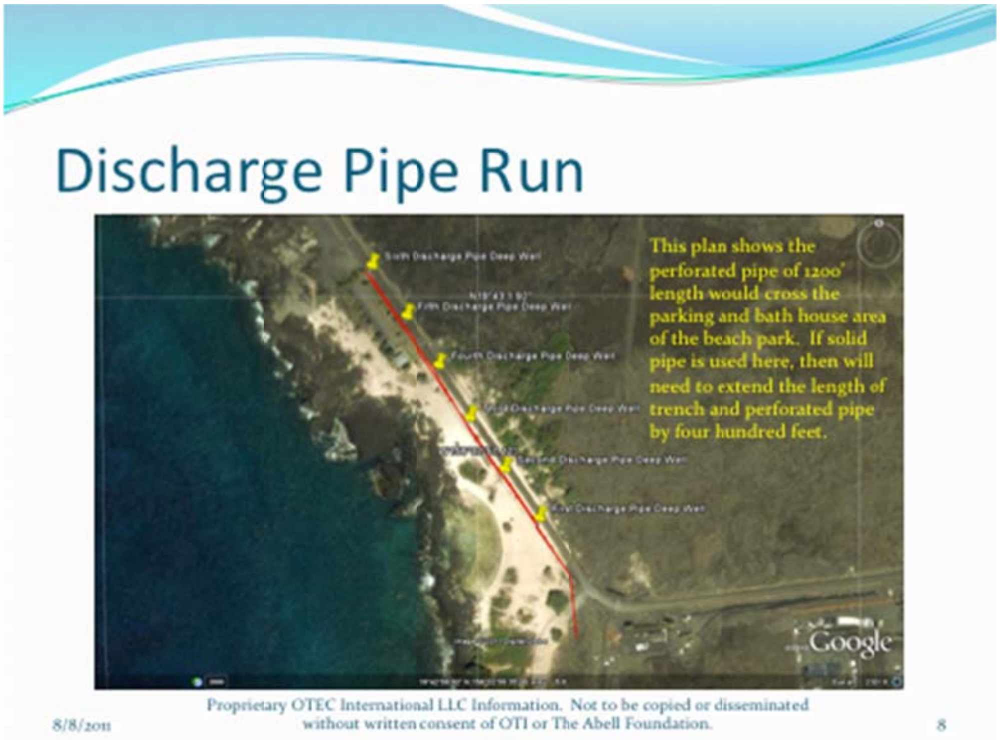

Figure 14. OTI Hybrid Discharge System proposed route.

5.3. Injection Well System

As noted earlier, disposal of effluent using deep injection wells is described in some detail in the HTDC FEIS (1985) and the MCM Planning FSEIS (1987). OTI considered various alignments and locations of injection wells for return of both DSW and SSW. One would align the deep well series along the existing utility right of way on the ocean side of the NELHA access road, with delivery of effluent to the wells through a solid manifold pipe installed at or near the lava surface. Figure 15 illustrates a version of this well field configuration. A more efficient location and alignment would be to install the injection well field as close as possible to the OTEC facility itself. As noted earlier, a deep injection well field parallel to and within several hundred feet of the shoreline was among the DSW injection designs evaluated by Dames and Moore (1986).

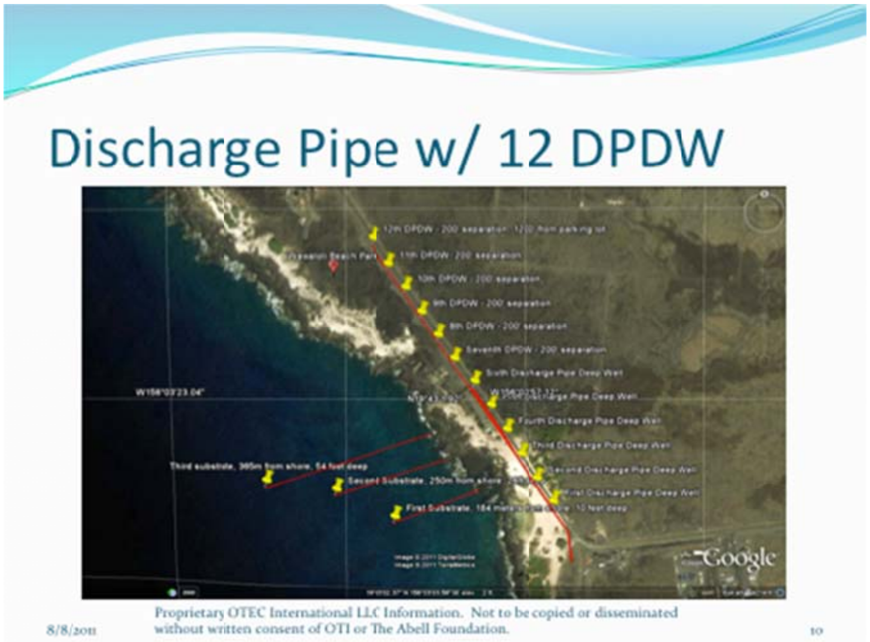

Figure 15. Proposed OTI Injection Well field and discharge manifold.

As with other disposal options, an injection well system has the advantage of being amenable to targeted engineering for achievement of desired discharge objectives. With sufficient lead information on regional permeability and subsurface flow characteristics, the system can be designed to meet or exceed performance requirements.

From a regional perspective, model simulations produce hemispherical plumes radiating in all directions downward from the point of discharge. In the case of injection well arrays parallel and in relatively close proximity to the coastline, a half-cylinder geometry may be more appropriate (Mink, 1992). For injection wells deep below the level of the water table, lateral movement of effluent through the substratum will travel as an expanding plume whose boundaries are determined by vectors of substratum permeability and by density-driven gravitational stratification (Dames and Moore, 1985; 1986). Injected effluent will enter the ocean via seepage through the ocean bottom at a range of depths that corresponds with the geometry of the plume at the point it intersects the ocean bottom interface. A plume introduced at a specified depth interval will migrate to a seepage field that reflects the combined influences of the depth of injection and the characteristics of density stratification.

As in the case of surface trenches, the plume from a shallow injection well designed with slotted casing starting near the surface will permeate upper levels of lava substrata. The effluent plume will displace the Ghyben Hertzberg lens and intersect the coastline, entering the coastal waters both along the linear shoreline interface and via seepage through the ocean bottom at a distance from the shoreline determined by the geometry of the plume in its transmission through subsurface geologic layers. Thus, the plume will appear in shoreline waters in proportion to the partitioning of the plume as a function of its geometry and dilution as it spreads through the substrata. A well of this design will not meet design objectives for the OTEC SSW return. Instead, OTI intends to discharge SSW into wells drilled to depths of 100-150ft, with solid casing down to a depth well below the groundwater lens.

Development of an injection well field with a capacity sufficient to receive both DSW and SSW flows at full OTEC operational flows appears technically feasible. However, the most important objective is to avoid displacement of the basal lens, thereby sidestepping likely shoreline WQS non-compliance issues. In order to isolate the SSW discharge plume from interaction with the basal lens, OTI will construct wells that inject below the brackish lens in a region capped by a low porosity layer, taking advantage of the higher density of the SSW, primarily due to higher salinity and secondarily as a result of lower temperature. Natural tendencies of the basal lens to float on more dense seawater will promote gravitational stratification, which is the goal of introducing the effluent into permeable strata at a depth below the lower diffusion boundary of the lens (see Figures 6 and 7). With the integrity of the basal lens largely preserved, problems relating to WQS issues at the shoreline would be alleviated. The deeper vertical migration of the effluent plume would, in turn, increase the discharge residence time and expand the zone of initial entry to deeper coastal waters farther from the shoreline.

Based on the foregoing considerations, OTI intends to design and implement an engineered injection well field with deep wells to channel returned DSW to ocean bottom seepage at depths of from -300 to -400 feet, and with shallower wells targeting offshore entry of SSW beyond the nearshore interface zone. Both the DSW and the SSW injections wells will be 2 feet in diameter. Because of differences in the density of the DSW and the SSW, OTI expects the plumes from each discharge to stratify separately at different depths, aided by well designs that localize injection at or near the target depth of plume propagation. Figures 16 and 17 illustrate intermediate stages of DSW and SSW plume development following initiation of seawater return. Results of model studies discussed previously (Dames and Moore, 1986) indicate that at full development, the subsurface plumes will expand considerably beyond the illustrated lateral boundaries.

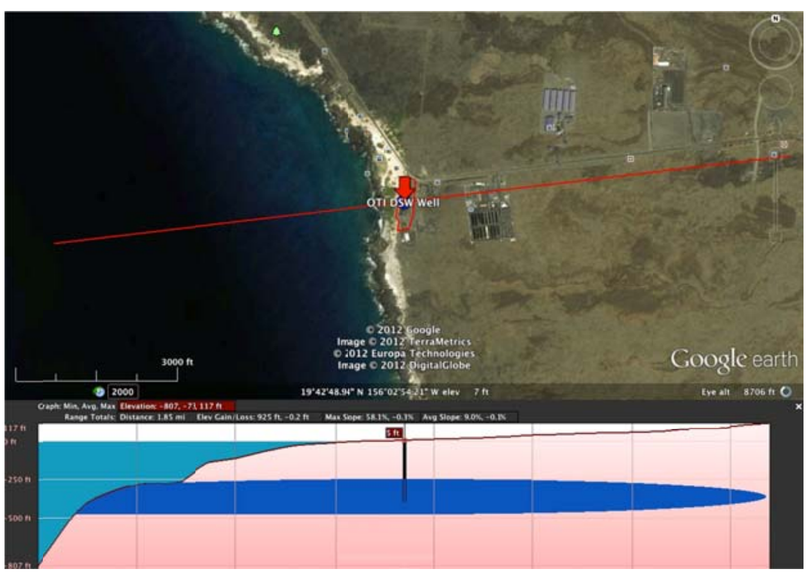

Figure 16. Plume cross section, DSW injection at -300 to -400 feet. Red line marks surface intersection of profile.

Figure 17. Plume Cross section, SSW injection at -100 to -150 feet. Red line marks surface intersection of profile.

Cross-sectional views of the DSW and SSW plumes (Figures 16, 17) illustrate the previously described seepage fields, the interface of the plumes' seaward boundaries with the ocean floor. As noted, the seepage field for each plume occupies the depth ranges defined by the upper and lower margins of the plumes. Translated orthogonally, the plan view of the OTI OTEC DSW seepage field at an intermediate stage of plume development would appear as shown in Figure 18. Note that the region of ocean entry occurs at a depth and location far removed from both the warm water and deep water inlets of the NELHA 55-inch seawater system.

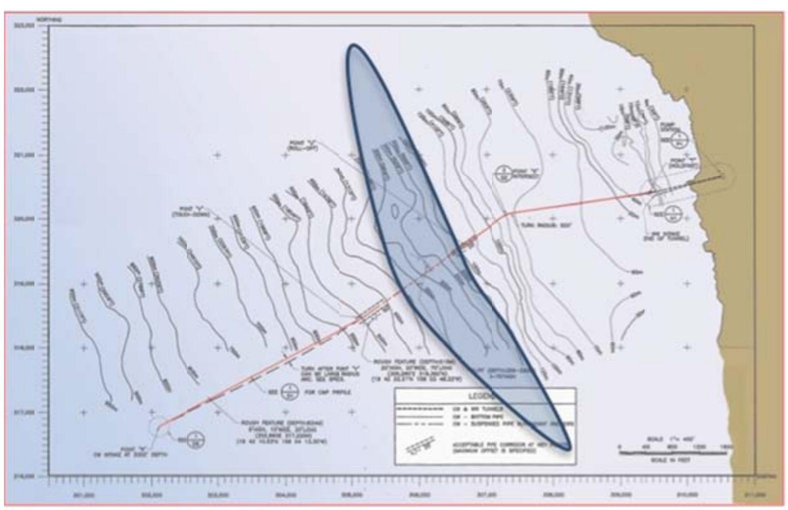

Figure 18. Schematic of the DSW bottom seepage area along the -300 to -400 foot bathymetric contours, intermediate stage plume development.

As previously stated, to avoid degradation of receiving waters, a successful seawater return system must be engineered to: 1) direct the effluent into rapidly mixing, transiting ocean water masses; 2) spread the effluent over as wide an area as possible, which ensures a high initial dilution at the point of effluent entry into the receiving waters, and; 3) avoid discharge into sensitive systems such as intertidal and anchialine pond waters.

Mixing and water mass exchange in the region of the seawater return receiving waters is known to be vigorous (Bathen, 1975; Bretschneider, 1978; Dollar and Atkinson, 1992). Using data gathered by Noda (1986), Oceanit (1987) derived a mean current velocity at 1 foot/sec, leading to an average water residence time per coastal mile of about 1.5 hours. Therefore, delivery of the DSW effluent to these waters (Figure 18) meets design objective 1) of a successful seawater return system.

As discussed earlier (Section 3.2), an analogous OTEC DSW return design was studied using model formulations and computer analyses (Dames and Moore, 1986). The study examined effluent plume behavior in a field of 4 wells, each 2 feet in diameter, with solid casing preventing entry of the DSW above a depth of 300ft. Total well depth extended to at least 400 feet. The wells were located 250 feet from the shoreline, and the estimated capacity of each well was 8,000gpm, with 2 wells in active use at a time and the others in reserve for maintenance and surge purposes. Total pumping rate for the purposes of the model was 16,100gpm.

Model results from this design suggest that at equilibrium, 85% of the discharge would be distributed over a longitudinal distance of 30,000' at or below the 300' bathymetric contour, producing seepage rates ranging from 1.2 to 2.9gpd/foot. Calculated initial dilution for the DSW effluent entering the overlying ocean waters in this region is roughly 1:40,000. To put the size of the seepage field into perspective, the length dimension of the shaded area shown in the intermediate stage seepage field in Figure 18 is less than a quarter of 30,000 feet. Thus, design objective 2) of a successful DSW return system also is clearly met.

Figure 16 illustrates the stratified geometry of the SSW plume. For the SSW effluent, the well discharges below the brackish groundwater lens, and the greater density of the SSW will maintain the stratification of the effluent below the basal lens. Unlike surface trench discharges, the SSW injection wells are designed to avoid displacement of the basal lens. Thus, the SSW plume does not interfere with the dynamic groundwater flux that sustains physical characteristics of anchialine ponds. In addition, the region of seepage of SSW effluent into the ocean is well beyond the sensitive nearshore and intertidal waters.

In the case of the DSW effluent plume (Figure 17), high nutrient DSW return waters remain well offshore and below the shallow productive coastal waters, as shown above. Isolation of both DSW and SSW effluents from sensitive anchialine and intertidal regions satisfies the final design objective for a successful seawater return system.

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Appendix C

STATUS OF THE ANCHIALINE POOL LOCATED ON THE OTI PROJECT SITE, HOST PARK, NELHA, KEAHOLE POINT, HAWAI'I

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EALLC Report No. 2012-13

June 2012

EXECUTIVE SUMMARY

Background

OTEC International, LLC (OTI) is moving forward with an Ocean Thermal Energy Conversion research and development project at the State of Hawai'i's HOST Park at Keahole Point, Hawai'i Island. This project will occupy a 9.8-acre lot in the Park. Recently, a single, small isolated anchialine pool was discovered on the project site. Since anchialine pools represent a relatively rare aquatic habitat that often has native aquatic species that are found nowhere else, this study was undertaken. This document reports on the status of (1) Hawaiian anchialine resources, (2) the biological resources in this pool as well as (3) presents some management options that OTI and NELHA may wish to consider in preserving this resource.

Anchialine pools are landlocked bodies of waters having no surface connections to the sea but have measurable salinities whose water surface rises and falls with the tides. Thus some anchialine pools may have no surface water present at low tides but on high tides cover a considerable lateral area depending on the configuration of the basin. There are probably about 1,050 anchialine pools in the islands and 85% of these are found on the island of Hawai'i with most being located on the West Hawai'i coast. Hawaiian anchialine pools harbor a unique assemblage of organisms, some of which are only known from this habitat. With the tremendous growth in population along the West Hawai'i coast over the last several decades has come development to many coastal areas as well as improved public access such that much of the coastal area and resources are now used by the public. Along with this use has come the indiscriminate introduction of alien fishes such as tilapia and topminnows (Family Poecilidae) into anchialine pools with the mistaken purpose for mosquito control or as possible baitfish for shoreline fishing. Over the last 40 years it is estimated that between 90 to 95% of the West Hawai'i anchialine pool resource has been biologically-degraded by the introduction and spread of these alien fishes which serve as predators on many of the unique native anchialine species. Alien fishes are able to complete their lifecycles in the anchialine system, thus permanently precluding many native species as long as water remains in the pool. At present there are no legal means of effectively removing alien fishes from Hawaiian anchialine pools.

Anchialine pools go through a natural senescence, where sediments accumulate in the pool basin, gradually filling in and replacing the water, eventually becoming a dry pocket of land in lava fields. Much of the sediment comes from leaf litter and encroaching vegetation. The presence of alien fish keeps native herbivorous shrimps from the pond allowing benthic algae to cover much of the pond substratum and changing both the benthic community and ecological succession in the pond. Thus senescence is increased in the presence of alien fishes. Thus the outlook for the native biological resources found in Hawaiian anchialine pools appears to be poor in the absence of adequate restoration and management. This statement is particularly true in light of the aquarium trade that has developed in the last ten years utilizing native anchialine shrimp which are sold primarily via the internet with the end result of further declines in the abundance of these organisms as well as decimation of the habitat by collectors.

Status of Biological Resources in the OTI Anchialine Pool

The OTI anchialine pool has the usual complement of common anchialine species (*Halocaridina rubra* and *Metabetaeus lohena*) and is a permanent pool (containing water through all stages of the tidal cycle. The high number of the alpheid shrimp, *Metabetaeus lohena* present in the pool is unusual.

Proposed Recommendations for the OTI Anchialine Pool

1. Given the fact that the OTI anchialine pool is located on the project site, it would appear that a logical management strategy for this pool would be to preserve it by keeping within the project's fence system thus precluding public use of the pool. The argument that these resources must be made public is not in the best interest of the resource. There are anchialine pools presently open to the public on the NELHA parcel; having one pool that up to recently was not publicly known behind a fence is not.

2. Because the Christmas berry tree as well as the fountain grass growing around the pool are non-native and contribute to the vegetative litter in the pond, it is suggested that removal of these species within an approximate five-foot radius of the pond be made and a fence be erected to keep construction debris and people outside of the pond.

3. Signage should be posted on the fence around the pool, informing construction personnel and employees to stay out of the pond and not place any aquatic species, chemical or debris in the pool. As pointed out below, there is no scientific justification for a "buffer zone" but the fence should be situated three to five feet from the upper edge of the pond basin.

4. As part of the orientation of all personnel (construction and employees), the importance of observing the rules regarding no (1) entry into the pool, (2) dumping of wastes, (3) release of aquatic species into the pool and (4) the importance of the signage around the anchialine pool should be made. Problems should be reported to NELHA staff.

INTRODUCTION

A. Purpose

With any coastal development there exists the potential for negative impacts to occur to resident aquatic biota. Hawaii Revised Statutes, Chapter 205-A as well as the County of Hawai'i Special Management Area Rules and Regulations recognize the potential for impact to occur to aquatic resources with coastal development and have been enacted to preserve, protect and where possible, to restore the natural resources of coastal zone areas. These regulations are the basis for which the County of Hawai'i and the Hawai'i State Department of Land and Natural Resources requires developers in the coastal zone area to institute programs and implement best management practices to insure the protection of aquatic species present on or adjacent to their project sites. The Hawai'i County Planning Commission Rules of Practice and Procedure that were updated in January 2006 provides guidelines for activities within designated Special Management Areas (Rule 9). It defines Special Management Areas as "...the land extending inland from the shoreline as delineated on the maps filed with the Authority as of June 8, 1977, or as amended pursuant to Section 9-21." All development within the Special Management Area is administered through the Department under this rule pursuant to the objectives and polices and the Special Management Area guidelines as provided by Chapter 205A of the Hawaii Revised Statutes. The project parcel described below is mapped within the Special Management Area (SMA) and is covered under the NELHA/HOST Park SMA Use Permit 239.

The Natural Energy Laboratory of Hawaii (NELH) was established by the Hawai'i State Legislature in 1974 with the mandate of promoting research and development of ocean thermal energy conversion (OTEC) processes and related technologies. As noted by Olson (2011), *"By 1984 it had become apparent that the seawater being pumped up for OTEC research could also be channeled into many other profitable uses. New legislation legalized commercialization on state property allowing NELH to host new tenant business ventures. In 1985, the Legislature created the Hawaii Ocean Science and Technology (HOST) Park on an adjacent 548 acres at Keahole in anticipation of expansion needs of NELH's growing businesses....Today, NELHA is 'landlord" to approximately 43 enterprises which generate approximately $50-60 million per year in total economic impact....Three pipeline systems pump deep and surface seawater to shore 24/7 with the third being the world's largest and deepest, to a depth of 3,000 feet."*

The OTI project represents a continuation of OTEC development and will occupy a 9.8-acre lot in the HOST Park. Recently, a single, small isolated anchialine pool was discovered on the project site. Since anchialine pools represent a relatively rare aquatic habitat that often has aquatic native species found nowhere else, the author was asked to examine this pool, describe the aquatic resources present and present some management options that OTI and NELHA may wish to consider in preserving this resource.

B. Background Information on Anchialine Resources

Anchialine pools are land-locked water features that have no surface connections to the sea, yet have measurable salinities and show tidal fluctuations thus are indirectly connected to the ocean. Usual characteristics of West Hawai'i anchialine pools include rocky basins often with biogenic sediments that are mostly small (less than 100 square meters) and shallow (less than a meter in depth) but having exceptionally clear mixohaline waters (salinities in the 5 to 15 ppt range). These pool are found in highly porous substrates (usually recent lavas or limestone) adjacent to the ocean and have been reported from the Red Sea as well as on islands situated in the tropic Indian, Pacific and Atlantic Oceans. Locations with the most numerous anchialine sites are in Fiji, the Ryukyus and Hawai'i. In terms of a statewide resource, Hawai'i Island has the largest number of anchialine pools and the majority of these ponds occur along the West Hawai'i coast from Kawaihae to Kailua-Kona. In this area about 650 pools have been surveyed and a conservative estimate places the total number anchialine pools on Hawai'i Island at about 900 ponds and the statewide number probably does not exceed 1,050 pools (personal observations).

Because of their relatively isolation from the sea, anchialine pools have a largely distinct biota and many of these species are found nowhere else. Anchialine pool organisms fall into two classes, i.e., epigeal and hypogeal species (*sensu* Maciolek 1983). The epigeal fauna is comprised of species that as adults require the well-illuminated (sunlit) part of the anchialine system. Most of these species are found in other Hawaiian aquatic habitats albeit individuals from anchialine systems frequently show ecotype (morphological) variations that are not found elsewhere in the range of those species. The epigeal species have life histories that require the larvae or early juvenile stages to be in the ocean, which with growth and development recruit to brackish waters along Hawai'i's coastlines where they are found as adults. A few of these species (mollusks) are able to complete their lifecycles within an anchialine system. The hypogeal organisms occur not only in the illuminated part of the system but also in the interconnected watertable below. These species are primarily decapod crustaceans, some of which are known only from the anchialine habitat.

The Hawaiian anchialine pool ecosystem is dominated by a characteristic assemblage of organisms including crustaceans (shrimps and amphipods), fishes, mollusks, a hydroid, sponges, polychaetes, tunicates, aquatic insects, algae and aquatic macrophytes. Most striking are a number of red-pigmented caridean shrimp species. These shrimps, as well as many other co-occurring faunal components, utilize the anchialine pond habitat and the underlying brackish watertable. Depending on pond depth, many of the shrimp species display a tidally linked migration, emerging from the rock interstices with the incoming tide to feed in the pond, and later returning via the interstices to the subterranean labyrinth with the falling tide (Fricke and Fricke 1979). The most characteristic species in Hawaiian anchialine systems is the small, red-pigmented caridean shrimp known as opae'ula or *Halocaridina rubra*.

Over the last forty years alien or exotic fishes have become established in most West Hawai'i anchialine pools. Unlike native fishes, many alien fishes (tilapia and topminnows) are able to complete their lifecycles in the anchialine habitat. These fishes prey on and exclude native hypogeal shrimp which are usually the dominant faunal component. Because the dominant opae'ula is largely herbivorous, when excluded from a single pond or an anchialine system due to the presence of alien fish, growth in the algal communities often becomes rampant causing major shifts in ecological succession in the benthic (bottom) communities. Left unchecked and without high herbivory, the often high algal productivity found in anchialine systems speeds up the natural senescence or infilling of the pools (Brock 1985, Bailey-Brock and Brock 1993). Encroaching vegetation drops leaf litter and increases root masses in adjacent pools all of which increases the infilling process. Left unchecked, ponds located in shallow basins may disappear within 20 to 40 years due to these natural processes.

More life history information is available for *Halocaridina rubra* or opae'ula than for any other of the hypogeal anchialine species. Opae'ula feed on detritus, benthic diatoms, phytoplankton, filamentous algae, vascular plant tissue (Wong 1975) and when available, animal tissue. *Halocaridina rubra* feed by plucking the substratum with bristled chelae; midwater and surface film feeding is accomplished by using the chelae and bristles as plankton filters (Bailey-Brock and Brock 1993). Opae'ula have been maintained in small sealed containers for years; presumably under these conditions as well as in the subterranean habitat, they are capable of utilizing bacterial films. Their long life expectancy (ca. 10 to 20 years) and ability to survive in small sealed containers attracted the interest of exobiologists and NASA scientists. More recently, the aquarium fish industry largely via the internet, markets sealed containers holding these shrimp with worldwide sales. This commercialization has put further pressure on the wild stocks of opae'ula with individuals collecting and supplying this shrimp species to the aquarium trade.

Anchialine pools with sufficient illumination must represent significant points of high benthic productivity relative to the watertable below. Sunlight and dissolved nutrients provide the necessary ingredients for this productivity. Many of the anchialine species appear to take advantage of these loci of food resources (i.e., ponds). With pond obliteration as through burial due to senescence (the slow natural infilling of basins due to the growth of vegetation), the total productivity within a given section of the underlying watertable would be significantly reduced; this suggests that the carrying capacity of the habitat with respect to the more unusual hypogeal species would be significantly lower with such obliteration due to the decrease in food resources. Loss of the illuminated part of the habitat results in the loss of epigeal species (crustaceans, mollusks, fishes and flora) because of their dependence on the illuminated high productivity water part of the anchialine system.

Proof of hypogeal species survival in the absence of anchialine pools has been encountered in the drilling of coastal wells on many islands where with drilling and initial pump testing of wells, opae'ula occasionally appear despite the fact that there may be no anchialine pools present. Individual shrimp have also been encountered in the groundwater effluxing along the shoreline on an Oahu beach in an area completely developed more than 75 years ago thus filling any anchialine pools that may have been present is further evidence of the ability of these hypogeal species to survive in the underlying watertable (Brock *et al*. 1999).

Maciolek and Brock (1974) found alien fish in 15 percent of the pools surveyed in 1972 on the West Hawai'i coast. Thirteen years later, OI Consultants (1985) noted exotic fishes in 46 percent of the ponds examined and more recently unpublished surveys by the USCOE (M.T. Lee) as well as this author suggest that alien fish are present in 90 to 95 percent of all West Hawai'i anchialine pools. The spread of these fishes has been aided by humans who have mistakenly released topminnows into anchialine pools presumably to control mosquitoes or as a later source of baitfish or for other unknown reasons. Once released into an anchialine pool, both tilapia and topminnows spread to other pools in the vicinity via the subterranean watertable as well as during spring high tides when the water of many low-lying pools coalesces allowing fish to swim from one pool to the next. The end result has been that former biologically pristine anchialine systems have been completely colonized by these fishes to a point that there may be just a single isolated pool in a otherwise contaminated large complex of pools that remains biologically intact.

Many biologically degraded West Hawai'i anchialine pools show dramatic shifts in appearance because of the loss of native herbivorous species. Algae previously kept "in check" by native grazers often becomes extremely abundant. Figure 1 shows an anchialine pool at Makalawena in North Kona surveyed in 1972 when it contained the normal complement of native shrimps. Not evident in the photograph is the exceptionally clear water and lack of macroalgae. A photograph of the same pool in 1985 (Figure 2) shows the water column and surface of the pond to be covered with the alga, *Cladophora* sp. having poor water clarity due to an abundance of phytoplankton. At that time native anchialine shrimps were absent and the pool was filled with alien topminnows (*Gambusia affinis*). Under these conditions of accelerated vegetative growth, the process of infilling is increased such that pools so affected could move through the steps of senescence changing from an open body of water, becoming a wetland covered with vegetation and finally to a dry land status in a matter of years rather than otherwise remaining as an open pool for a much longer period of time. Some West Hawai'i pools are located in dated lava flows, thus their age is known. Examining pools with the native complement of species and those infested with alien fishes in the same dated lava flow provides insight as to the speed of habitat decline that may occur.

Over the years considerable effort has been expended in finding suitable ways to rid anchialine pools of alien fish. Both topminnows and tilapia have high fecundity (i.e., birth rates). Topminnows are live-bearers and with tilapia, the male carries the fertilized eggs and earliest juvenile stages in his mouth making complete removal of these fish very difficult for if one pregnant topminnow or a male tilapia carrying eggs escapes, the population of these fishes will return. Furthermore, unless successful removal of all fishes from all pools in a complex is done simultaneously, fish in remaining contaminated pools will recolonize the recently cleared pools. Experiments to find ways of successfully remove fish from anchialine pools has met with little success; topminnows have been placed in light-tight containers that occlude all light for periods up to three months with the result being these fishes survive and reproduce under these conditions. Other experimental work has entailed the use of a radical decrease (or increase) in ambient salinities but these hardy euryhaline fishes continue to thrive. However, in the past, rotenone derived from the root of the derris plant has been successfully used in ridding anchialine pools of unwanted alien fishes. Rotenone is an ichthyocide (i.e., fish poison) and is used by wildlife biologists and aquaculturalists to control unwanted fishes. Rotenone blocks the oxygen receptors on the gills of fishes but will not affect invertebrates or algae at the concentrations normally used. Rotenone is the principal product in "Tomato Dust" which is the most widely used insecticide for row crops in the US to control unwanted insect pests. However, successful use of rotenone in many anchialine pools is difficult because of the usually porous substratum that forms the basins allow fishes to escape to the underlying watertable.

Despite these problems, rotenone is presently the most effective means of control but in recent years its use in aquatic systems has been curtailed by the US EPA due to concerns created by past mistakes by wildlife biologists applying the material inappropriately resulting in destroying more fish over an area larger than intended. Presently, it is illegal under both federal and state statutes to use rotenone in saline waters of the United States and one of the attributes of anchialine pools is their saline waters. Thus there is no legal chemical remedy for the alien fish problem in anchialine systems.

In the old Hawaiian culture, the leaves, bark and roots of the 'akia or false ohelo (*Wikstroemia* sp.) were pounded up, placed in porous containers and sunk in salt-water pools to narcotize fish for easy collection (Neal 1965). Although banned by State law for this purpose, the author has heard that some individuals have tried this method in West Hawai'i anchialine pools for the removal unwanted alien fish with varying success. Again, state statutes ban this use in either anchialine pools or the ocean. In freshwater one tool used by wildlife biologists for the collection of stream organisms is by electroshocking where a electrical field stuns organisms for easy collection. Our early experiments with commercially available electroshockers found that these tools are not effective due to the salinity of anchialine waters thus the electrical field passes around rather than through the organisms and not stunning them. Again, electroshocking in Hawaiian aquatic systems is illegal as per Hawaii State law.

Thus within the last 40 years, most of the West Hawai'i anchialine resource no longer provides suitable habitat for the endemic anchialine caridean shrimps. The rapid decline in habitat quality has been primarily due to the spread of alien fishes in these systems resulting in the displacement of many of the native endemic species. Furthermore, state and federal statutes prohibit use of the only known effective tools to eliminate these unwanted fishes. In short, the long-term outlook for the unique anchialine species appears to be poor because of habitat degradation. Furthermore in the last ten years or so has come another threat to native anchialine shrimp which comes from the aquarium industry. Because opae'ula are relatively small, have striking red pigment, feed on a variety of materials and often naturally occur in relatively high densities, they are able to easily survive in open aquaria or in sealed containers, thus are often collected for the aquarium trade. These shrimp are also used by some for "live food" for rare or unusual saltwater species such as sea horses, etc. Opae'ula are frequently sold through internet sources resulting in a wide distribution. Increasing interest in these unusual "pets" has resulted in heavy collecting in the wild by enterprising individuals selling individual shrimp up to two dollars apiece and the end result is a further decline in the abundance of this species as well as decimation of the habitat by overzealous collectors.

C. Characteristics of Anchialine Pool Water Chemistry

In the last 40 years development of the West Hawai'i coastline has increased tremendously. Our anchialine pool studies commenced on the West Hawai'i coast in 1972 thus preceding much of this recent development and have covered an area from Mahukona to Ka Lae (South Point) in West Hawai'i and up the southeast coast to Hawai'i Volcanoes National Park but most of the work has focused in the South Kohala to South Kona Districts. Over this period of time, we have sampled water quality in marine waters, anchialine pools and wells situated in completely undeveloped settings as well as on developed parcels both before, during and following the completion of construction. Some developed parcels have drilled water quality monitoring wells as well as wells used as a source of low salinity coastal water for irrigation; these wells lie both inland, within and seaward of the developments. Wells situated inland of the development sample the groundwater as it enters beneath a development and wells situated adjacent to the sea sample the groundwater after it has passed beneath the development but before it enters the sea. Differences in measured concentrations of parameters from inland or mauka wells to those lying close to the sea (makai wells), may demonstrate inputs occurring due to the development. Costs for these monitoring programs have been primarily borne by coastal developers but funds for this work have also come as grants from state and federal agencies. Some of these monitoring programs have been in place for more than twenty years. The water quality data sets from these monitoring programs is large; to date, more than 9,700 water quality samples have been analyzed from marine waters and more than 5,500 samples are from anchialine pools and wells. In short, our West Hawai'i survey efforts has resulted in one of the most comprehensive water quality data sets from anywhere in the Hawaiian Islands.

Analysis of this information has noted that the measured concentrations of inorganic nutrients in anchialine pools situated in areas with no surrounding development show that the nutrient chemistry of West Hawai'i groundwater is highly variable and concentrations are frequently in excess of biological needs. Furthermore, some of the highest concentrations are found at locations that lack surrounding development. Development frequently alters the chemistry of the underlying groundwater, increasing concentrations of measured nutrients due to fertilizers and irrigation applied in excess. However, these increases oscillate over time and are not permanent nor do they increase over what has been measured at some completely undeveloped sites. The studies suggest that inorganic nutrients are not limiting in natural anchialine systems on the West Hawai'i coast. In many aquatic habitats other than West Hawai'i anchialine pools, inorganic nutrients are limiting and when supplied in excess, result in major shifts occurring in the aquatic communities. Since inorganic nutrients often naturally occur in excess in Hawaiian anchialine systems and the biota appear to be completely insensitive to changes in the ranges of concentration observed thus far, it is concluded that the increases in concentration that have been measured at many developments have no apparent negative impact on the biota of biologically-intact anchialine pools. This insensitivity is probably due to these species having evolved in a system where inorganic nutrients are not limiting and thus changes in concentrations in the ranges that we have measured on the West Hawai'i coast have no impact. The absence of declines in the abundance of anchialine species in biologically-intact pools on developed parcels further supports the lack of impact to biota from changes in water quality. Finally, the efflux of high nutrient groundwater to the sea along the West Hawai'i shoreline is responsible for many nutrient parameters not meeting State regional water quality standards in the marine environment. However, analysis of the change in compliance with standards prior to and after the commencement of project site construction finds that noncompliance is either no different or greater at control site stations (with no development) relative to those fronting the development. Furthermore, the greatest values of geometric means (used for determining compliance or lack thereof) at control stations are usually significantly greater than those fronting the development thus despite inputs to groundwater measured with development, these changes do not cause a measurable change in the nutrient chemistry of the adjacent ocean. Another finding has been that if the concentration of a measured parameter in the ocean increases at sites fronting development, it increases in a similar way at undeveloped control sites during the same sampling period. These finding support the contention that changes in nutrient chemistry in the West Hawai'i marine waters occurs on a coast-wide basis and not due to some increased input from the development. The probable drivers for these changes are related to coast-wide changes in groundwater inputs as well as changes in coastal current patterns.

The water chemistry studies carried out on the West Hawai'i coast also sample for pesticides used on developed parcels. Since the costs for pesticide analyses are expensive, this sampling focuses on products that have either been in use for some time at a particular project site or have been used recently in relatively large quantities and sampling is usually done on an annual basis. Project site managers furnish a list of all materials used, their quantity, time of application and location of application. From this list and using the criteria given above, sampling for four to seven of the most important products is carried out. In the past, sampling has been undertaken on water and sediment samples usually from anchialine pools as well as in the ocean fronting the project site. Most of these pesticide sampling programs sample not only on the project site but also at a control site having no surrounding development (many programs use the anchialine pools and nearshore waters fronting the undeveloped Awakee-Makalawena parcel). Summarizing the results to date have not found any pesticide product used except one instance of glyphosate (the active ingredient for the herbicide, RoundUp) in a sediment sample from Kukio. This positive finding was due to use of Roundup on weeds within a few feet of our sample site two days prior to the pesticide sampling and following spring high tides which bathed and washed the product from the weeds. The only other significant finding has been a low concentration of the element arsenic which is an active ingredient for several sampled herbicide products. However the measured concentration of arsenic found in West Hawaii'i anchialine pool water and sediment samples are roughly the same among all project site and control site samples which suggests this element is coming from the natural weathering of the native volcanic soils thus the sources are natural.

In summary, the widely-held belief that changes in water chemistry due to development on the West Hawai'i coast are responsible for the changes seen in both marine and anchialine pool biota are not correct. The major negative impact to West Hawai'i anchialine pools has been the release and spread of nonnative fishes which has reduced the habitat available to native anchialine species to less than ten percent of what was available 35 to 40 years ago. Similarly, the declines in average sizes and abundance of targeted marine species is simply the result of indiscriminate overuse and is not related to any imagined change in marine water quality. These statements are made on the basis of 35 years of field observations and the analysis of more than 15,200 water quality samples all collected and processed following US EPA and DOH guidelines.

D. Buffer Zones Around Anchialine Pools

Prior to the implementation of many of the present rules and regulations regarding anchialine pools and extending back into prehistoric times, anchialine pools were modified. With prehistoric/early historic modifications, many of the changes are still apparent today (dry stack rock walls to retain surrounding loose materials from entering pools, steps built down into pools to ease access to the water for drinking purposes, bathing or for the collection of opae'ula to be used as bait). Undoubtedly some anchialine pools were biologically modified by introducing euryhaline native fish including the mullets (uouoa - *Neomyxus chaptalii*, 'ama'ama - *Mugil cephalus*), jacks or papio (members of the family Carangidae), flagtails or aholehole (*Kuhlia sandvicensis*), threadfin or moi (*Polydactylus sexfilis*) and a host of other reef species. These introductions were made to hold fishes that were surplus to immediate needs as well as for purposes of grow-out (i.e., aquaculture). Modification of anchialine pools continued in the historic period with walling and construction of modern homes. Inspection of many of these modified pools finds them today having the normal complement of native species present in normal abundances despite past physical or biological modifications that did not include the use of intentional buffer zones. However, the release of many native fish species into anchialine pools would have undoubtedly resulted in the disappearance of anchialine species (primarily the shrimps) due to predation by the introduced fishes but since all of these fish species require the ocean for successful reproduction, the loss would only be apparent for the duration of the predator's individual lifespan.

Early modifications or no, the three mechanisms resulting in the permanent loss of native anchialine species from the habitat include (1) the intentional burial of pools, (2) the release of alien fish species such as tilapia and topminnows that serve as predators on the native species and can complete their lifecycles in the pond systems thus never disappear as long as a pond is present, and (3) the end result of natural succession due to infilling by the accumulation of plant materials resulting in loss of the water portion of the pond. As noted above, the presence of alien fish in a pond may increase the rapidity of senescence (infilling) if left unchecked.

Buffer zones have been used by the regulatory community for many years to protect a wide range of significant natural and man-made features from activities occurring in the near vicinity. With respect to anchialine pools on the West Hawai'i coast, buffer zones were required for the establishment of the Waikoloa Anchialine Pond Preserve Area (or WAPPA) and these were set fourth in the project Environmental Impact Statement (US Army Engineer District, Honolulu 1985) where a five-foot buffer was required in which no development (i.e., in this case the toe of fill) was to occur between the edge of an anchialine pond and the toe of the fill. Edges of anchialine pools are set by the maximum lateral extent of the pond water surface which occurs at the highest of tides. At the other extreme, the State Land Use Commission placed a thirty-foot buffer between any anchialine pool and development on the (then) Nansay property (now the Kohanaiki Shores project site). Under US COE and County approval, this buffer was modified to allow bridges over some anchialine pools, golf cart pathways adjacent to them and restoration of anchialine pools including the removal of accumulated sediments and construction of walling to keep sedimentary materials from moving into ponds. Thus, anchialine pool buffer zones have varied greatly from zero (prior to modern regulations) to at least forty feet for projects larger than a single family dwelling but nowhere in the information that the author has encountered regarding regulatory permits, is there any scientific rationale for determining the appropriate width for a buffer zone. Lacking a scientific basis brings into question the need for buffer zones.

Having a buffer zone provides a strip of fastland (i.e., dry land) between any construction activities and the actual pond itself thus keeping workers and construction materials out of the pond. Furthermore, a buffer zone can be designated to be left completely undisturbed so as to curtail the importation of soil and planting of non-naturally occurring vegetation directly adjacent to the open pond water. Soils are susceptible to runoff into the adjacent pond coming either from irrigation or from high rainfall events. Buffer zones can and usually are designated as a "no entry" zones except for maintenance purposes which adds another level of protection from accidental or intentional human intervention into the pool.

One common misconception regarding buffer zones around West Hawai'i anchialine pools is that a buffer zone confers some level of protection with respect to the use of fertilizers or pesticides on adjacent developed areas. The highly porous nature of West Hawai'i lava flows (where most anchialine pools are located) means that if a material of a given concentration is going to leach to the underlying groundwater, the width of any buffer zone used to date (five to forty feet) by the regulatory community has little or no impact on the concentration of that material measured in the anchialine pool. Thus buffer zone widths afford little protection from chemicals from anthropogenic sources carried in the seaward flowing groundwater. Changes in the concentration of such materials occurs by uptake, dilution with intruding seawater and sequestration into the bottom sediments all of which actually occur in the ponds themselves.

Figure 3 shows an anchialine pool on the golf course at Mauna Lani Resort in the South Kohala District. This pool contains the normal suite of anchialine species which maintain the benthic community and high water clarity in the pond despite the surrounding development. The five to ten foot wide buffer zone substratum is comprised of highly porous and rough a'a lava that is surrounded on two sides by golf course turf which receives fertilization, pesticides and irrigation yet there has been no impact to the appearance or the native anchialine species in the system. In this case, the lack of impact from anthropogenic inputs is not related to the buffer zone width because of the extreme porosity of the substratum but it supports the contention that the major impact to West Hawai'i anchialine systems are mediated through the release and spread of alien fish, not through changes in water chemistry or the width of any buffer zone imposed by the regulatory community.

STATUS OF THE BIOLOGICAL RESOURCES IN THE OTI ANCHIALINE POOL

A single anchialine pool is present in the OTI project parcel. Mr. Jan War (Operations Manager, NELHA) visited the pond and provided some preliminary notes on the pond location and size as well as aquatic biota seen. The subject pool is located approximately at 19º42'50.39" North, 156º02'54.14" West. Mr. War noted the presence of the red cariden native shrimp (*Halocaridina rubra*) in the pool.

We visited the pool on 31 May 2012 between 1100 and 1230 hours at which time the tide was rising from +1.4 feet to +1.9 feet with the peak occurring at ~1300 hours at +2.0 feet. The pool is situated in a pahoehoe flow and the top of the pool basin is about 3.7 m in diameter and the bottom of the basin lies about 1.8 m below the surrounding pahoehoe surface. The bottom of the pool is comprised of fine terrigeneous mud. The south edge of the basin has been fitted with water-worn basalt rocks providing a means to climb down to the pool's surface (Figure 4). The presence of these stones suggests that the pool was used as a source of drinking water or for the collection of opae'ula as fishing bait in times past. A Christmas berry tree (*Schinus terebinthifolius*) is growing out of the makai wall of the pond and the immediate surrounding vegetation includes fountain grass (*Pennisetum setaceum*; see Figure 4). The depth of water present in the pool was close to 45 cm at 1230 hours and the water surface area was roughly 1.3 m^2. Salinity of the water at the surface was 12.5 ppt, temperature was 21.8ºC and the pH was 7.50.

Mr. War noted that at the time he visited the pool, the local tide was about -0.2 feet and the and the depth of water in the pool was about 10 cm and the water surface covered a roughly 76 x 97 cm area (or 0.74 m^2). His observation probably coincides with close to the lowest part of the tide cycle thus this pool probably contains water through all normal tidal cycles and thus can be considered a "permanent" pool (i.e., continuously having water present).

Aquatic species seen include the ubiquitous opae'ula (*Halocaridina rubra*) occurring at densities between 80 to 125 shrimp/0.1 m^2 and the native alpheid shrimp, *Metabetaeus lohena* (the latter being a Category 5 Candidate Endangered Species) initially occurring at a density of roughly one individual/0.5 m^2. However with the application of bait used to draw out cryptic predaceous species, the abundance of *M. lohena* dramatically rose to more than 20 individuals/0.1 m^2 (see Figure 5). During the 1.5 hours of observation, several small unidentified red amphipods were also seen in the pool. Although not seen by us, melanid snails which are very common in most anchialine habitats are probably also present in this pool.

In summary, this anchialine pool remains in its unaltered state and supports the usual complement of native shrimp species. However the abundance of *Metabetaeus lohena* is unusual which enhances the importance of this pool.

MANAGEMENT OPTIONS FOR THE OTI ANCHIALINE POOL

A. Background Information

Prior to the discovery of the anchialine pool on the OTI HOST Park parcel, there were fifteen known anchialine pools on adjacent NELHA lands. These pools occur in two clusters; one north of the NELHA offices (the north cluster) and the second cluster located just north of the NELHA access road where it first meets the coast (the south cluster). The north complex of pools is comprised of six ponds with one pool (N-6) being recently constructed (by an unknown party) and in the southern cluster, there are nine pools present. Brock (2008) noted that prior to his August 2008 survey, all five pools (then present) in the north complex had been colonized by alien fish that were subsequently removed by unknown means and by the August 2008 survey, native shrimp had returned to the five pools. At the same time in the south complex of pools, only two ponds remained free of alien fish (Brock 2008). More recently, Ziemann and Conquest (2011) found native anchialine biota present (*Halocaridina rubra*) in the five north cluster of pools as well as in a newly constructed pool (labeled N-6). At the same time five of the nine pools in the southern cluster contained native anchialine species (pond numbers S-2, 4, 6, 8 and 9) while four pools (S-1, 3, 5 and 7) continued to be colonized by alien fishes.

Thus the biological status of eleven of fifteen NELHA anchialine pools (or 64%) appear to have their complement of native species as given in the most recent Ziemann and Conquest (2011) survey completed in November 2010. However and as noted above, the biological status of seven of the fourteen known pools (or 50%) prior to the August 2008 survey was poor due to the presence of alien fishes that had displaced many of the native species. At that time the recent return of native aquatic species in the north cluster of pools must have been due to the intentional use of an ichthyocide to remove the alien fish. The historical changes that have occurred in the biota of the now fifteen NELHA anchialine ponds demonstrates how quickly human use can affect a negative change in the pond biota. As noted above, the only effective means to remove alien fishes is via chemical methodologies which are illegal. Thus an “open access” policy to anchialine resources by the general public represents high risk to the biological integrity of those resources.

A case in point is the decline of anchialine resources that occurred in the Waikoloa Anchialine Pond Preserve located at Waikoloa roughly 29 km north of Keahole Point. As noted by Brock (2011, p. 66):

“Sometime between 9 December 2003 and 9 March 2004 field surveys, someone had intentionally released tilapia into the anchialine pools of the WAPPA (the Waikoloa Anchialine

Pond Preservation Area) *on the makai side of the road. The largest and oldest fish were in pond numbers 31 and 32 directly adjacent to the roadway and at the time of their discovery, these fish were actively reproducing. About 20 pools or roughly one-third of the system was infested with the problem on 9 March 2004. No native shrimp were present in any of the pools containing tilapia. It was surmised that the release of fish had been done in late December 2003 or early January 2004 which would account for the extent of the spread. Waikoloa management was immediately notified of the problem and they along with representatives from the U.S. Army Corps of Engineers instituted a management program and strategies to control the spread of these alien fish species.*

At the time of the first quarter 2004 survey, tilapia were present in Pond 155 (site 11) but had not colonized site 22 (Pond 188) but by the second quarterly (6 May 2004) survey, tilapia were present in all but one small isolated pool on the makai side of the roadway. Because the tilapia are predators on the native shrimp, these shrimp disappear and the diurnal census for these species shows them to be absent. Their absence results in statistically significant changes (decreases) in their abundance as noted above.

However, tilapia had not colonized the anchialine pools located on the mauka (inland) side of the access road that bisects the WAPPA up through the 8 January 2008 survey. Thus one of the routine sample sites located in the mauka portion of the preserve (Pond 48 or site 21) continued to have high counts of native shrimp present. Mr. Tim Cooke resident pond manager tracked the spread of tilapia in the mauka WAPPA system noting that it was in January 2008 that he first saw a tilapia '...in the mauka anchialine pond system. It was limited to just one pond in the northwest corner. Within two months the population had grown expontentially to several hundred and the pond showed signs of degradation, slight build up of silt and the algal mat was shrinking in size. Within four months, April 2008, the silt build up had increased to at least 4 to 6 inches in the deeper portions of the pond, the algal mat was virtually gone and the tilapia population continued to increase. Six months later, July 2008, the silt depth was 12 or omre inches, the algal mat was completely gone and the tilapia population seemed to have leveled off to several hundred.' ....Subsequently, tilapia have spread throughout the pools in the WAPPA such that today we are aware of no more than two small isolated pools in the WAPPA that remain free of tilapia."

With no legal means of controlling the spread of alien fishes, we can expect that the anchialine resource in areas that are accessible to the general public will continue to decline due primarily to the release and spread of alien fishes. It is only a matter of time. The disappearance of alien fishes in NELHA pools could have only occurred through the illegal use of a chemical ichthyocide by someone willing to take that risk to preserve the rapidly declining resource. This may be commendable, but it is illegal. Had it not happened (along with the digging of a "new" pond), twelve of the fourteen known natural pools at NELHA (or 86%) would be biologically degraded today due to the presence of alien fishes. This demonstrates the vulnerability of the anchialine system for its continued viability.

B. Recommendations

1. Given the above and the fact that the OTI anchialine pool is located on the project site, it would appear that a logical management strategy for this pool would be to preserve it by keeping within the project's fence system thus precluding public use of the pool. The argument that these resources must be made public is not in the best interest of the resource. There are anchialine pools presently open to the public on the NELHA parcel; having one pool that up to recently was not publicly known behind a fence is not.

2. Because the Christmas berry tree as well as the fountain grass growing around the pool are non-native and contribute to the vegetative litter in the pond, it is suggested that removal of these species within an approximate five-foot radius of the pond be made and a fence be erected to keep construction debris and people outside of the pond.

3. Signage should be posted around the pool, informing construction personnel and employees to stay out of the pond and not place any aquatic species, chemical or debris in the pool. As noted above, there is no scientific justification for a "buffer zone" but the fence should be situated three to five feet from the upper edge of the pond basin.

4. As part of the orientation of all personnel (construction and employees), the importance of observing the rules regarding no (1) entry into the pool, (2) dumping of wastes, (3) release of aquatic species into the pool and (4) signage around the anchialine pool should be made. Problems should be reported to NELHA staff.

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Limitations: Although the author has spent 40 years studying Hawaiian anchialine systems and the impact of coastal development on these as well as on marine resources, he is not an expert on the legal issues or regulatory-issued permits associated with development. Thus comments regarding setbacks or buffer zones with respect to development herein are solely based on the considerable data base and the expected impact or lack thereof on the resource targeted for protection and are not based on any legal or permit requirements.

FIGURE 1. Photograph of an anchialine pool at Makalawena, North Kona, July 1972. Not apparent in the photograph is the high clarity of the water, rocky basin with the characteristic cyanobacterial mat (*Schizothrix*) and the numerous native red cariden shrimp present. (Author photo).

FIGURE 2. Photograph of the same pool shown in Figure 1, Makalawena, North Kona, August 1985. In the interim between these two photographs, topminnows (*Gambusia affinis*) were introduced to this pool and many other anchialine ponds at Makalawena. In this photograph, the water column and water surface are covered with the stringy green alga, *Cladophora* sp. Not evident in the photograph is the lack of water clarity due to high levels of phytoplankton present in the pool and the loss of the cyanobacterial mat and native herbivorous shrimp species. (Author photo).

FIGURE 3. Photograph of an anchialine pool situated in porous a'a lava on the golf course at Mauna Lani Resort, South Kohala, West Hawai'i, 1992. Note the high water clarity, the cyanobacterial mat across much of the rocky pool bottom and the development of turf to within five feet of the pond. Not evident in the photograph are the high numbers of native opae'ula or *Halocardina rubra*. (Author photo).

FIGURE 4. Photograph taken on 31 May 2012 of the subject anchialine pool showing the water worn basalt rocks in the foreground put in place to assist in climbing down to the water's surface. Marine tide height at the time was roughly +1.4 feet and rising and apparent water depth in the pool was about 30 cm. Also apparent is the Christmas berry tree to the left that deposits leaf litter in the pool and fountain grass to the right.

FIGURE 5. Photograph of the predaceous native anchialine shrimp, *Metabetaeus lohena* feeding on bait placed in the subject anchialine pool. *Metabetaeus lohena* is a Category 5 Candidate Endangered Species. These shrimp are about 20 mm in length.