Job No. 25-OW-A

PUMPED STORAGE HYDROELECTRIC POWER PLANT STUDY

OAHU, HAWAII

Report R-109

Prepared by:
Okahara & Associates, Inc.
200 Kohola Street
Hilo, Hawaii 96720

1959

State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT AND TOURISM
and
HAWAIIAN ELECTRIC COMPANY, INC.
Honolulu, Hawaii

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1. Department of Land and Natural Resources:
    - Division of Water and Land Development
    - State Historic Preservation Division

2. Department of Business, Economic Development and Tourism
    - Energy Division

3. Hawaiian Electric Company
    - Engineering Department
    - Generation Planning Department
    - Transmission and Distribution Department
    - Environmental Department

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EXECUTIVE SUMMARY

The State of Hawaii Department of Land and Natural Resources in cooperation with the Department of Business, Economic Development and Tourism, and Hawaiian Electric Company sponsored a study to improve the understanding of the issues related to construction and operation of a Pumped Storage Hydroelectric facility on Oahu. Pumped Storage Hydroelectric is a well established technology with many operating facilities worldwide. These facilities provide electrical generating capacity during peak power demand on the electric utility by releasing stored water in an upper reservoir through generators to a lower reservoir. The water that is stored in the upper reservoir is initially pumped there from the lower reservoir during off-peak utility demand periods.

Pumped storage hydroelectric generation is included as one of a number of established generating technologies in the Integrated Resource Planning work that is being performed by Hawaiian Electric Company. In support of that work this study focused on two specific sites (located as shown on figure ii-1) for a pumped storage hydroelectric facility;

1. Koko Crater as the upper reservoir with the lower reservoir formed by the adjacent ocean area enclosed by a pervious breakwater, using salt water as the working fluid. Figure ii-2 is an artist concept of the dam at the Koko Crater, and Figure ii-3 is an artist enhanced photograph of a salt water pump storage hydroelectric project on Okinawa. The Koko Crater project will be similar to it.

2. Kaau Crater as the upper reservoir with a lower reservoir in Maunawili Valley using fresh water as the working fluid.

The objective of this study is to determine the feasibility of installing a pumped storage hydroelectric facility at either site and to select one site for further consideration.

Both sites were sized for a nominal electrical output of 160 megawatts of generation for a period of 6 hours and a pumping period of 8 hours. The generating/pumping cycle would be repeated daily, seven days a week. In the Kaau Crater/Maunawili project the reservoirs would hold approximately 455 million gallons of fresh water; Koko Crater would hold approximately 1,220 million gallons of salt water. Each facility would cost approximately $250 million and require about 7 years of construction.

While both sites have significant environmental issues associated with development of a pumped storage hydroelectric facility, the Kaau Crater/Maunawili project would have far more significant impacts. The most significant issues are the following;

Koko Crater Project

- Public concerns about the safety of the reservoir dam.

- Affects on the marine environment by the breakwater structure.

- Relocation of the Botanical Garden and use of the crater park.

- Routing of the transmission line from the crater.

-Visual impact of the reservoir dam.

Kaau Crater/Maunawili Project

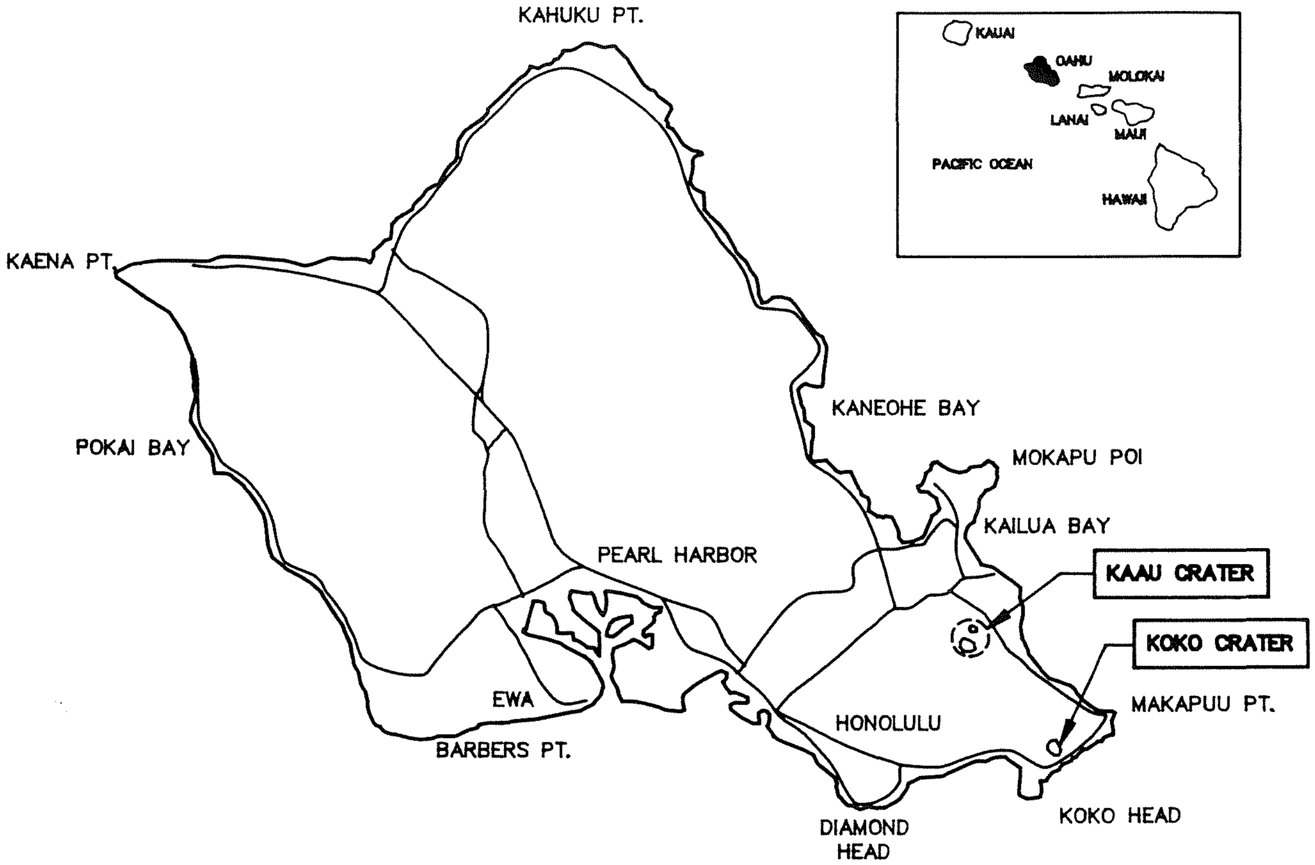
- Replacement of the Kaau Crater wetlands with a fresh water reservoir.

- Disruption of water flow into the Maunawili Ditch and Kawainui Marsh and inundation of portions of the Maunawili Ditch with a fresh water reservoir.

- Impact on many acres of habitat on the lower slopes of the Koolaus.
- Visual and environmental impact of the access road to Kaau Crater from Palolo Valley.
- Public concerns about the safety and visual impact of the reservoir dam.
- Relocation of the banana farmers in Maunawili Valley.
- Potential disruption of archaeological sites.

The study concluded that both projects were technologically and economically feasible; however, the environmental impacts, with no evident mitigation measures, of the Kaau Crater/Maunawili project caused this project to be eliminated from further consideration. The Koko Crater project, however, appears to have reasonable mitigation measures available to make this project environmentally feasible.

This report provides only an elementary understanding of the construction, environmental and economic issues related to pumped storage hydroelectric on Oahu. Therefore, it is recommended that additional work be performed including 1) the preparation of an Environmental Assessment to better define the environment of the Koko Crater and the adjacent ocean area, and to address the technical, social, safety and economic issues; and 2) geotechnical field work to characterize the structure of the crater and the ocean floor adjacent thereto.



ISLAND OF OAHU

NOT TO SCALE

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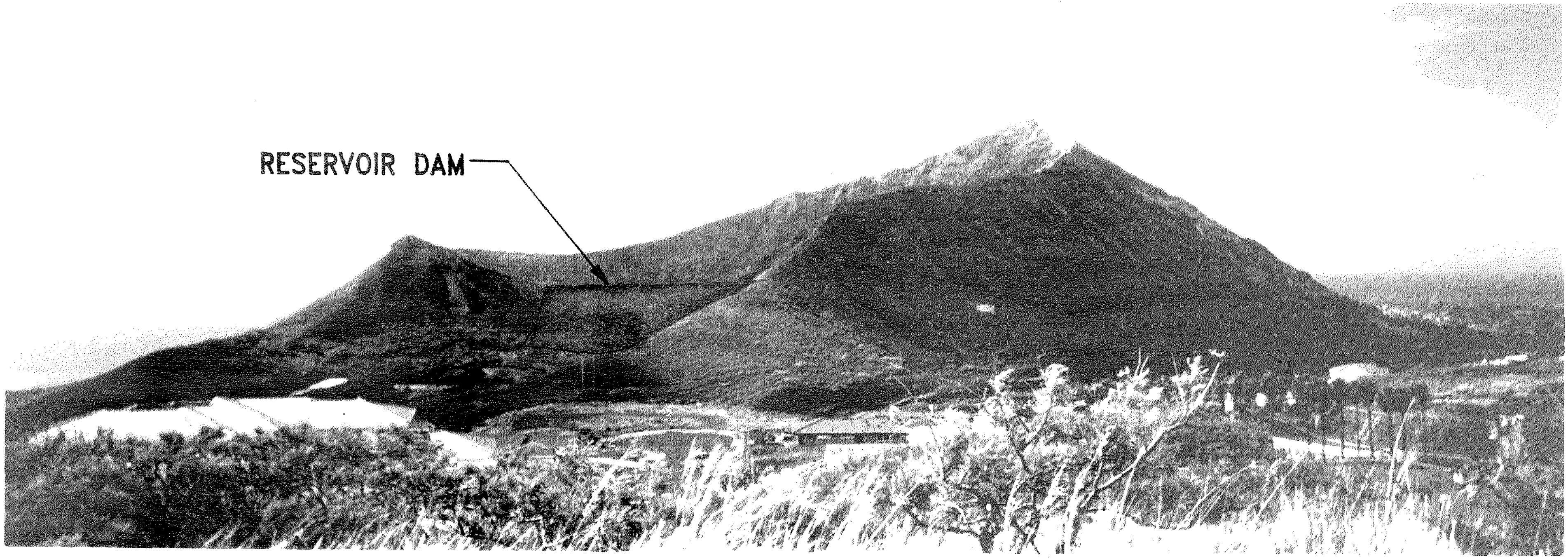
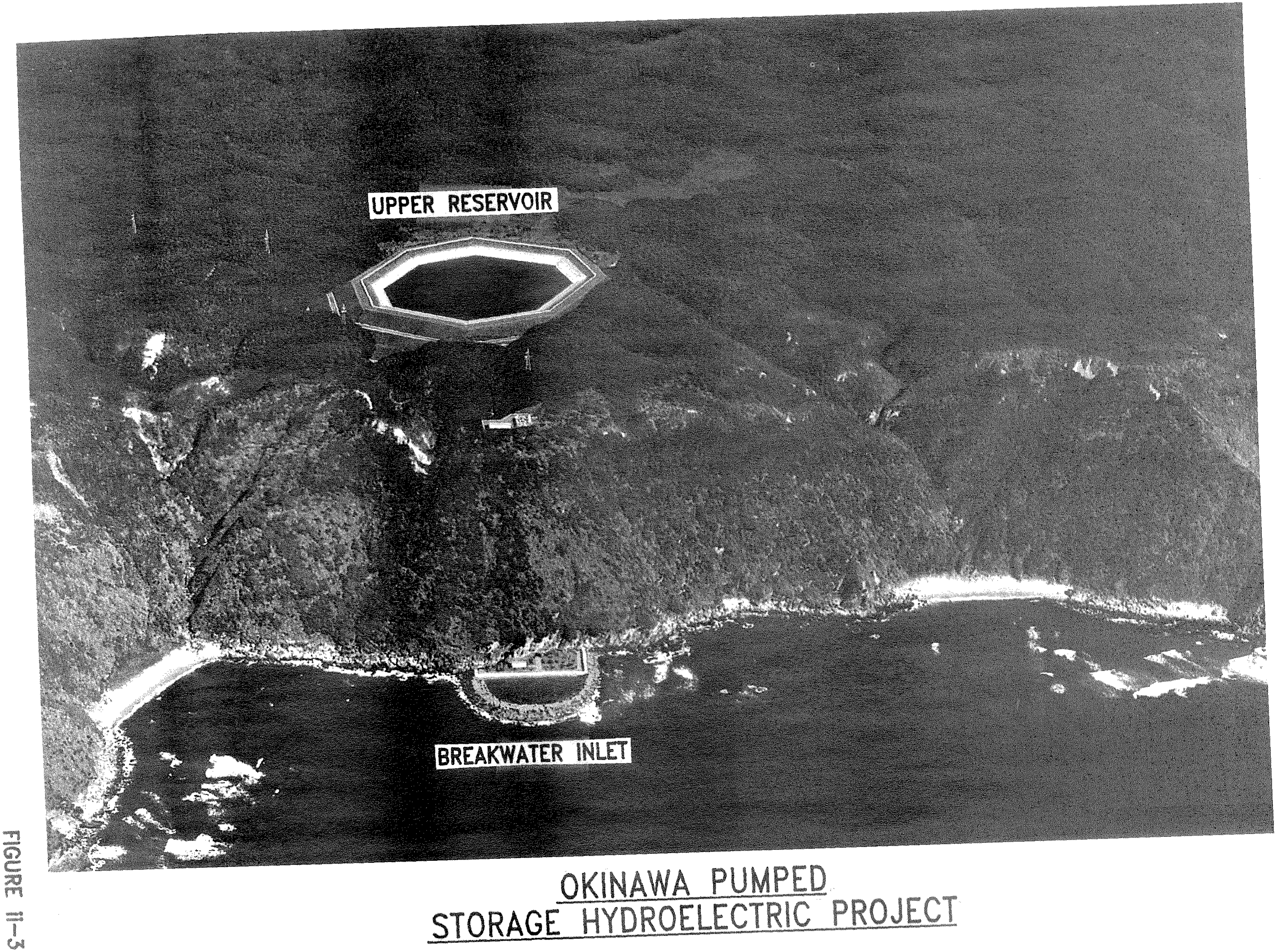
PROJECT SITE LOCATION

FIGURE ii-1



KOKO CRATER RESERVOIR

FIGURE 11-2



OKINAWA PUMPED
STORAGE HYDROELECTRIC PROJECT

FIGURE 11-3

SECTION I. INTRODUCTION

A. Purpose of Report

Since the early 1970's, the State of Hawaii has promoted policies to reduce its dependence on imported fossil fuel and the Hawaiian Electric Company (HECO) has been supportive of these policies through its many initiatives in alternative energy projects such as wind farms and geothermal energy. Under the direction of the State of Hawaii's Public Utilities Commission (PUC), HECO recently developed a long range plan for its future energy needs on Oahu. This effort culminated in a document titled "Integrated Resource Planning" (1) This document details generation demand-side strategies to the year 2013. One of the generation strategies that appears promising is pumped storage hydroelectric.

Pumped storage hydroelectric (PSH) operates on the basis that an overall increase in utility operating efficiency can be realized by pumping water from a lower reservoir to an upper reservoir during utility off peak hours and then using the flow to generate electricity during peak demand. PSH technology is well established and is represented by many large and small projects throughout the United States and the world. It has the advantage of reducing the overall consumption of fossil fuels and is generally considered environmentally clean since it results in a net reduction of gaseous emissions compared to other alternatives. In addition PSH plants have a relatively useful life of 50 - 100 years (2) compared to conventional fossil fuel technologies.

This report documents the work performed by the State of Hawaii Department of Land and Natural Resources (DLNR), the Department of Business Economic Development and Tourism, and HECO to examine the technical, economic, and environmental feasibility of a PSH facility on the Island of Oahu. The timing of this work is appropriate since the total lead time to develop a PSH facility is 8-12 years (2) and HECO studies indicate the use of PSH in about 2005.

The objective of this study is to determine the feasibility of installing a pumped storage hydroelectric facility at the Koko Crater and the Ka'au Crater/Maunawili Valley and to select one feasible site for further consideration.

B. Organization of Report

This document is organized into four parts;

First, it describes the work by HECO that lead it to consider PSH in its future generation mix, and to broadly identify some of the environmental and conceptual design considerations that needed to be addressed.

Second, a more in-depth discussion of environmental and legal considerations--based on literature search, field surveys and discussions with various agencies and individuals is presented.

Third, expanded design concepts of the two HECO concepts --one for the Koko Crater and the other for the Kaau Crater is discussed. The location of these sites is shown on figure I-1.

Fourth, recommendations on the environmental, technical and economic feasibility of each project are presented, as well as what future direction and effort should be undertaken for the Pumped Storage Hydroelectric concept for Oahu.

Several reports were prepared as part of this endeavor and are included in their entirety as appendices. The salient points in these reports are included in the body of this document.

C. BACKGROUND

1. Integrated Resource Planning

The State of Hawaii Public Utilities Commission (PUC) directed HECO to undertake an integrated resource planning effort with the goal as "the identification of the resources or the mix of resources for meeting near and long term consumer energy needs in an efficient and reliable manner at the lowest reasonable cost.". (1) The planners understood this goal would be achieved through balancing the customer, utility and societal perspectives.

Toward this goal HECO analyzed a matrix of feasible power generating resources, demand-side management programs, existing facilities replacement requirements, transmission lines, environmental considerations, statutory requirements, and costs. The planning horizon was over a time frame of twenty years to the year 2013. In this time frame it was projected that there would be an annual 1.6% long term growth in demand as well as the need to replace aging facilities. The IRP forecasts that peak demand would grow from the 1993 level of about 1200 megawatts (MW) to a 2013 level of about 1500 to 1800MW depending on whether the economic growth on Oahu is viewed as depressed or optimistic. This long range perspective allowed the consideration of demand side programs, such as solar and heat pump water-heating that would reduce the consumption of electricity, and consideration of generating facilities other than fossil fuel steam plants which are the major type of facility in the HECO system.

PSH was included in the IRP analysis because it provided for diversity of supply resources and it is a technology that is currently available through competitive bidding practices for utility application. Although PSH technology was not included in HECO's "preferred plan", PSH was considered a technology important enough to merit further study, and was included as an action item in the IRP 5-year action plan.

Two sites were identified in the IRP-Koko Crater and Kaau Crater/Maunawili. Although the work by HECO concluded that there would be significant environmental and societal impacts if either project were to go forward, PSH offered a cleaner alternative to a fossil fuel plant. In addition, siting a generating plant in East Oahu could have beneficial effects on the stability and reliability of the HECO system.

Since some of the highest ranking integrated plans included PSH, HECO in cooperation with the DLNR and DBEDT undertook an effort to further explore the feasibility of having a PSH facility built and operated as part of the HECO utility system. HECO performed calculations and prepared cost estimates of an elementary nature to support the integration analysis. This work was performed by the engineering firm of Black & Veatch and is summarized in Section I-3 following.

2. Environmental report

In support of its work on the analysis of alternative supply-side facility plans, HECO had the firm of EnviroSearch International develop an assessment of the environmental issues related to each of the different facility technologies, i.e. coal-fired, oil-fired, wind, and pumped storage hydroelectric.

The work by EnviroSearch was reported in a document titled "Environmental Assessment of Supply-Side Technologies". (3) This report concluded that both the Koko Crater and Kaau Crater projects would have significant impacts on various elements of the environment. Unlike the IRP which analyzed the different facility groupings against each other, the ranking of PSH by EnviroSearch was against environmental criteria. That is, PSH was ranked at each of the two sites in terms of its direct impact on water, air, biodiversity, cultural, physical, etc. For example, coal-fired, oil-fired, and PSH are all ranked "low" in terms of impacts on air quality while it is clear that PSH has a much lower impact on air quality than either coal-fired or oil-fired plants.

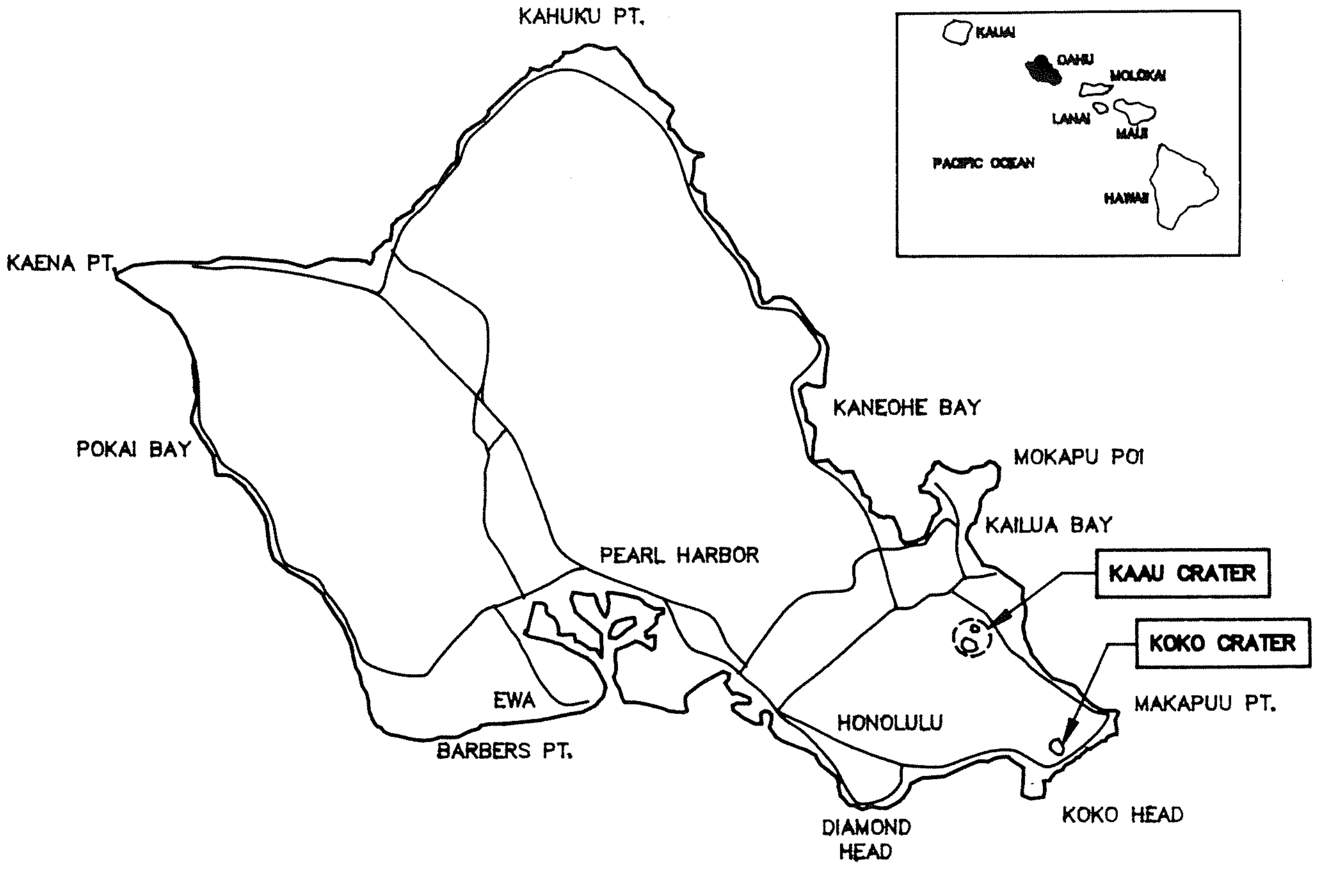
The present report expands on EnviroSearch's work by supplying more detail and specificity to each of the environmental issues and includes an effort to identify mitigating measures for each site.

3. Baseline Design by Black and Veatch (4)

The recognition of PSH as a potential generating facility for HECO led to the development of a conceptual design to provide a better understanding of the technical features and conceptual costs of the projects. Black & Veatch developed elementary concepts with the following features:

	Koko Crater	Kaau/Maunawili
Crater Power level: MW	160	250
Reservoir storage: ac-ft	4470	3100
	(1475Mgal)	(1023Mgal)
Head: ft	345	970
Surface area: acres	60	53 upper
		46 lower
Dam height: ft	160	100 upper
		130 lower
Dam length: ft	750	400 upper
		2670 lower
Total Capital Cost	$161M	$256M
	$1,007/kw	$1025/kw

The above characteristics formed the basis for the conceptual design described in Section III of this report.



ISLAND OF OAHU
NOT TO SCALE

PROJECT SITE LOCATION

FIGURE I-1

PART II - ENVIRONMENTAL AND LEGAL ISSUES

A. APPROACH

Hawaiian Electric Company's Integrated Resource Plan (IRP)(1) contained reconnaissance level descriptions of the major project components, performance estimates, cost estimates, potential environmental impacts, and objective characterizations for a pumped storage hydroelectric (PSH) facility located either at Koko Crater or Kaau Crater on Oahu. The IRP stated that should the pumped storage option appear favorable, the next step in the assessment process would be a pre-feasibility study. Such a study would give a more specific indication of the technical feasibility of the sites, potential environmental impacts, and mitigations. A pre-feasibility study usually involves the acquisition of basic environmental data specific to the site through field inspections.

The environmental data and other legal considerations summarized herein are based on reviews of other pertinent studies, interviews with agency personnel and citizens' group representatives, and limited field reconnaissance of both potential sites. Specialists in flora, fauna, and archaeology visited each site, and their respective reports may be found in Appendices A through D.

The environmental baseline information and impact analyses provided herein are similar to the contents of a formal environmental assessment (EA) as described in Chapter 343, Hawaii Revised Statutes (Hawaii's Environmental Impact Statement (EIS) Law) and Chapter 200, Hawaii Administrative Rules (Hawaii's EIS Rules); however, not all of the requirements are met. The scope of this report was limited with the intent of selecting the more feasible of the two sites before a full environmental assessment was made. Should either of the two potential sites be selected for further work, a formal EA, and likely an EIS, would be required.

Sections II-B and II-C respectively describe the site characteristics, ownership, land use and permitting requirements for the Koko Crater and the Kaau Crater/Maunawili PSH projects. Sections II-D and II-E discuss conclusions regarding the feasibility of each project and recommendations for follow on work.

B. KOKO CRATER PROJECT

1. Landside Facilities

a. General Site Characteristics

Koko Crater is located on the southeastern portion of the island of Oahu, in the Honolulu Judicial District. The crater, rising to about 1,200 feet above sea level, is horseshoe-shaped, opening to the northeast. The crater is a compound tuff cone formed by volcanic eruptions along the Koko fissure two million years or more after the principal volcanic activity which built the Koolau Shield Volcano. It is the highest, best preserved and probably most recently formed tuff cone on Oahu.(2) (Appendix E provides detail on the crater's geological features)

Koko Crater is separated from the ocean by Kalanianaole Highway and extends from Koko Head to Sandy Beach. The interior of the crater contains a 200-acre botanical garden and a riding stable at its opening. The botanical garden includes a wide variety of cacti, plumeria, and other plants. A portion of the Hawaii Kai Golf Course is located on the north side of the crater. The crater is part of the Koko Head Park.(3)

Koko Head Park, administered by the City and County of Honolulu Department of Parks and Recreation, was established in 1928, and is the largest City-owned park on Oahu. The park area consists of 19 separate parcels of land totaling 1,275 acres. With the exception of three parcels totalling about one acre in area owned by Hawaiian Telephone Company, the land is owned by the City and County of Honolulu. The land was acquired by the City from the Estate of Bernice Pauahi Bishop, with a deed restriction that use of the area be limited to public parks or rights-of-way. According to the deed, any non-recreational activities in the park must be approved by the Bishop Estate Trustees.(4) Figure II-1 shows the ownership of parcels within and surrounding the Koko Crater project site.

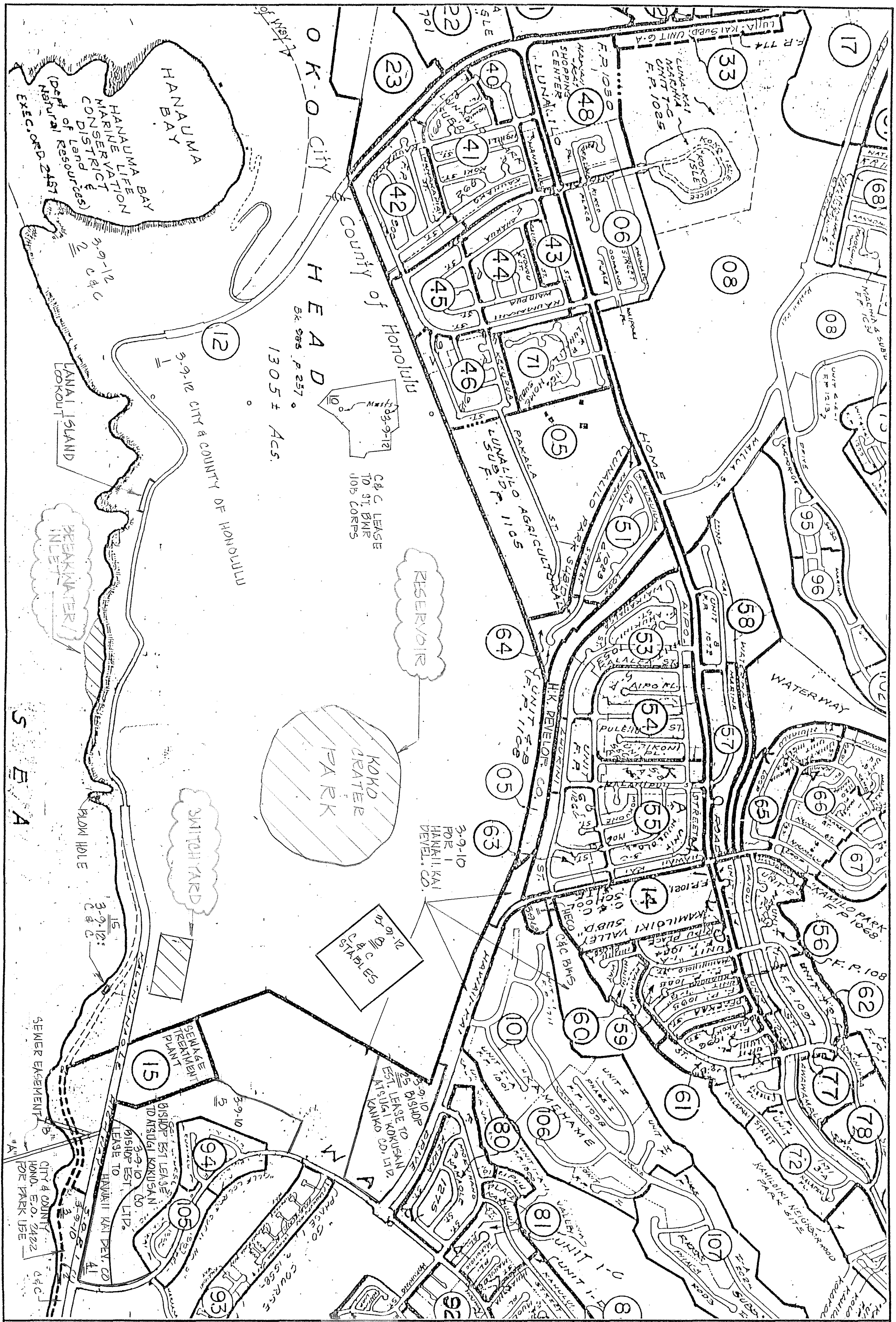


FIGURE II–1

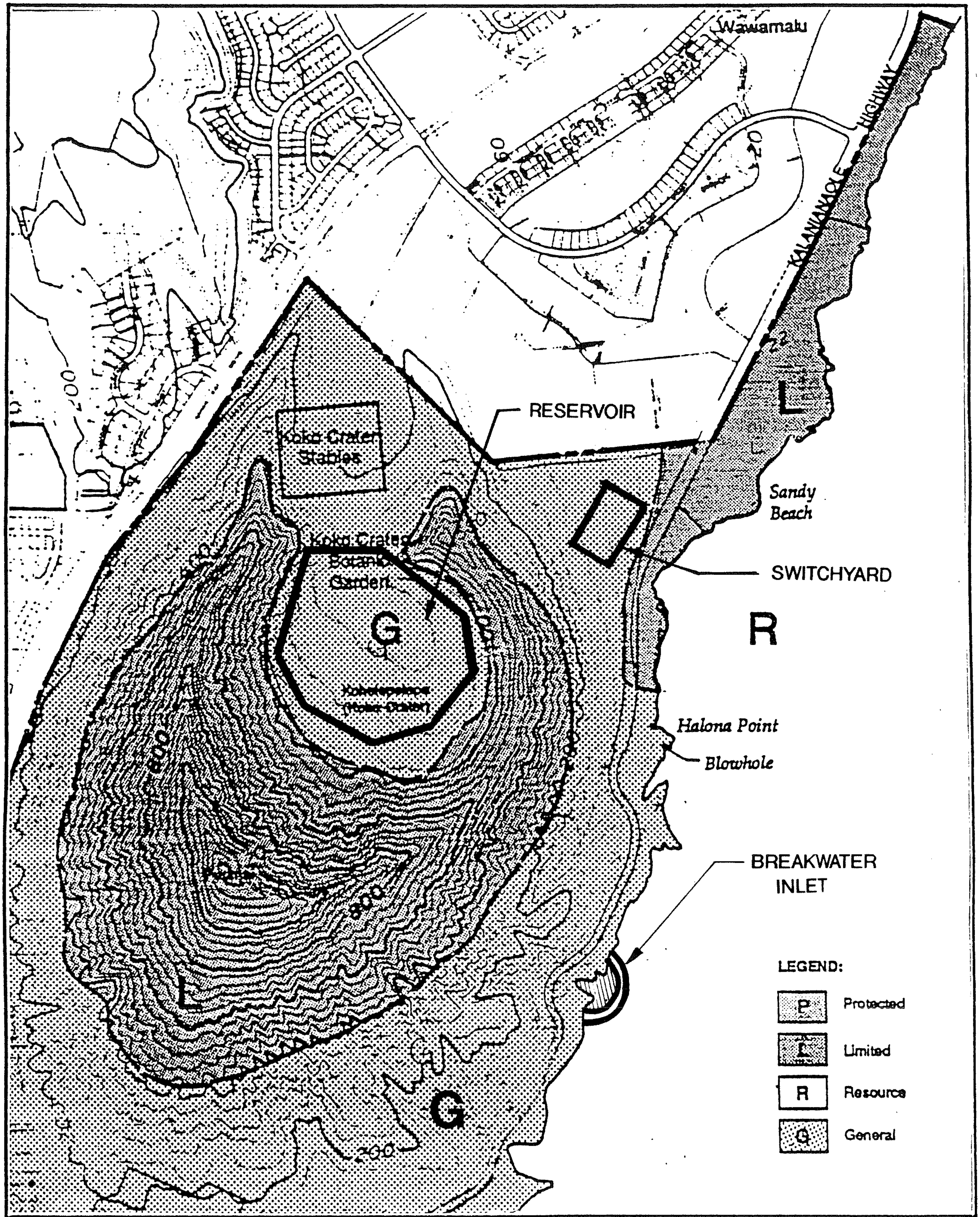
KOKO CRATER PSH PROJECT

LAND OWNERSHIP

Landside facilities associated with the PSH project would include an upper reservoir (Koko Crater), an access road into the mouth of the crater, tunnels through the crater to a combined, below-grade pump-house generating station, and electrical transmission lines and switchyard. All but the transmission line would be situated on City lands. The conceptual plans call for the electrical switching station to be located adjacent to the existing Hawaii Kai Sewage Treatment Plant on lands within Koko Crater Park. Routing the transmission lines will likely involve both public and private land easements. The shoreline breakwater/inlet is discussed in Section II-B.2.

Koko Head Park and the adjacent nearshore waters are within the State Conservation District. Surrounding lands, including the potential switchyard site, are designated Urban. The State Conservation District is divided into subzones according to the degree of protection accorded specific areas. Figure II-2 shows the Conservation District subzones in the project area. The floor of the crater and lands from the shoreline to about the 400-foot elevation are in the General subzone. The objective of this subzone is to designate open space where specific conservation uses may not be defined, but where urban use would be premature. A specifically permitted use in this subzone is development of water collection, pumping, storage, control, and transmission; however, application of this permission to a pumped storage hydroelectric facility may exceed the intent of the permitted use.

Waters offshore of Koko Crater are in the Resource subzone. The objective of this subzone is to develop, with proper management, areas to ensure sustained use of the natural resources of those areas. The slopes of Koko Crater above about the 400-foot elevation are in the Limited subzone. The objective of this subzone is to limit uses where natural conditions suggest constraints on human activities. In any subzone, governmental use is permitted where public benefit outweighs any impact on the conservation district. Generally, a utility use may be considered governmental use, but a formal environmental assessment (and likely an EIS) would be required to assess the relative benefits and impacts of the PSH project.



KOKO CRATER PUMPED STORAGE HYDROELECTRIC PROJECT

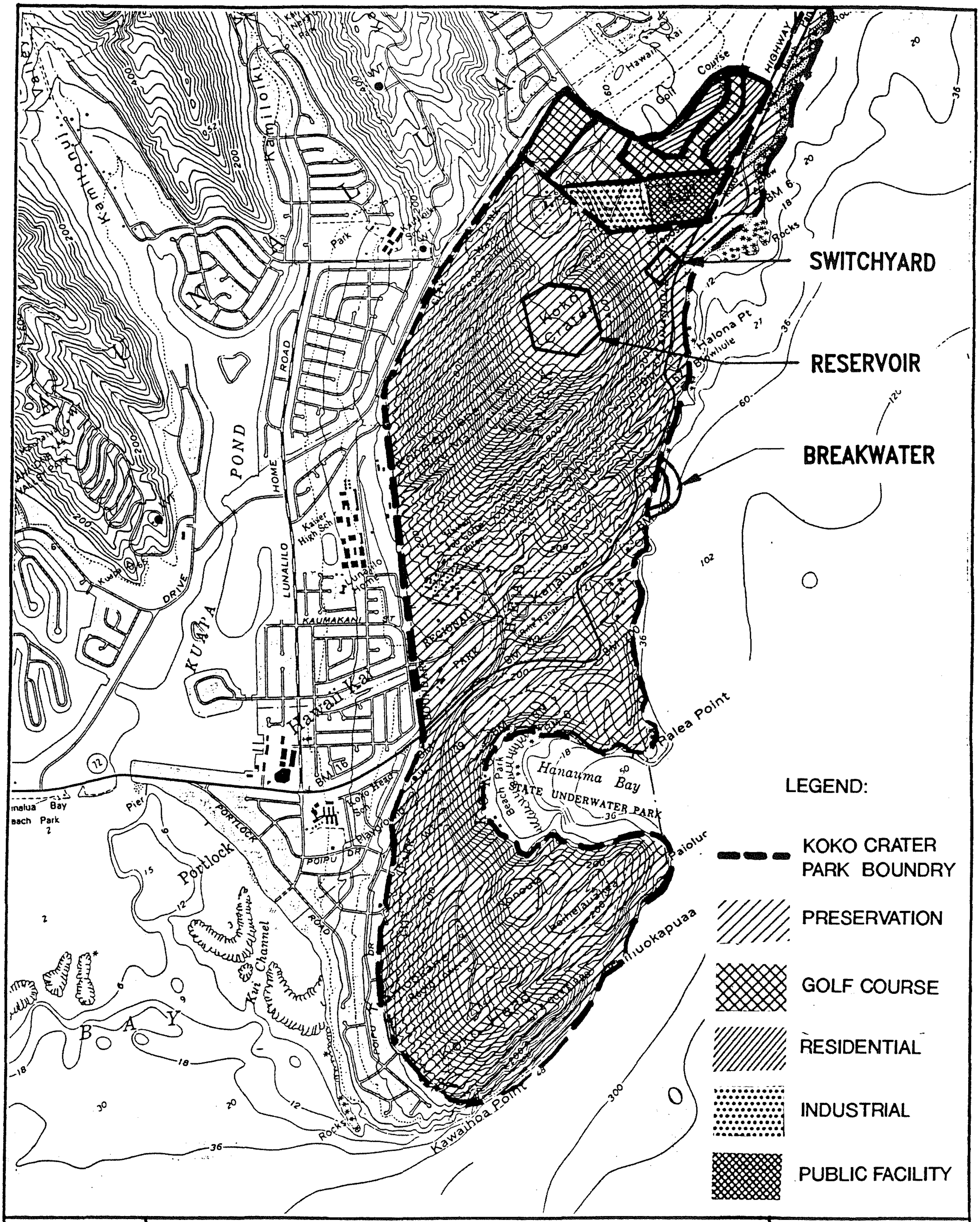
STATE LAND USE SUBZONES

FIGURE II-2

At the City level, future land uses are guided by the Development Plan. Koko Head Park is located in the East Honolulu Development Plan area. The entire park is designated as Preservation on the Development Plan's land use map. This designation is consistent with the State designation of the area as Conservation.(4) Figure II-3 indicates the East Honolulu Development Plan land use for the project area. The Sewage Treatment Plant site is designated Public Facility. Mauka of that is a parcel designated Industrial, where the proposed switching station could alternatively be located. The East Honolulu Public Facilities Map shows development of a solid waste transfer station in this area and improvements to the Koko Crater Botanic Garden.

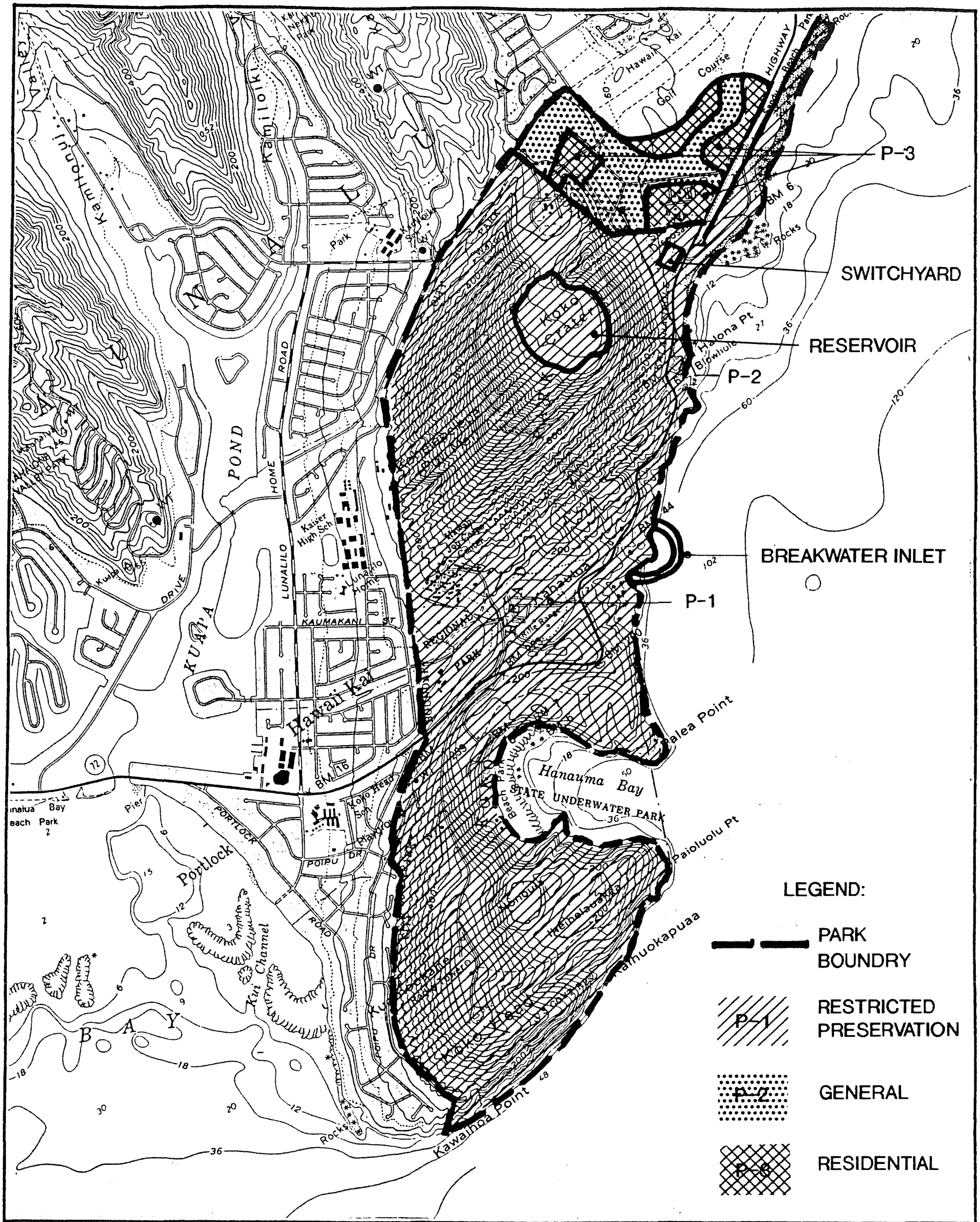
Special Provisions of the East Honolulu Development Plan relating to urban design considerations specify that high priority shall be given to visibility, preservation, enhancement and accessibility of open space in the design of developments near Koko Crater.

Specific land use zoning and development controls for all property on the Island of Oahu are established in the City & County Land Use Ordinance (LUO).(5) Eleven zoning categories are identified in the LUO: Preservation, Agricultural, Country, Residential, Apartment, Apartment Mixed Use, Resort, Business, Business Mixed Use, Industrial, and Industrial-Commercial Mixed Use. Most of these classifications are further broken down into specific zoning designations which dictate both density and use. Figure II-4 shows the zoning designations in the project area. Koko Head Park is zoned P-1 Restricted Preservation, one of three possible designations under the Preservation Classification. According to Section 5.10 of the LUO, "It is intended that all lands within a State-designated Conservation District be zoned P-1 Restricted Preservation District." Section 5.10-1 establishes the Uses and Development Standards for the three Preservation Zoning Districts. It states, in part, "Within the P-1 Restricted Preservation District, all uses, structures and development standards shall be governed by the appropriate State agencies." It is, therefore, important to note that while Koko Head Park is zoned by the City and County of Honolulu, and regulated by the City's East Honolulu



KOKO CRATER PUMPED
STORAGE HYDROELECTRIC PROJECT
EAST HONOLULU DEVELOPMENT PLAN

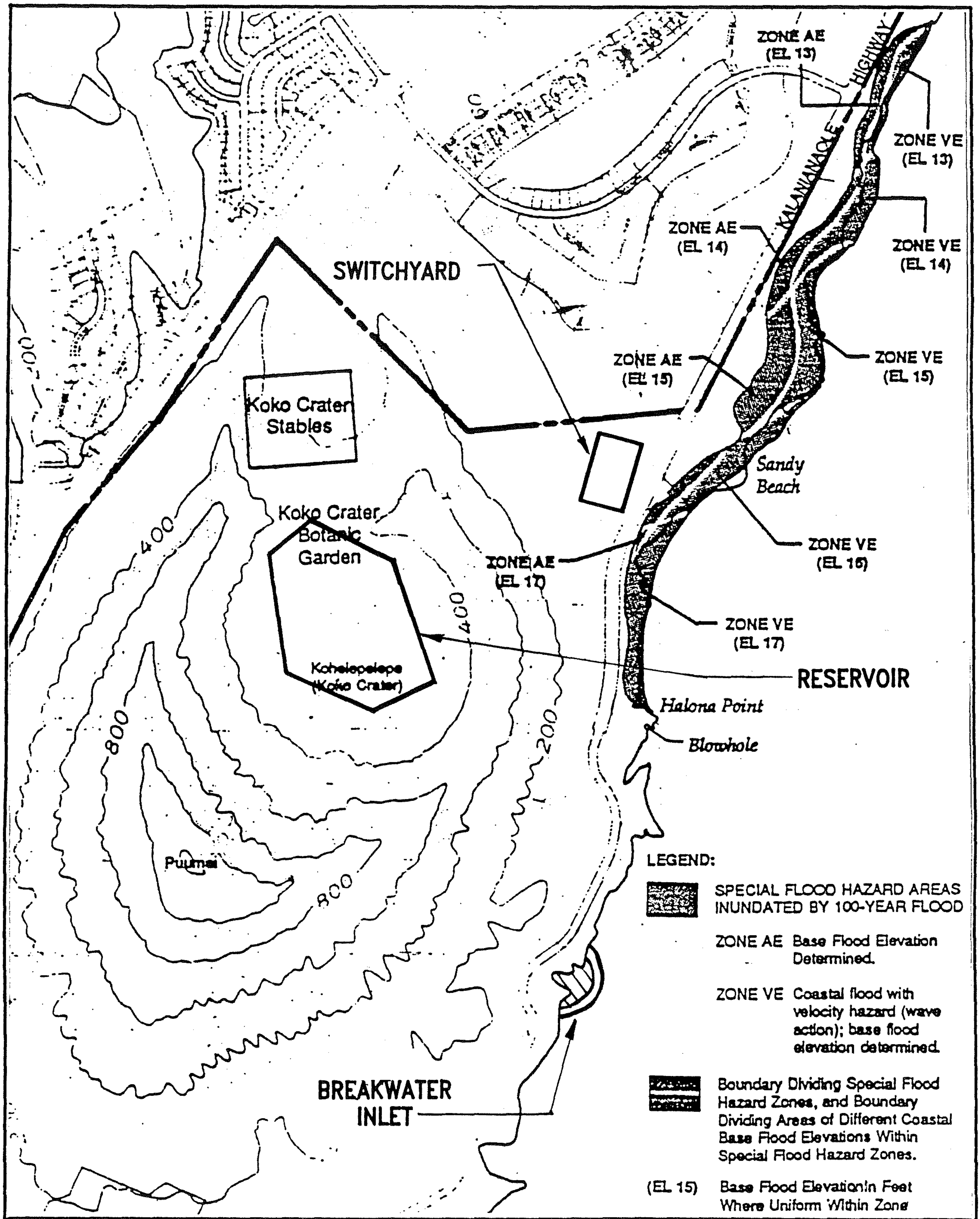
FIGURE II-3



KOKO CRATER PUMPED STORAGE HYDROELECTRIC PROJECT

EXISTING ZONING

FIGURE II-4



KOKO CRATER PUMPED STORAGE HYDROELECTRIC PROJECT

FLOOD ZONES

FIGURE II-5

Development Plan, the actual control over uses, structures and development standards lies with the State's Department of Land and Natural Resources through the vehicle of a Conservation District Use Permit. Thus, although the City establishes regulations over such matters as uses and height limits in Preservation Districts, in those districts zoned P-1 (such as Koko Head Park), it has no authority to enforce its regulations. Enforcement is left to the Department of Land and Natural Resources. The City is traditionally consulted on all Conservation District Use Applications which are submitted to the DLNR, however, the DLNR is under no obligation to act on City recommendations or enforce City policy.(4)

As a consequence of enactment of the U.S. National Flood Insurance Act of 1968 (Public Laws 90-448 and 91-152), as amended, and the U.S. Flood Disaster Protection Act of 1973 (Public Law 93-234), as amended, the LUO contains restrictions on development within flood hazard zones. Figure II-5 shows the flood hazard designations in the area as delineated on the Flood Insurance Rate Maps prepared by the Federal Insurance Administration, Federal Emergency Management Agency. The majority of the park property has been designated Zone D, areas in which flood hazards are undetermined. A small portion of the park along the shoreline from about Halona Point to Sandy Beach is subject to tsunami flooding. These areas are designated Zones AE (base flood elevations determined) and VE (coastal flood with velocity hazard (wave action) and base flood elevations determined). The smaller portion is also within the 100-year flood zone and has a velocity (wave action) ranging from 22 to 25 feet. Base flood elevations along this stretch of land range from 13 to 17 feet above mean sea level. According to the Atlas of Hawaii, the 1946 tsunami reached heights up to 31 feet along the coastline near Sandy Beach.(6) None of the proposed PSH facilities would encroach into designated flood zones.

For emergency evacuation purposes, however, the City and County of Honolulu, Civil Defense Agency designates a tsunami inundation area from Koko Head to Makapuu Point as follows:

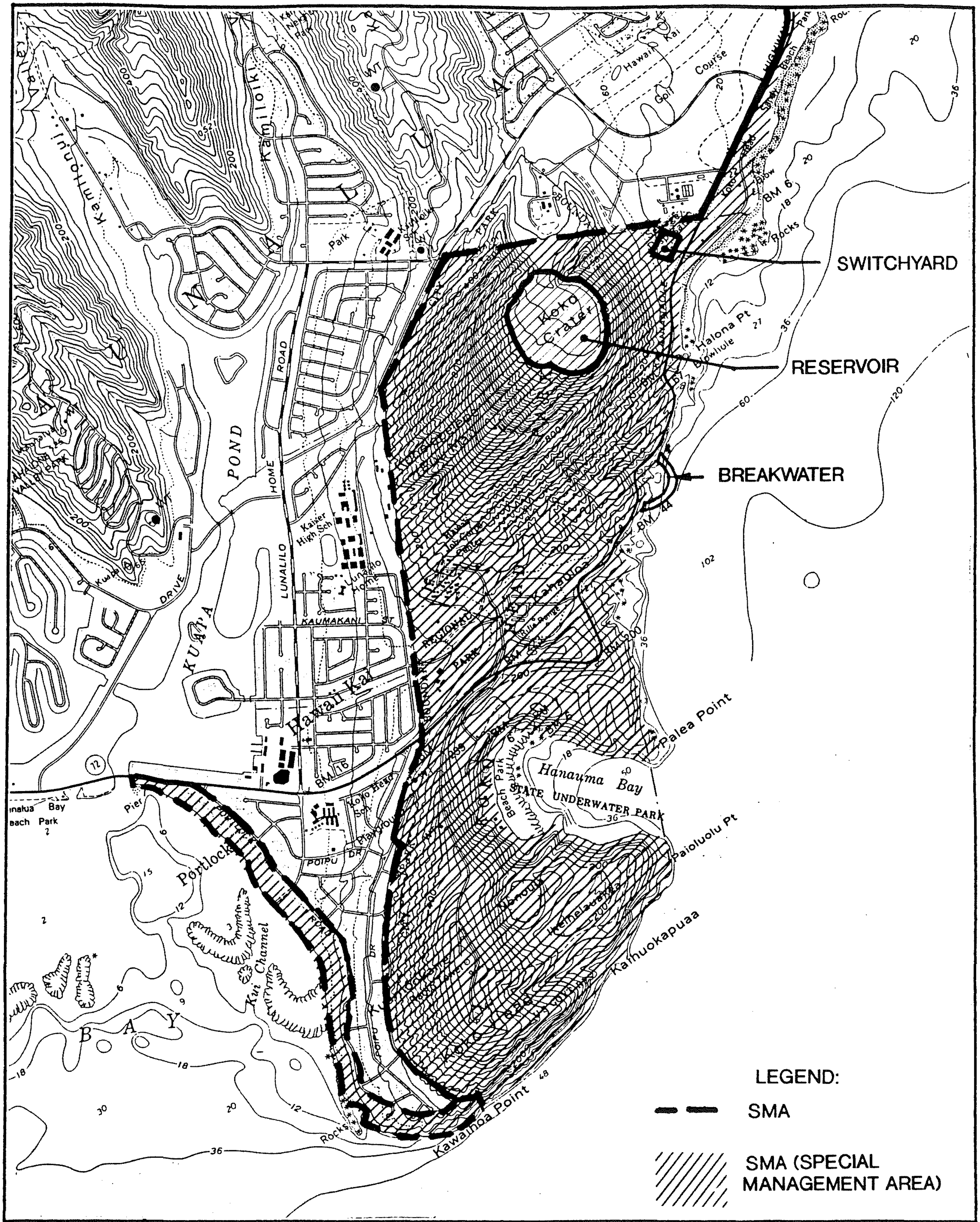
> *A line 50 feet above sea level from Koko Head to the Blowhole. From the Blowhole a line extending one-half mile inland of Sandy Beach through the FAA Radio Station and the Hawaii Kai Golf Course Clubhouse. From the clubhouse along Kalanianaole Highway to its junction with the Makapuu Lighthouse road. Then around Makapuu Head at the 50-foot elevation above sea level.(4)*

The only proposed structures within this area are the tunnel beneath Kalanianaole Highway and the breakwater offshore. Even though situated mauka of the highway, the below-grade elevation of the generating station/pump house would require evacuation in the event of an impending hurricane or tsunami due to the possibility of flooding the break water access tunnel. Depending on the final site, a portion of the switchyard could also lie within the Civil Defense tsunami inundation area.

The City and County of Honolulu, pursuant to Part II of Chapter 205A, Hawaii Revised Statutes, is authorized to regulate development within the Special Management Area (SMA). The SMA boundary in the project area is shown on Figure II-6. Several significant guidelines used to evaluate developments in the SMA are as follows:

> *Alterations to existing land forms and vegetation, except crops, and construction of structures shall cause minimum adverse effect to water resources and scenic and recreational amenities and minimum danger of floods, landslides, erosion, siltation, or failure in the event of earthquake. The development will not have any substantial, adverse environmental or ecological effect except as such adverse effect is minimized to the extent practicable and clearly outweighed by public health and safety, or compelling public interest; Minimize any development which would reduce or impose restrictions upon public access to tidal and submerged*

lands; Minimize any development which would adversely affect water quality, existing areas of open water free of visible structures, existing and potential fishing grounds...



KOKO CRATER HYDROELECTRIC PROJECT

SPECIAL MANAGEMENT AREA BOUNDARY

FIGURE II-6

The proposed breakwater would seem to conflict with several of these guidelines. It would alter scenic and recreational resources; it would impose restrictions upon public access to tidal and submerged lands; it would add a highly visible structure within a presently open water area; it would adversely impact several types of fishing activities; and it could alter water quality in the immediate vicinity.

b. Significant Environmental Resources

Archaeology.

Koko Crater, known to the Hawaiians as Kohelepelepe, is a traditional cultural historic site. The shape of the crater is the subject of a legend concerning Pele and her sister, Kapo. According to correspondence from the Administrator of the State Historic Preservation Division (SHPD):

> *There are three known archaeological historical sites at Koko Crater, all on the outer slopes. Site 50-80-15-36, is a house site of undetermined age on the low ridge of Koko Crater, Makapu'u side. Site 50-80-15-37, is a series of terraces and a possible house site on the northwest slope of Koko Crater, facing Kamilo Iki Valley. Site 50-80-15-4194, is a human burial of undetermined age on the southeast slope of the crater that was found by hikers and reburied by our staff. We believe that other human burials are likely to be found at Koko Head Crater. The crater has not been inventoried for historic sites, so we do not know whether there are sites present within the crater. The environmental conditions make it an unlikely place for traditional Hawaiian settlement, so we would not expect extensive remains.*(7)

Appendix D contains a review of known archaeological information regarding the project sites. This report was prepared by SHPD staff archaeologist, Ms. Carol Kawachi, who performed a literature review and a limited site survey. With respect to the Koko Crater area, her report summarizes...

> *Maunalua is a large land area which was extensively developed in the 1960s-1970s into Hawaii Kai, a residential neighborhood. Development has obliterated most of the inland sites but undeveloped coastlines, deep valleys and steep slopes may still yield remnants of past times. Post-Contact land use included sweet potato cultivation and ranching.*
>
> *Farming in the terraces in the back valleys was probably during the rainy season but the dominant crop appears to have been sweet potatoes planted on the coastal plain and along the slopes. Permanent habitation was probably along the shores of Kuapa Pond and the sea. Fishing and sweet potato cultivation appear to have been the prime activities of the area.*
>
> *The presence of only three small probable heiau in such a large area and the lack of smaller divisions of lands ('ili), suggest that Maunalua was not a place of high-status residents.*

With respect to Koko Crater itself...

> *Very little has been written about the proposed project area. An archaeological survey is needed within the crater and along the seaward exit to determine whether significant archaeological sites are present. It is not likely that habitation or agricultural sites would be found on the crater floor. It is likely, however, that burials might be found on the interior slopes*

> *and the crater floor. However, the crater is a traditional cultural place associated with Pele accounts.*

These conclusions agree with those of the Koko Head Park Master Plan study which summarizes the archaeological significance of the park lands as follows:

> *In comparison to areas adjacent to the west, north and east, the Koko Head Regional Park project area would appear to have a relative paucity of archaeological sites....Perhaps this paucity of sites reflects the relatively marginal nature of most of the project area, in terms of traditional habitation and exploitation activities, when compared to the areas adjacent to the west, north and east.*(4)

Earlier studies reviewed in production of the Park Master Plan suggest the likelihood of habitation sites and possibly dryland agricultural sites in several areas including natural overhang shelter areas along the dissected, seaward-facing lower slopes of Koko Crater, above Kalanianaole Highway, the interior of Koko Crater, especially immediately adjacent to the base of the steep slope, and the two ridge areas, now covered with dense vegetation, that extend to the northeast on both sides of the gap into Koko Crater.(4)

Many of the surface prehistoric and historic sites in the area, particularly along the coastline and in low areas such as Sandy and Queens beaches, were destroyed by the 1946 tsunami.(8)

Current Uses.

Current uses of Koko Head Park are described in the Park Master Plan as follows:

> *For the most part, Koko Head Regional Park has remained an undeveloped area. However, there are nine separate areas within the park that are subjected to varying levels of recreational and non-recreational use. These include the summit of Koko Head upon which are located a number of radio antennas and microwave relay stations, the Hanauma Bay Nature Park and Underwater Marine Life Conservation Area, Blow Hole and Halona Point, the Koko Head District Park, the Hawaii Job Corps Center, the Koko Head Rifle Range, Koko Crater Botanical Garden, and Koko Crater Stables and Sandy Beach.*

Areas of the Park which would be impacted by implementation of the PSH project include the shoreline and nearshore waters, the Botanical Garden and the Stables. The Master Plan summarizes these pertinent resources as follows.

> *The Koko Head viewshed is well recognized for its unique visual assets. The entire park has both regional and local scenic resources....The scenic drive provides an uninterrupted visual sequence of the park's shoreline and its unique geological features as well as views of Lanai and Molokai. Three lookout points with access off Kalanianaole Highway include: Kuapa Pond Lookout with views overlooking Hawaii Kai and Koko Crater; Lanai Lookout and Halona Point/Blowhole Lookout which have views of Lanai and Molokai and the shoreline to Makapuu.*
>
> *Aside from beach-related activities such as sunbathing, swimming and surfing, the only other major activity along the park's shoreline is fishing and food gathering.*
>
> *One of the most popular destinations, if not widely known, is the tramway running up the face of Koko Crater. Although difficult to climb, the reward to be found at the 1,200 foot summit is a variety of spectacular views*

> *ranging from Diamond Head to Makapuu Point. Despite being closed since 1966 the tramway remains remarkably well-preserved and offers the hiker a challenging exercise....*(4)

Koko Crater Botanical Garden (including the Dean G. Conklin plumeria grove and the Charles M. Willis cactus garden) is one of four botanical gardens administered by the Department of Parks and Recreation of the City and County of Honolulu. The Koko Crater Botanical Garden is open to the public from 9 a.m. to 4 p.m. daily except Christmas and New Year's. The garden's objective is to conserve and protect the unique and endangered plants found in xeriphytic (desert) environments. The garden was first planted in 1957, and has grown to be an important collection, including over 1,000 species from around the world. According to Mr. Walter Ozawa, Director of the City Department of Parks and Recreation, "The garden contains a unique, 20-year old collection of rare and endangered Madagascan plants. Other notable features of the garden include a stand of native Hawaiian wiliwili trees which are on the City's list of protected exceptional trees, a 30-year old collection of cacti and succulents, and Hawaii's largest collection of hybrid plumeria." In reference to the possible use of Koko Crater for PSH, Mr. Ozawa considers the garden "...too valuable a community resource to be abandoned....", and goes on to say, "We, therefore, will not consider changing the use of Koko Crater."(9)

> *In 1962, the city's Parks Department issued a ten-year lease to a private contractor for the establishment of a stable and riding facility at the mouth of Koko Crater. The result has been the creation of a 10-acre facility, complete with polo field/arena, practice area, and boarding facilities for up to 60 horses. Originally, the stable was a western riding facility. However, in the early 1970's the facility expanded and became an English-riding facility. Trail rides were once provided around the Koko Crater area but have been discontinued due to the rising costs of liability insurance....the Stables...is recognized as Oahu's only English training facility.*(4)

The proposed Pumped Storage facility would displace the botanical garden and probably the stables, although the future of the stables beyond its present owners is somewhat conjectural in any event. Shoreline vistas would be altered by the visual intrusion of the breakwater structure. Views into the crater from mauka hillsides would be altered by the presence of the dam and reservoir.

The Master Plan further expresses concern about potential uses near the park such as in the area envisaged for the switch yard.

> *...existing and proposed land uses around the park may constrain future recreational activities. Of particular concern is the sewage treatment plant (STP) across the highway from Sandy Beach, the proposed light industrial area mauka of the STP, the residentially zoned area adjacent to the entrance to Koko Crater, and development of telecommunications facilities on Koko Head summit.*(4)
>
> *The East Honolulu Treatment Plant, located east of Koko Head Crater....is a 3.9 million gallon per day (mgd) activated sludge facility....Following secondary treatment, effluent is discharged into coastal waters via a 1400-foot long, 46-foot deep and 36-inch diameter outfall pipe.*(4)

Recommended improvements to park lands and facilities include, among other things, construction of new hiking trails along the crater's slopes, improvement of the tramway trail, and improvements to the botanical garden, itself the subject of a separate Master Plan.

In addition to the City's plans for the park proper, the State Legislature in 1988 adopted two resolutions calling for the creation of a new park area, to be called Ka Iwi Park, extending from Makapuu to Hanauma Bay. To examine the potential of the area for inclusion in the National Parks System, the National Parks Service (NPS) completed a reconnaissance survey of the area and studied management alternatives.(8) They concluded the area does not meet all criteria for establishment of a National Park. Nevertheless, the state is in the process of preparing its own master plan for the Koko Rift area and is considering a Ka' Iwi State Park that would incorporate Makapuu State Park and some of the intervening private lands in the area, permitting public access to the Makapuu area....The 1992 master plan for the area calls for a redesign of the existing Sandy Beach parking area and an extension of Sandy Beach road to provide greater access to the Ka Iwi shoreline.(8)

Flora.

Introduced plant species dominate the area. Native plant communities are restricted to the harshest locations where their particular characteristics have allowed them so far to out compete alien species. The Hawaii Heritage program database identifies one listed endangered plant species, the 'Awiwi, a native coastal plant. The last sighting of the 'Awiwi is uncertain.(3)

On the Regional Park site, five general vegetation types are recognized. On the rocky coastal cliff areas and windward facing slopes of Koko Head, the vegetation is of low stature due to exposure to the prevailing winds and, during periods of storms and high surf, to salt spray. This **coastal scrub** is composed primarily of native species which occur as scattered pockets between the cliffs and Kalanianaole Highway. The **strand vegetation**, characterized by beach naupaka shrubs, occurs on sandy areas between Sandy Beach and Queen's Beach. Inland of the highway, on the windward facing slopes of Koko Crater and on a large portion of Koko Head, **kiawe scrub** with open, grassy patches is the dominant vegetation type. In more sheltered areas, the kiawe forms a forest, 12 to 25 feet tall, with a subcanopy layer of koa-haole (**kiawe/koa-haole forest**). On the leeward facing slopes of Koko Crater, a **koa-haole scrub** with a few scattered kiawe trees can be found.

Although no endangered species of flora or fauna have been identified within the park, a native water fern (*Marsilea villosa*) listed as a Category 1 (likely to be listed) proposed endangered species by the U.S. Fish and Wildlife Service (1985), has been found at 'Ihi'ihilauakea Crater. The Nature Conservancy of Hawaii, together with the City and County of Honolulu, have prepared a management plan for the area. Although not widely publicized, since 1987 'Ihi'ihilauakea Crater has been under the management of the Nature Conservancy in an effort to protect the native vegetation. The primary focus of the Conservancy's management plan has been to restrict vehicular access to the crater.(4) 'Ihi'ihilauakea Crater is southeast of Hanauma Bay, and nearly a mile and a half away from any disturbance which would be associated with the PSH project.

Schiedea globosa and *Lipochaeta lobata* are considered rare. They are found in the coastal scrub and kiawe scrub, near the rim of Koko Crater. The native caper or pua-pilo (*Capparia sandwichiana*), another rare species, was reported from the general Koko Head area and from Halona Point.

Fauna.

A field survey of the Koko Crater site was conducted by Dr. Leonard Freed on October 17, 1993. His report, summarizing the results of the field survey and literature reviews, as well as consultations with biologists at the Bishop Museum, U.S. Fish and Wildlife Service, Hawaii State Division of Forestry and Wildlife, and the University of Hawaii, comprises Appendix A to this report. No endangered, threatened, or declining species were seen or heard. Animal taxa in the area are typical of dry coastal and lowland settings on Oahu.

The threatened White Tern (*Gygis alba rothschildi*) on Oahu is known from a nesting attempt at Koko Head during 1961. It may therefore occur at Koko Crater, although the population now on Oahu is concentrated in Kapiolani Park and portions of urban Honolulu.

The Hawaii Heritage program database identifies one federally-listed endangered animal species, the Hawaiian Hoary Bat (*Lasiurus cinerus semotus*). The bat was last observed in 1963. The Short-eared Owl or Pueo (*Asio flammeus sandwichensis*), an endemic land bird, has been observed on Koko Crater near Halona Point. The subspecies is listed as endangered on Oahu by the State of Hawaii Department of Land and Natural Resources Division of Forestry and Wildlife.(3) The Pueo inhabits dry forests and rain forests, but is most often seen hunting in grasslands. It may occasionally forage through the Koko Crater site.

Two migratory indigenous (native) birds, the Pacific Golden Plover (*Pluvialis dominica fulva*) and the Wandering Tattler (*Hereroscelus incanus*) utilize the study area. The Plover is highly site-faithful year to year.(3) Two migratory indigenous (native) shorebirds, the Ruddy Turnstone (*Arenaria interpres*) and Sanderling (*Calidris alba*) are common along the shoreline.(3) Numerous species of resident indigenous (native) seabirds overfly and some nest on the inaccessible seaward facing cliffs at Koko Head.

2. OCEAN BREAKWATER/INTAKE

a. General Site Characteristics

The marine areas potentially affected by implementation of the Pumped Storage Project include those areas from the "Lanai Lookout" to Sandy Beach. This segment of coastline also includes the Halona Blowhole, a popular tourist attraction. Waters offshore of this coastal area are heavily used by sport divers and fishermen. Sandy Beach is a public beach that is particularly popular with bodyboarders, bodysurfers, and surfers.(3)

The unique and spectacular appearance of the coast between Hanauma Bay and Sandy Beach is due to the type of volcanic material - tuff (hardened ash) - of which it is composed. Tuff is relatively easily eroded and sculptured by wind, waves, and wave spray. The stretch from Palea Point to Sandy Beach has the most conspicuous and most complete assemblage of water-leveled landforms on Oahu. Typically there is a distinct bench or low terrace cut in the tuff a few feet above sea level. Bench elevations are higher at points and lower in more protected settings. Tidepools are present in the bench at the base of Halona Point.(2)

The entire coast from Koko Head to Makapu'u Head is geologically youthful. Coral growth occurs as scattered heads rather than as true reef formations. Deep waters occur very close to shore. The sea cliff along the ridge between Lanai Lookout and the Halona Blowhole extends underwater as a plummeting face, in some places with a vertical drop of 40 feet. Southwest of Halona Cove, depths of 50 feet or more occur directly off the shore. The bottom is predominantly sand, with scattered rocks, including some massive tuff breccia. Sand bottom areas increase with depth.(2)

b. Significant Environmental Resources

Archaeology.

To the southwest of the proposed breakwater site are the Koko Head Petroglyphs which, although extensively altered over the years by wave erosion and collectors, are recognized by DLNR as being significant examples of petroglyph art, rare on Oahu.

Current Uses.

Uses of the coastal area are summarized in the *Oahu Coral Reef Inventory*(2), from which most of the below information is taken. At Lanai Lookout, a parking area off Kalanianaole Highway provides access to a scenic viewpoint. The lookout northeast of Halona Cove is visited by large numbers of people daily who view the Blowhole activity and the rugged coastline. This coast is one of the better places on Oahu to observe humpback (*Megaptera novaeangliae*) and sperm whales which winter annually in offshore waters.

The more or less continuous bench along the coast between Halona Point and Palea Point is a popular hiking and nature-walk area. During calm seas the tidepools at the base of Halona Point offer outstanding nature study opportunities.

The waters off Lanai Lookout are popular for SCUBA diving when seas are calm. Underwater visibility is exceptional, at times reaching 150 feet or more, providing good opportunities for underwater photography. Large fish populations and submarine erosional features on a submerged shelf of tuff are major attractions. Commercial dive shops take advanced SCUBA classes and dive charters into the waters off Sandy Beach. The relatively easy access to deep waters outside Halona Cove make this a popular SCUBA diving area. Commercial dive shops run advanced SCUBA classes and dive charters there. Entries and exits are made from a sandy beach at the head of the cove which is accessible by a trail from the blowhole parking lot. The bottom drops off much faster south of Halona Cove than directly seaward or north toward Sandy Beach. The most interesting diving is found south in the direction of Hanauma Bay, where the bottom plummets to depths over 50 feet immediately offshore. Shell collectors also frequent these waters.(2)

Fishing activity along the coast northeast of Hanauma Bay to Sandy Beach is generally heavy. Pole fishing is the most common method, with Halona Point as the focus of some of the heaviest shore fishing effort on Oahu. Because of its popularity to bamboo pole fishermen, Halona Point is also known as "Bamboo Ridge". Fishes sought here are ulua, papio, surgeonfish, wrasses, and snappers. Other rocky points along this section are also heavily used by pole fishermen. Opihi collectors, as well as shore fishermen, risk their lives when surf is high. Some shorecasting occurs along the beaches at Sandy Beach Park and some throw-netting occurs from the rocky shore northeast of Sandy Beach. Net fishing occurs only rarely. Hand-netting of ornamental fishes is common. Lobster is taken off the rocky point southwest of Sandy Beach. Trapping of reef fishes and crustaceans in the deep waters found close to shore is an important activity along this entire coast.

Sandy Beach is one of the most popular beaches with Oahu's youthful sunbathers, and the body-surfing waves are as popular as those at Makapu'u Beach.

Flora.

The composition of the coastal strand vegetation is described in the terrestrial section above. According to the *Oahu Coral Reef Inventory*(2), the deep water west of Halona Cove harbors dense patches of the seaweed, *Dictyopteris plagiogramma*.

Fauna.

As evidenced by the density of fishermen, sport divers, shell and shellfish collectors, the waters offshore of this reach of coast harbor a diverse and abundant marine fauna typical of rocky surge coastlines in Hawaii. The tidepools along the wave-cut bench are also rich in marine life. The submarine cliff off the coast between Lanai Lookout and Halona Cove drops to a sand bottom with no corals or fishes evident. Heads of the coral *Pocillopora meandrina* occur close to Lanai Lookout, but cover does not exceed 10% and other coral species are not evident. The sea urchin, *Tripneustes gratilla*, is seen occasionally.(2)

3. KOKO CRATER PROJECT POTENTIAL IMPACTS AND MITIGATION MEASURES

a. Construction Phase

Site Work.

Site work would take place in the crater, outside the mouth of the crater, outside the crater mauka of the highway, near the Sewage Treatment Plant, in a 138 KV transmission line right-of-way, and immediately offshore. Underground tunnels, and a power house would also be excavated through the crater. The site work will directly alter landforms and indirectly, it would be responsible for all of the other construction phase impacts identified below.

The major landform alteration would result from construction of the reservoir and the dam across the crater mouth. The crater floor and inside perimeter would be graded and compacted prior to installation of an impermeable liner. The plans call for a balance between cut and fill so that no significant import or export of soil would be required. The crater's interior topography would be altered to provide uniform sloped surfaces. The mouth of the crater would be dammed, altering the natural form of the crater when viewed from the northeast. Grading would also be required along the access road and at the site of the switchyard. The route of the transmission line is presently defined only schematically, however, it is expected to involve both above ground and under ground site work.

The generally flat, arid and porous crater floor and surrounding lands would tend to mitigate against erosion and runoff problems during construction, but dust generation could be significant. Adherence to the City's Grading Ordinance, frequent watering, and prompt paving of the access road, would reduce dust generation and potential erosion. Adherence to the Clean Water Act would require temporary ponding and other control measures to eliminate siltation into drainage channels during rainfall. Because the project would involve disturbance of more than 5 acres of total land area, an NPDES General Permit under DOH Chapter 55 would be required.

Construction of the outlet structure and breakwater would require installation of temporary sheet pilings, excavation and dewatering at the shoreline and in the nearshore environment. The breakwater would extend from 40 feet below mean sea level to 15 feet above sea level and cover a portion of the ocean bottom. Its 40-foot wide crest would extend offshore about 250 feet in an arc more than 500 feet along the shore line.

Water Quality.

It is not expected that the landside portion of the site work would have significant effects on water quality if appropriate siltation control measures are taken. There are neither surface water sources nor drinking water resources in the area, and erosion can be effectively controlled. The major concern with respect to water quality is generation of suspended solids and turbidity by the shoreline and offshore work. Initial placement of the pilings and rubblemound would cause some turbidity nearby. Subsequently the enclosed area would be dewatered and excavated. A pulse of sediments could be expected when the outlet structure is initially flooded.

The State's general policy against water quality degradation reads as follows (§11-54-01.1, HAR):

> *Waters whose quality are higher than established water quality standards shall not be lowered in quality unless it has been affirmatively demonstrated to the director that the change is justifiable as a result of important economic or social development* ***and*** *will not interfere with or become injurious to any assigned uses made of, or presently in, those waters.* (emphasis added)

As indicated above, construction work will affect the water quality at the site. While this may be a temporary negative impact, the completed structure will permanently interfere with the present uses.

The area in question would be classified as Class A "open coastal marine water" with a Class II "lava rock shoreline" bottom subtype. From Chapter 54, HAR, "Water Quality Standards,":

It is the objective of Class A waters that their use for recreational purposes and aesthetic enjoyment be protected. Any other use shall be permitted as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class.

It is the objective of Class II marine bottom ecosystems that their use for protection including propagation of fish, shellfish, and wildlife, and for recreational purposes not be limited in any way. The uses to be protected in this class of marine bottom ecosystems are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation. Any action which may permanently or completely modify, alter, consume, or degrade marine bottoms, such as...wastewater effluent outfall structures may be allowed upon securing approval in writing from the director, considering the environmental impact and the public interest....

In terms of the basic water quality criteria applicable to all waters:

All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including:

> *(1) Materials that will settle to form objectionable sludge or bottom deposits;...*
>
> *(3) Substances in amounts sufficient to produce... objectionable...turbidity...in the receiving waters;*
>
> *(4) High or low temperatures; biocides;...at levels or in combinations sufficient to be toxic or harmful to human, animal plant or aquatic life, or in amounts sufficient to interfere with any beneficial uses of the water;...*

(6) Soil particles resulting from erosion on land involved in earthwork....

Appropriate pollution control technologies and the contents of any required monitoring program would be defined and established in the permitting process with the state and Army Corps of Engineers.

Land Tenure.

Most of the Koko Crater project would occupy lands now owned by the City and County of Honolulu. As noted, there is a restriction on the deed from Bishop Estate to the City requiring approval of the trustees of the estate for any land use other than recreational. Such approvals have been given in the past, such as for the Hawaii Job Corps Center. For a commercial use, however, the estate might seek monetary compensation in exchange for the waiver of the deed provision.(10)

Current plans are to locate the switchyard on city park lands. An alternative location would be on the parcel mauka of the STP owned by Bishop Estate and leased to Hawaii Kai Development Company. These leased lands are designated for limited industrial use on the City's Development Plan Map. Several community groups and City Councilman John Felix would like the parcel down-designated to preservation status (11), and Councilman Felix has initiated a Development Plan amendment.(10) The Department of General Planning is currently reviewing proposed DP amendments, and the administration's position will be published in July. According to Mr. Paul Cathcart of Bishop Estate, the Estate's intentions for the area include development, perhaps into a business park or similar use. A switchyard would not be incompatible with the intended use, and while an adequate area could be made available, the estate would prefer the switchyard be located on City land.

A right-of-way for the 138 KV transmission line would also be required, and would likely pass over private lands (the route this line might take is presently unspecified) and offshore lands are state-owned. All of these areas would have to be acquired or a means for their legal control established, thus eliminating their potential for other uses. Interestingly, the State Agriculture Plan considers the lands in Koko Crater "prime agricultural land, if irrigated."(12)

Recreational and Aesthetic Uses.

Construction of the reservoir and access road would effectively curtail use of a large portion of Koko Head Park. Obviously the Botanical Garden would be displaced, as most likely would the stables. The planned expansion of hiking trails around the crater ridge would not necessarily be inhibited because the reservoir would in any event have to be fenced for safety and security and therefore permit access to the upper reaches of the crater's interior.

Both the Botanical Garden and the stables could be relocated to other suitable areas. The arid environment desired for cultivation of the xeriphytic species may be found in other parts of the island; perhaps a portion of the Barbers Point Naval Air Station could be secured once the base is decommissioned or it could be integrated with the Board of Water Supply's xeriphytic demonstration garden in Halawa Valley. The Diamond Head crater interior and the smaller craters surrounding Hanauma Bay are other sites with environments similar to Koko Crater.

Construction of the breakwater/outlet structure would effectively curtail recreational use of the enclosed area for safety consideration. Partial mitigation might be possible by allowing access to the breakwater crest for fishing the waters on the sea side of the breakwater.

Aesthetically, the project would degrade views into the crater itself, views from the coastal highway and scenic lookouts, and perhaps underwater visibility as well.

Biota.

Lining of the crater floor and internal perimeter would remove vegetation and habitat including rare (though no native) plants within the Botanical Garden and "exceptional trees" listed by City ordinance. Mitigation could include transplantation, propagation or additional importation for cultivation at an alternative site. Some amount of forage area for endangered owls and bats would be lost, but no protected fauna would be directly impacted.

Biota resident in the area to be covered and enclosed by the breakwater would be lost. The breakwater structure itself might provide some complex habitat for encrusting and other species. The velocity of the currents passing through the structure when the facility is operational could inhibit colonization and growth; these velocities are expected to be lower than existing tidal currents. It might be possible to compensate for the lost habitat by creating artificial reefs offshore and adjacent to the breakwater.

Noise.

Development of the project site would involve grubbing, grading, tunnel drilling, road paving, and the construction of the powerhouse and the switchyard. Construction operations can generate significant amounts of noise, although actual noise levels would depend on the methods of construction employed during each stage of the process. Earthmoving equipment such as bulldozers and diesel powered trucks would probably be the loudest equipment used during the construction. Back-up alarms, in particular, have proven especially disturbing to residents near construction sites. Because of the distance between the proposed project location and nearby residence, the noise from construction operations would not cause "unreasonable" or "excessive" noise as defined by "Chapter 43 - Community Noise Control for Oahu".(13)

All construction equipment and on-site vehicles or devices requiring an exhaust of gas or air must be equipped with mufflers. Also, construction vehicles using trafficways will satisfy the noise level requirements adopted for Oahu for similar noise generation ("Chapter 42 - Vehicular Noise Control for Oahu").(14)

It is likely that blasting would be employed in excavating the tunnels and below-grade generating station. Prior to blasting, potentially affected neighbors should be notified. If blasting within the marine environment is necessary, consultation with the National Marine Fisheries Service will be required to establish measures to mitigate potential impacts on endangered humpback whales and threatened green sea turtles.

Traffic and Air Quality.

Traffic in the project area would increase during construction due to delivery of equipment and materials and particularly worker vehicles. Even if there are no direct lane closures required by the project, work visible from Kalanianaole Highway has the potential to impede traffic flow due to "rubberneckers."

Short-term direct and indirect impacts to air quality could potentially occur due to project construction. There are two types of air pollutant emissions which could directly result in short-term air quality impacts during the construction phase: (1) fugitive dust (particulate matter) from vehicle movement and site excavation; and (2) exhaust emissions (primarily nitrogen oxides, but also carbon monoxide, sulfur oxides and hydrocarbons) from on-site construction equipment. Indirectly, there could also be short-term impacts from slow-moving construction equipment traveling to and from the project site and from a temporary increase in local automotive traffic caused by commuting construction workers. Carbon monoxide comprises the largest fraction of emissions from gasoline-powered vehicles.

Strict compliance with State of Hawaii Air Pollution Control Regulations (Section 11-60-5, HAR) regarding establishment of a regular dust-watering program and covering of dirt-hauling trucks would be required to effectively mitigate fugitive dust emissions from construction activities. Twice-daily watering is estimated to reduce dust emissions by up to 50 percent. Soil transported onto paved roads by construction vehicles and activities should be promptly removed. Use of wind screens and/or limiting the area that is disturbed at any given time may be required in such a dust-prone area. Paving of designated areas, landscaping as early as possible in the construction sequencing, and timely installation of the reservoir liner would reduce total fugitive dust emissions. Construction equipment should be properly maintained and tuned to minimize exhaust emissions (Section 11-60-4, HAR) and equipment should be shut down rather than left idling when not in use.(15)

Archaeological Resources.

The portions of Koko Crater with traditional significance in Hawaiian legends (the summit) would not be modified in any way, although the appearance of the crater from above would change with the addition of the dam and reservoir. Potential archaeological resources at the crater mouth, along the inside of the crater walls and along the outside of the walls could be impacted by construction. Additional archaeological surveying and possibly mitigation work would be required before proceeding with the proposed project.

b. Operational Phase

Water Quality.

The PSH facility would cycle about 1 billion gallons of seawater each day. Marine water quality impacts could result from both the uptake and discharge cycles of the process. During uptake and discharge scouring of the ocean bottom may result in increased turbidity due to the suspension of bottom materials. This impact could potentially be mitigated by locating the outfall/intake at great depth and the installing of diffusers. The water discharged could differ from that taken up in temperature, oxygen content, and chemical composition. The latter could be affected by the introduction of cleaning agents to the system. Mitigation could involve selection of low toxicity agents and restricted concentrations, or use of mechanical cleaning methods. Destruction of organisms and lysing of cells could increase the concentration of organics in the discharge.

Oxygen depletion and thermal changes are always of concern when they occur in marine waters. These effects could result from the stored water warming and from oxygen depletion at depth in the large reservoir. These impacts, however, are anticipated to be essentially non-existent due to the short residence time of the water in the reservoir. Approximately 85% of the water in the reservoir would be exchanged each day, and the filling and draining of the reservoir would result in significant mixing of the residual water, thereby minimizing oxygen depletion effects and thermal changes.

Land Use.

Although the visible shoreside facilities would not, with the exception of the electrical switchyard, appear industrial in character, the proposed project would constitute an expansion of industrial uses and facilities adjacent to lands designated preservation, and extensively used for recreational purposes.

Although mitigation measures could significantly reduce some of the consequences of the proposed action, the breakwater would seem to conflict with several of the SMA guidelines. It would alter scenic and recreational resources; it would impose restrictions upon public access to tidal and submerged lands; it would add a visible structure within a presently open water area; it would impact several types of fishing activities; and it could alter water quality in the immediate vicinity.

Industrialization of the area might affect residential property values as could a perceived potential for seawater overflows as a consequence of operational problems or leakage from the reservoir resulting from natural disasters. An effective public information program might allay such fears.

Recreational and Aesthetic Uses.

The proposed PSH facility would have recreational, aesthetic and cultural impacts. The primary impacts to recreational use would result from displacement of the botanical garden and probably the stables, although the future of the stables beyond its present owners is somewhat conjectural in any event. Hiking opportunities both in and on the crater and along the coastline would be reduced. In the area of the outfall structure and breakwater, access for fishing and diving would be lost, although the breakwater represents a small portion of the coastline. The currents outside the breakwater resulting from intake and discharge of water through the PSH facility would not be of a magnitude to endanger nearby divers.

Aesthetic impacts would be significant. Shoreline vistas would be altered by the visual intrusion of the breakwater structure. Views into the crater from mauka hillsides would be altered by the presence of the dam and reservoir. Although the powerhouse would be below grade, the other appurtenances including the switchyard and any overhead transmission lines would have negative aesthetic effects.

Because the crater's shape is an integral part of the Pele Legend, altering the crater shape by the addition of a dam could have significant cultural effects. The relevant portion of the crater, however, is the crest area to the southwest, opposite the mouth where the dam would be built.

Biota.

Impacts to biota from operations of the PSH facility would affect both terrestrial and marine ecosystems. The main impacts to terrestrial habitats would take place during construction and start-up, but operations and maintenance would continue to affect terrestrial biota through vegetation removal along rights-of-way and at the switchyard. There will perhaps be a microclimate modification in the crater due to the presence of a large body of salt water in the reservoir.

Marine biota could be affected in a number of ways. Direct effects could include impingement and entrainment of plankton and nekton due to the velocities in the waterways. The breakwater would help to filter the intake and diffuse the discharge, but undoubtedly some organisms would be carried into the flow stream. Organisms too large to pass through the voids in the breakwater could still be damaged by impingement on the rocks. Smaller organisms which pass through the breakwater would undergo mechanical stresses associated with passage through the system into the reservoir and a high percentage of entrained organisms would likely be destroyed. The discharge plume at the breakwater is expected to have a velocity of about 0.4 fps (1/4 knot). This velocity is typical for natural currents in the area.

Noise.

Noise from the PSH facility would result from operation of the pumps and generator, and to some extent from the moving water itself. The combined pump house/generating station would be below grade, thereby greatly reducing ambient noise impacts, especially at higher frequencies. There may also be some noise associated with operations of the switchyard, but this would be localized. The mechanical noise propagated through the water may have an impact on whales which traverse the area.

Air Quality and Climate.

Air quality effects at the site would be minimal and would primarily be associated with the incremental increase in emissions at established power plant sites which provide electricity to the PSH facility during pumping operations. The project itself would have no emissions of air pollutants; it would actually result in lower island wide emissions because of its displacement of fossil-fuel generators during peak power production.

The presence of a large water body in the crater could alter the microclimate to which flora on the upper slopes of the crater interior is exposed by increasing local humidity and lowering temperature through evaporative processes. Mitigation of this potential impact would involve covering the reservoir. This measure is an unnecessarily complex and expensive remedy, considering the quality of the resident flora.

EMF and RI.

Electrical switching gear and transmission lines generate ambient electro-magnetic fields (EMF). There appears to be no definitive linkage of EMF and human health or ecological risks at this time. Some localized radio interference (RI) could occur around the high voltage facilities.

4. SOCIOLOGICAL/POLITICAL CONSIDERATIONS

a. Housing/Infrastructure

With the exception of the necessity for a right-of-way for a 138 KV electrical transmission line from the switchyard to the Pukele substation in Palolo Valley, direct impacts to housing would be minimal. Depending on the route selected, property acquisitions both public and private might be necessary. Effects on infrastructure in Hawaii Kai would be minimal.

b. Neighborhood Board Concerns

On August 10, 1993, Fred Kobashikawa (HECO) briefed the Planning and Zoning Committee of the Hawaii Kai Neighborhood Board on the pumped storage hydro concept for Koko Crater. Summarizing the contents of the report "Integrated Resource Planning, 1994-2013," Mr. Kobashikawa cited potential visual and environmental impacts. Identified potential impacts include loss of marine benthic communities, impingement and entrainment of marine organisms, elevated discharge water temperature, as well as the visual intrusiveness of the dam, powerhouse and transmission lines. Seismic instability of the area and the potential for a natural disaster was a concern of some board members. Further presentation of the findings of this report will need to be undertaken to identify the mitigations that are available to meet the neighborhood board concerns.

c. Residential Concerns

At the Hawaii Kai Neighborhood Board meeting (reported in the *Hawaii Kai Sun Press*), residents of the area were invited to submit comments on the proposal to the Public Utilities Commission. Only one letter has been submitted to the PUC and it was negative toward the project.

5. REGULATORY REQUIREMENTS

The project would need permits and approvals at federal, state, county and private levels to proceed (Table 1). The coordinating agency at the federal level would be the Army Corps of Engineers. Construction of a breakwater in the navigable waters of the United States would require a Corps permit under Section 10 of the Rivers and Harbors

Act of 1899 (33 U.S.C. 403). The need for a federal permit would trigger additional requirements. The magnitude of potential impacts would likely trigger a federal environmental impact statement (EIS) under the National Environmental Policy Act (NEPA). Hydroelectric projects normally require licensing by the U.S. Federal Energy Regulatory Commission (FERC), however, it is not clear that the State of Hawaii is subject to FERC regulation.

Section 7 of the Endangered Species Act (ESA), 16 U.S.C. 1536, requires that each federal agency insure that any activity authorized, funded or carried out by it is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of any critical habitat for such species. Construction and operation of the Pump Storage facility would involve modification of the physical environment as well as potential impacts on living organisms. Accordingly, review of the project for endangered species impacts will form a part of the process of granting any federal permit or authorization for the project.

The Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661-666c, requires that federal permitting agencies give full consideration to conservation of wildlife resource values in the permitting process. This is accomplished through consultations between the permitting agency and the affected state wildlife agency, the U.S. Fish and Wildlife Service Regional Director and the National Marine Fisheries Service Regional Director, as appropriate. The purpose of these consultations is, to the maximum practical extent, to avoid project-caused losses of wildlife resources, to compensate for unavoidable wildlife resource losses, and to enhance wildlife resource values.(16)

If the proposed Humpback Whale National Marine Sanctuary is established, and if the sanctuary is defined to include all Hawaii waters shallower than 600 feet, as one alternative now reads, then a National Marine Sanctuaries Review under the Marine Protection, Research and Sanctuaries Act (16 U.S.C 1431-1434) would be required.

Because Hawaii has an approved Coastal Zone Management Program, a Coastal Zone Management Consistency Certification (Section 307(c) of the Coastal Zone Management Act of 1972 (16 U.S.C. 1456 (c)) would be required. An applicant for any federal license or permit must certify that the proposed activity is consistent with the state plan.

A state Water Quality Certification from DOH pursuant to Section 401 of the Clean Water Act is required by any applicant for a federal license or permit to conduct an activity in state waters that would include the construction and operation of facilities that may result in any discharge.

Emplacement of the breakwater would also have to meet U.S. Coast Guard Navigation Safety Requirements.

Much of the proposed infrastructure for the project would be situated on lands classified Conservation by the state. Accordingly, a Conservation District Use Permit (CDUP) would be required from the Board of Land and Natural Resources. Use of Conservation District Lands would also trigger a state EIS under Chapter 343, HRS. Historic Site Review (Chapter 6A) would be undertaken as part of the EIS process. The requirement for a permit for work in ocean waters of the state, is consolidated into the CDUP process when a CDUP is required. A revocable permit for use of state lands would also be required from the Division of Land Management.

Construction of the dam and reservoir would require a permit from the BLNR. If the dam is judged to be of high hazard, an emergency preparedness plan would be required.

The ocean discharge would require an individual National Pollutant Discharge Elimination System (NPDES) permit which would typically set limits to pollutant concentrations and establish monitoring requirements. Because the project would involve disturbance of more than five acres of total land area, an NPDES General Permit under DOH Chapter 55 (Hawaii Administrative Rules) for "Discharges of Storm Water Associated with Construction Activity" would be required. A second NPDES General Permit will be required for "Discharges Associated with Construction Activity Dewatering" Similarly, an NPDES General Permit will be required for "Discharges of Hydrotesting Waters."

If it is determined that the discharge water from the facility would violate state Water Quality Standards, a zone of mixing or a treatment system would have to be approved by the Department of Health.

It is anticipated that Kalanianaole Highway would not be directly affected by the construction; nevertheless, a permit to perform work upon a state highway may still be required, as the right-of-way extends below grade where the underground tunnels will be located. A permit may also be required to install utilities within the state highway right-of-way.

At the City and County level both discretionary and ministerial permits would be required. The Development Plan would require amendment, which may in turn trigger an EIS requirement. Most of the project area is within the Special Management Area (SMA), and an SMA Use Permit would be required. A single EIS can be written to fulfill the requirements at federal, state and county levels. Construction within the Shoreline Setback would require a variance. This is usually combined with the SMA permit process.(17) A Zoning Waiver for Public Utilities may be granted by the Director of Land Utilization, and may be appropriate for the proposed project.

Ministerial permits would include a Building Permit, Certificate of Occupancy, and a Grubbing, Grading and Stockpiling Permit. The contractor will be required to prepare an erosion control plan prior to receiving a grading permit.

Another approval would have to come from the Trustees of the Bishop Estate pursuant to a deed restriction on the property specifying it be used for recreational purposes only.

The permits and approvals necessary to develop the Koko Crater site are listed in Table II-1.

TABLE II-1

KOKO CRATER PERMITS AND APPROVALS

PERMIT OR APPROVAL	AGENCY OR ENTITY
Section 10 Permit (Rivers and Harbors Act)	U.S. Army Corps of Engineers (COE)
Section 7 (ESA) Consultation and Fish and Wildlife Coordination	COE with National Marine Fisheries Service (NMFS), Fish and Wildlife Service (FWS) and Hawaii Department of Land and Natural Resources (DLNR)
Environmental Impact Statement (NEPA)	COE, Office of Environmental Policy
Navigational Safety Certification	U.S. Coast Guard
Coastal Zone Management Program Consistency Certification	Hawaii Office of State Planning
Water Quality Certification	Hawaii Department of Health (DOH)
Conservation District Use Permit	Hawaii Board of Land and Natural Resources (BLNR)
EIS (Chapter 343, HRS)	Governor (through the Hawaii Office of Environmental Quality Control)
Historic Site Review (Chapter 6A, HRS)	DLNR, Division of Historic Preservation
Revocable Permit for Use of State Lands	DLNR, Division of Land Management
Dam Safety Approval	BLNR

NPDES Permits	DOH
Permit to Perform Work on State Highway	Hawaii Department of Transportation (DOT)
Permit to Install Utilities Within State Highway Right-of-Way	DOT
Use of City Land	Honolulu City Council
Development Plan Amendment	Honolulu Department of General Planning (DGP) and Planning Commission
Special Management Area (SMA) Use Permit	Honolulu Department of Land Utilization (DLU) and City Council
EIS (Chapter 25, ROH)	DLU and DGP
Shoreline Setback Variance	DLU
Zoning Waiver for Public Utilities	DLU
Building Permit	Honolulu Building Department (BD)
Certificate of Occupancy	BD
Grubbing, Grading and Stockpiling Permit	Honolulu Department of Public Works (DPW)
Deed Waiver for Non-recreational Use	The Bishop Estate

C. KAAU CRATER PROJECT

1. KAAU CRATER

a. General Site Characteristics

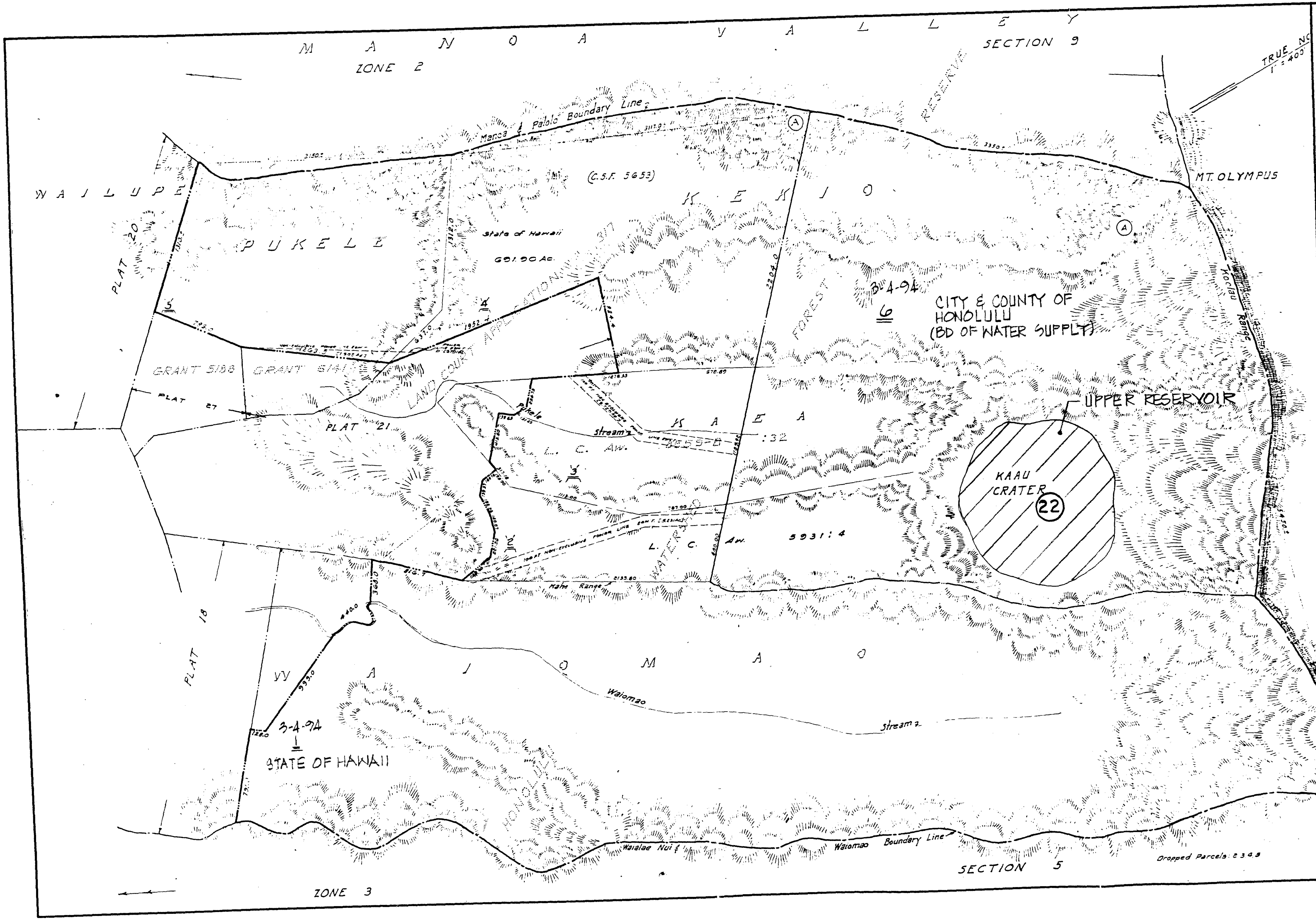
Kaau Crater is within Oahu Tax Map Key 3-4-22:06. This parcel, owned by the City and County of Honolulu, is shown on Figure 7. The Kaau Crater site is located high on the Honolulu side of the Koolau range, deep in Palolo Valley. The crater and the surrounding lands are located in the Honolulu Watershed Forest Preserve which is surrounded by State lands of the Pukele and Waiomao Forest Reserves. The state land use designation is Conservation, and the County zoning is Preservation P-1. The geological characteristics are discussed in section III.

b. Significant Environmental Resources

Archaeology.

According to Don Hibbard, Historic Preservation Division Administrator:

> *Kaau Crater is State site 50-80-14-57. The crater, itself, is significant in traditional Hawaiian culture as the grave site of the demi-god Maui's fishhook, Manaiakalani. The crater has not been inventoried for archaeological remains or historic sites and none are known to be present. Given the crater's location and its swampy interior it is unlikely that habitation or agricultural remains will be found there. Sediments within the crater will undoubtedly contain a good record of vegetation changes through prehistory, and so would be considered significant for the information on Hawaiian history and prehistory that they contain.*(7)



KAAU CRATER HYDROELECTRIC PROJECT

LAND OWNERSHIP

FIGURE II-7

Ms. Carol Kawachi, staff archaeologist with the State Historic Preservation Division summarized the existing information regarding the crater. Her report comprises Appendix D to this report. With respect to the area around Kaau Crater...

> *The valley floors of both Palolo and Manoa Valleys were once extensively cultivated in taro pondfields. The streams from both valleys met and watered the large pondfield system and fishponds between Mo'ili'ili and Waikiki. From Wai'alae to Kuli'ou'ou, there were only intermittent streams. The agricultural pattern was mainly dryland agricultural on the coastal plains with taro pondfields along the flowing streams. Each 'ili had a fishpond. Some had terraces but what specific crop was being cultivated is unknown. Dryland taro was cultivated where there was sufficient rainfall. Sweet potatoes and other crops were also cultivated on the broad coastal plain. Palolo and Manoa 'ili held large populations, with many on the shore and others scattered inland. The numbers of awards and early census data indicate the larger populations of these 'ili. The small valleys to the east seem to have had much smaller populations based on Mahele data with most living on the shore.*

With respect to Kaau Crater...

> *There is no archaeological information on the crater so an archaeological inventory survey would be needed for planning. It is not likely that habitation or agricultural remains would be found on the floor of Kaau Crater, which is presently a marsh.*
>
> *Oral accounts clearly show that the crater and its spring are traditional cultural places. Both would be significant for their traditional cultural significance. This fact might be a constraint for the project.*

Current Uses.

The crater is a destination for recreational hikers and the Hawaiian Trail and Mountain Club organizes group excursions to the crater.(18) The area is also frequented by pig hunters.

Flora.

According to a preliminary environmental assessment of supply-side technologies performed in support of the Integrated Resource Plan by EnviroSearch:

> *The Hawaiian Heritage Program database lists some eleven listed endangered species. It also lists nine species for which the U.S. Fish and Wildlife has substantial information on biological vulnerability and threats to support a proposal to list them as endangered or threatened, and four species that are recommended as rare by a Hawaiian biologist and confirmed by the Heritage data. These listings include 15 plants and six animals (five invertebrates and one vertebrate species). A number of specific locations within the general site had observed occurrences of these species.*(3)

Field investigations (Appendix C) showed that the Kaau Crater floor is covered by three major vegetation associations. A low, wet meadow composed of the native sawgrass (*Cladium jamaicensis*), honohono (*Commelina diffusa*), and great bulrush (*Shoenoplectus lacustris*) covers most of the crater floor. On the southwestern half of the crater is a low, open scrub composed of 'ohi'a (*Metrosideros polymorpha*), strawberry guava (*Psidium cattleianum*), and hame (*Antidesma platyphyllum*). A tall, dense thicket of strawberry guava is found on the northeastern edge of the crater. The crater floor is an identified wetlands, and therefore, a "navigable waterway" under the jurisdiction of the Army Corps of Engineers.

On the lower slopes of the crater, where the proposed inlet/outlet structure would be sighted, the vegetation consists primarily of guava (*Psidium guajava*) thickets, dense clumps of ti (*Cordyline fructicosa*), and scattered patches of banana (*Musa* X *paradisiaca*).

Fauna.

A field survey of the Kaau Crater site was conducted by Dr. Leonard Freed on October 3, 1993. (See Appendix A.) No endangered, threatened, or declining bird species were seen or heard. Three endangered waterbirds have been known historically to use Kaau Crater. They are the American Coot (*Fulica americana alai*), the Black-necked Stilt (*Himantopus mexicanus knudseni*), and the Hawaiian Duck (*Anas wyvilliana*).

Eight species of the federally endangered genus *Achatinella* ("Oahu Tree Snails") historically occurred along the summit, lee slopes and windward ridge of Kaau Crater. Appendix B summarizes the historical occurrence of these snails in the area and the results of a field survey conducted on October 3, 1993. Although no endangered snails were seen during the field survey, there was sufficient surveying to confirm this finding.

An ornithological survey in 1977 revealed tadpoles and adults of the Japanese Wrinkled Frog in open pools on the crater floor, along with small gastropod mollusks and some aquatic insects.(19) The author noted that the surrounding ohia forest supported an impressive concentration of native forest birds ('Apapane, 'Amakihi) as well as exotic Japanese White-Eyes and Spotted Doves. A pair of Koloa and three Hawaiian Coots were observed in small pools within the crater. Sightings of Hawaiian Stilt by others were reported.

Water.

The USGS Topographical Map indicates the existence of wetlands in the Kaau crater. The field surveys undertaken for this report confirmed the bog-like conditions of the crater floor. The crater satisfies the Army Corps of Engineers criteria for wetland delineation.(20) It has hydric soils, hydrophytic vegetation and wetland hydrology.

A synopsis of the crater environs and a plant species list were presented in a comprehensive evaluation of Hawaii's wetlands by Elliott and Hall (21). The crater was once a lake, but encroachment of marsh vegetation completely covered the lake. Early use by Hawaiians involved fish culture in the lake, and numerous non-native plants such as banana and ti were introduced. The authors state further :

> *...The most extreme form of disturbance occurred soon after 1900 when Honolulu hydrologists built an earthen dam at the crater's only outlet, in the hopes of creating a large reservoir for city water supply. This dam, located at the northeastern corner of the crater, caused extensive flooding and destruction of native forest. Within a few years, however, the dam had partially broken and most of the reservoir waters had leaked out.*

There are perennial and intermittent streams in the Kaau Crater area, notably Waiomao Stream to the east and Pukele Stream to the west. These are both tributaries of Palolo Stream which joins Manoa Stream at the drainage channel into the Ala Wai Canal. The Palolo Tunnel drains a dike impounded aquifer several hundred feet below the crater floor and is a significant county water resource serving Palolo and Kaimuki. Flows vary from 200,000 to more than 400,000 gallons per day.(22) There is a surface flow out of the crater which eventually feeds into Waiomao Stream.

According to the *Hawaii Stream Assessment* (23), the Ala Wai Stream System of which Palolo Stream and its tributaries are a part, is rated regionally outstanding for its recreational values. Recreational opportunities throughout the system include hiking, swimming, hunting, nature study, boating, scenic views, parks and fishing. The stream system is rated of moderate aquatic resource value, with a healthy native stream ecosystem, at least in upper reaches. Riparian resources were not highly ranked with ten percent surrounding native forest and only one threatened and endangered bird present. Cultural resources were likewise not highly ranked, but archaeological information is sparse. There is a small amount of taro cultivation downstream.

2. MAUNAWILI VALLEY

a. General Site Characteristics

The Kaau Crater Pumped Storage project would have its lower reservoir located on the windward side of the Koolaus in Maunawili Valley. Maunawili Valley is a watershed of about 18 square miles in area, which drains into Kawainui Marsh and Kailua Bay. Kawainui Marsh occupies about 1,000 acres between the 1-foot and 40-foot elevation contours. It is a lagoonal marsh, formed by a barrier beach that isolated the mouths of two large valleys from Kailua Bay.(8)

The lower reservoir site is located in the Waimanalo Forest Reserve on land owned by the State of Hawaii designated as TMK: 4-02-10:1 (Figure 8). The land is in the state Conservation District (Figure 9), designated Preservation on the County Development Plan (Figure 10), and zoned P-1. The geological characteristics are discussed in section III.

b. Significant Environmental Resources

Archaeology.

A field survey of the Maunawili Valley site was conducted on November 10, 1993 by Ms. Carol Kawachi, staff archaeologist with the State Historic Preservation Division. Her report comprises Appendix D to this report.

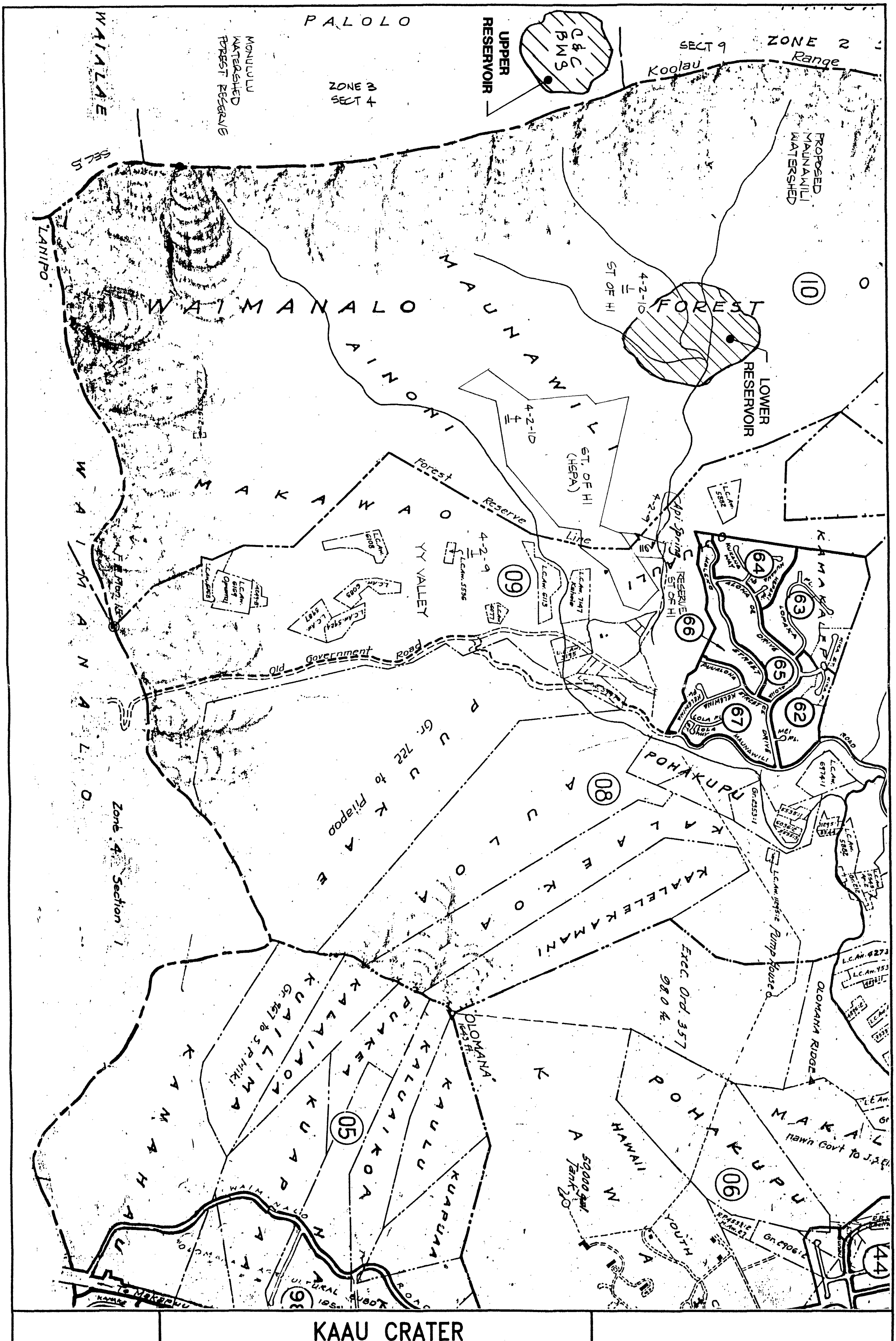
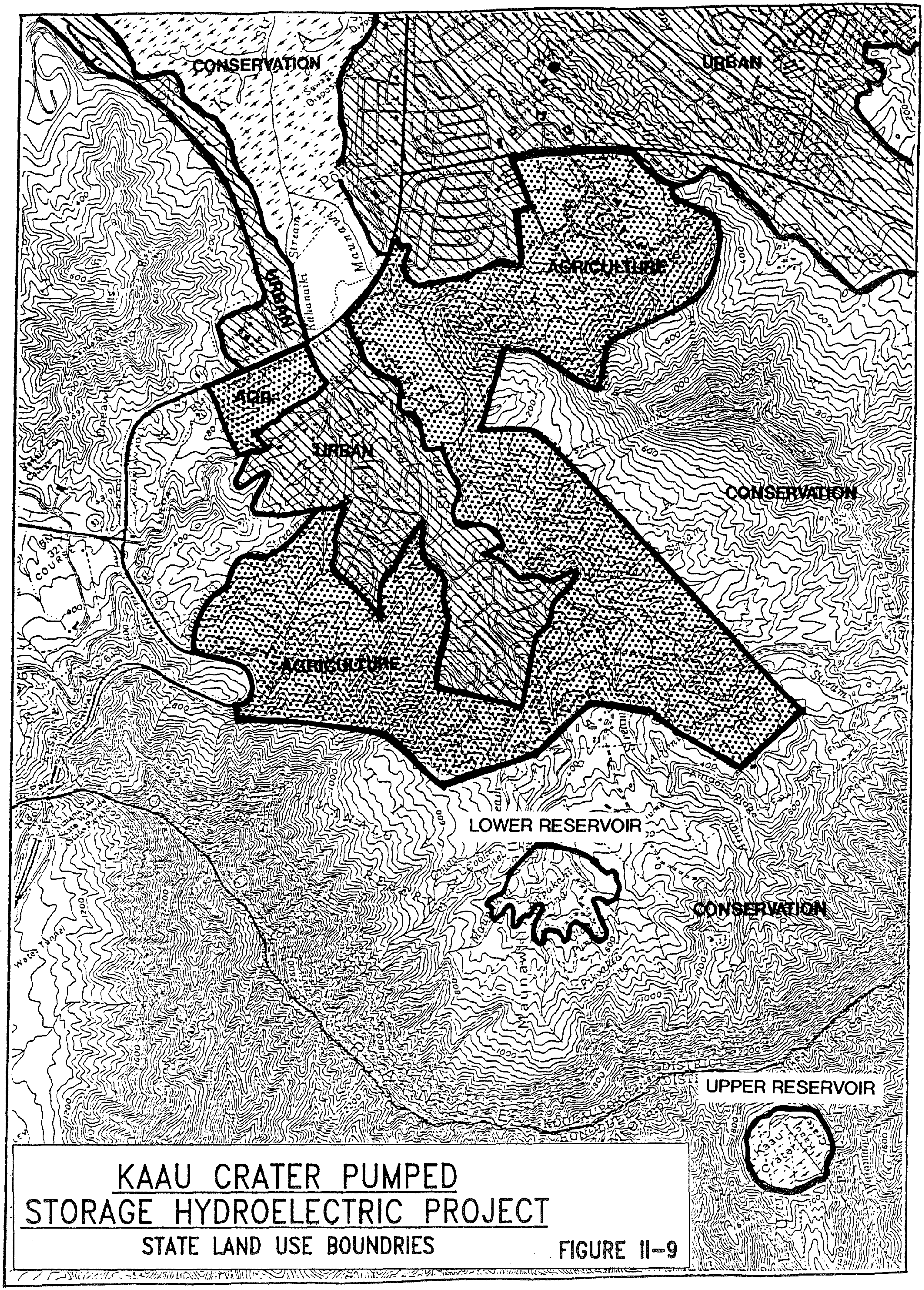


FIGURE II–8

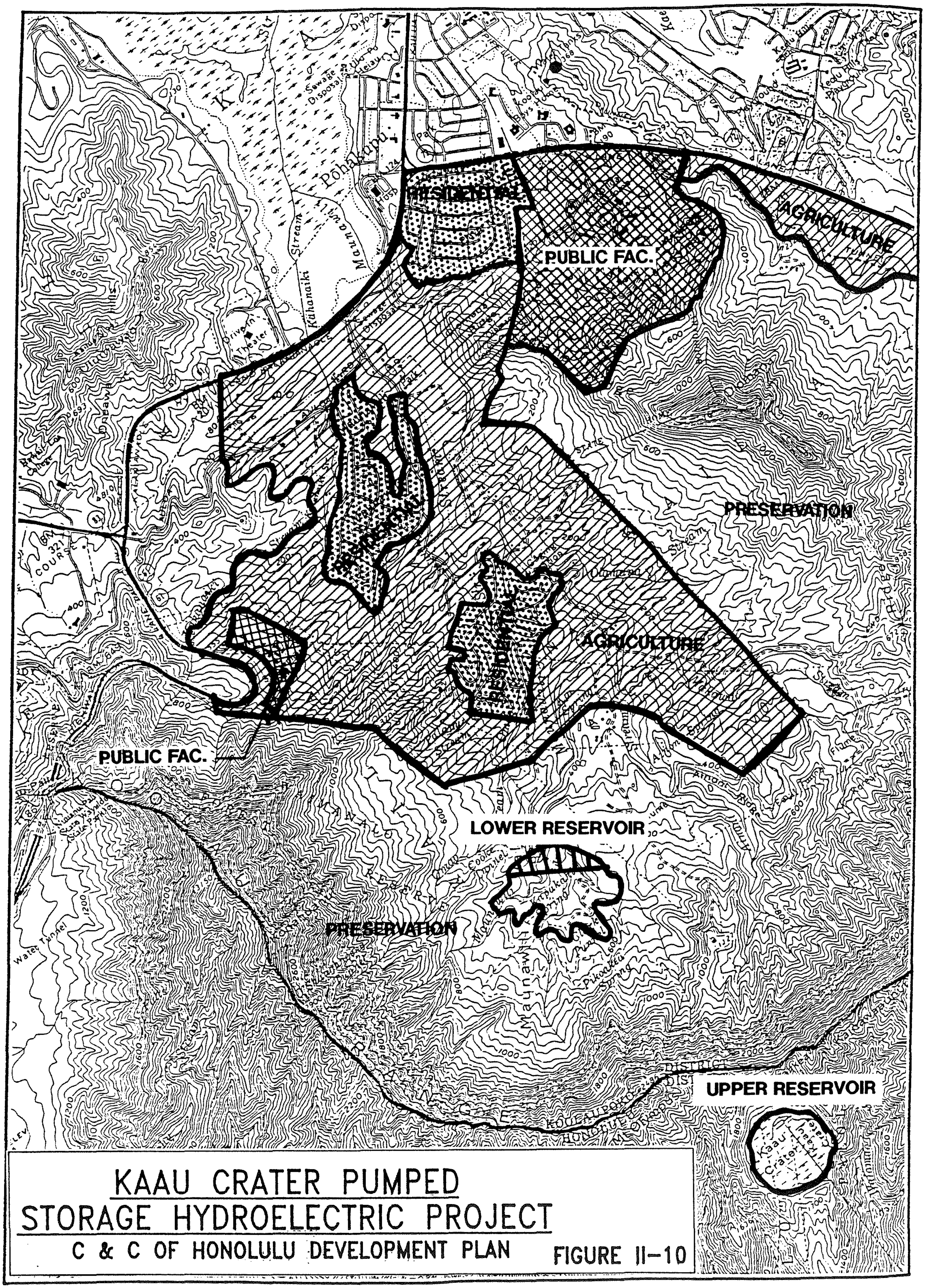
KAAU CRATER
HYDROELECTRIC PROJECT
MAUNAWILI VALLEY LAND OWNERSHIP



KAAU CRATER PUMPED STORAGE HYDROELECTRIC PROJECT

STATE LAND USE BOUNDRIES

FIGURE II-9



KAAU CRATER PUMPED STORAGE HYDROELECTRIC PROJECT

C & C OF HONOLULU DEVELOPMENT PLAN

FIGURE II-10

Research in areas similar to Maunawili Valley indicates that pondfield terraces, temporary habitation structures for farmers and gatherers of forest products and religious structures could be expected. Approximately sixty percent of the project area was surveyed by the Bishop Museum in preparation for the relocation of the Luluku banana farmers. Evidence of taro pondfields and remnants of habitation sites were found. All of theses sites were mitigated.(24)

From Appendix D...

The project area is at the base of the Ko'olau Mountain Range at the back of Maunawili Valley, covering approximately 45 acres (18.2ha), and cutting across four tributaries to Maunawili Stream..., approximately 6 miles (10km) from the coast. This area was formerly Forest Reserve land which was reforested during the 1920s by the Territory of Hawaii....Small truck farms were also here between the late 1920s to the 1960s, growing banana, papaya, ginger and sweet potatoes....Vegetation, therefore, varies from areas reforested to those once under cultivation.

Since 1930, approximately twenty archaeological surveys have been reported in Maunawili Valley. Only two were done in the lower valley. The pattern in the lower valley was pondfields on the valley floor with dryland agriculture and habitation sites on the slopes.

Forty percent of the proposed project area has already undergone archaeological inventory survey...in preparation for the relocation of the Luluku banana farmers displaced by the construction of H-3....Most of the sites recorded in the narrow upper valleys were associated with agriculture, both irrigated and dryland....The pondfields or irrigated systems, near streams or springs, ranged from very small systems across rivulets to a large complex of terraces on both sides of Maunawili Stream. Dryland

> *agriculture fields were in the form of terraces and mounds....In some cases, both irrigated and non-irrigated fields were in the same complex....Kukapoki heiau was the only heiau identified and it overlooked a large complex of terraces along Maunawili Stream, suggesting the heiau was probably an agriculture heiau.*

According to the Final EIS for the Maunawili Ditch System improvements:

> *The Waimanalo Irrigation System, which includes the Maunawili Ditch System, was determined to be eligible for inclusion in the National Register of Historic Places.*(25)

Current Uses.

The Maunawili reservoir site is used for banana cultivation by farmers displaced from Luluku by construction of the H-3 highway. The reservoir would intersect a portion of the Maunawili Ditch System. According to a National Marine Fisheries Service representative, Maunawili Stream supports a little-known recreational Smallmouth Bass fishery.(26)

Flora.

Vegetation on the proposed reservoir site in Maunawili Valley consists of actively cultivated banana fields on the slopes and a mixed introduced forest within the gulches that cross the project site. A native plant community composed primarily of koa (*Acacia koa*) and the matted uluhe fern (*Dicranopteris linearis*) occurs on the steeper slopes behind the proposed reservoir.

> *Eighteen rare plants have been reported along the Koolau summit ridge high above Maunawili Valley. However, no rare plant taxa have been*

> *reported...in...lower Maunawili Valley....Ten of the 18 rare species are candidates for federal listing, but none have been officially listed or proposed for listing.*(8)

Fauna.

A field survey of the Maunawili Valley site was conducted by Dr. Leonard Freed on October 10, 1993. (See Appendix A.) No endangered, threatened, or declining bird species were seen or heard. The Short-eared Owl or Pueo (*Asio flammeus sandwichensis*), an endemic land bird, is known from Maunawili Valley. The subspecies is listed as endangered on Oahu by the State of Hawaii Department of Land and Natural Resources Division of Forestry and Wildlife. The Oahu Elepaio (*Chasiempis sandwichensis gayi*), a declining species on Oahu, has been known to occur near Maunawili Valley. The threatened Newell's Shearwater (*Puffinus newelli*) may occur in the Maunawili area. Kawainui Marsh, the largest remaining freshwater wetland in the state, provides habitat for five species of endangered waterbirds.(8)

Biological studies of the flora and fauna around the ditch and in Maunawili, Ainoni and Makawao Streams for the Ditch System Improvements EIS found no endangered or threatened species. Most of the species are exotic, although two native species (mountain shrimp, *Atya bisulcata*, and Tahitian prawn, *Macrobrachium lar*) were found in the streams. The streams are highly modified and harbor mainly introduced species. The streams are completely dewatered during low flow at the elevation of the ditch system intakes. Low flow, substantial silt deposits, large populations of the predaceous crayfish and other exotics, channelized portions of the stream bed, and only one endemic stream species result in a low biological quality ranking.(25)

> *...the Hawaiian continuous perennial stream community is considered rare by the Hawaii Heritage Program. This community runs through the Maunawili Valley and Kawainui Marsh, and on to the sea through the Oneawa Channel.*(8)

Water.

The Maunawili Ditch System is the major source of irrigation water to the Waimanalo Watershed. Extensive repairs to the system have been made in recent years. The system is described in the Final EIS for the ditch improvements (25):

> *The Maunawili Ditch System is in conservation lands and is part of the Waimanalo Forest Reserve....Maunawili Valley is primarily drained by two perennial streams, the Maunawili and Kahanaiki Streams and their numerous tributaries. The two streams are the major contributors of flow into Kawainui Marsh, a critical wetland and Special Management Area. Average discharge into the marsh is estimated at 5.8 MGD* [million gallons per day] *from Maunawili Stream and 1.0 MGD from Kahanaiki Stream. The Maunawili Ditch System intercepts virtually all of the dry-weather flows of the Ainoni, Makawao, and East Maunawili Streams (all tributaries of Maunawili Stream) above the 440-480 ft. elevation. Other streams in the valley are unaffected by the ditch system. These include the Palapu, Omau, West Maunawili, Olomana Streams (all tributaries of Maunawili Stream) and the Kahanaiki Stream and its tributaries. The Clark, Fault, and Korean Tunnels and the Pikoakea Spring are the major dry-weather streamflow sources to the affected streams, and thus provide most of the dry-weather flow diverted by the ditch to Waimanalo....about 2.7 MGD are diverted by the five existing intakes.*
>
> *The Ditch System consists of over 16,000 ft. of lined and unlined ditches, tunnels, and elevated wooden flumes....The abandoned portion of the system formerly collected water from Omao Stream and Cooke Tunnel.*
>
> *Ground water in Maunawili Valley appears to be readily available as evidenced by the numerous springs and seeps in the area. Among the*

> *major springs in the valley are the Pikoakea, Omao, Kapakahi, Api, and Ainoni Springs....The major tunnel sources in Maunawili are the Cooke, Clark, Fault, and Korean Tunnels. Of the major groundwater sources in Maunawili Valley, the Maunawili Ditch System intercepts water from the Pikoakea Spring, and the Clark, Fault, and Korean Tunnels. These sources provide most of the flow diverted by the ditch to Waimanalo.*

The *Hawaii Stream Assessment* (23) identifies Maunawili Stream as a candidate for protection, with a diversity of riparian, cultural and recreational resources. In particular, the cultural and riparian resources associated with the stream were of outstanding value. The overall sensitivity of the valley based on density of archaeological sites and land disturbance was high. The recreational resources were substantial; the aquatic resources were of limited value. This study considers "Kawainui/Maunawili Stream" to include Maunawili, Kahanaiki, Olomana, Omao, Ainoni, Makawao and Palapu Streams, Kawainui Marsh and the Oneawa Channel. Kawainui/Maunawili Stream is classified a "small" stream, with a median flow of 8.7 cubic feet per second (cfs). Included are wetlands, estuarine areas and recovery habitat for waterbirds.

3. KAAU CRATER PROJECT POTENTIAL IMPACTS AND MITIGATION MEASURES

a. Construction Phase

Site Work.

Site work would take place in Kaau Crater, at the mouth of the crater, along an access road up to the crater, at the lower reservoir site in Maunawili Valley, along an access road to the lower reservoir, at a switchyard, and in a 138 KV transmission line right-of-way. Tunnels would also be drilled through the Koolau Mountains connecting the upper and lower reservoirs. Site work will directly alter landforms and indirectly, would be responsible for all of the other construction phase impacts identified below.

A major landform alteration would result from construction of the dam and upper reservoir in Kaau Crater. The crater floor would be excavated, graded and compacted prior to installation of an impermeable liner. The plans assume a balance between cut and fill so that neither import nor export of soil would be required. (If a significant portion of the soil in the floor of the crater proves to be unusable as construction material, large quantities of import and export will be required). The general topography would be little altered, but the land form would eventually be obscured by the reservoir. The mouth of the crater would be dammed, altering the natural form of the crater. Grading would also be required along the access road, estimated to be 3.5 miles in length.

The same types of activities would be necessary to construct the lower reservoir in Maunawili Valley. In addition, excavation would be required for the powerhouse and tunnels. Clearing, grubbing and grading would also be necessary at the switchyard and along the route of the transmission line. (see Section III-F re: transmission lines).

In contrast to the conditions at Koko Crater, the climate at Kaau and Maunawili is considerably wetter and the topography steeper; prevention of soil erosion will be a major consideration for the contractor. Under dry conditions, dust generation could also be significant. Adherence to the City's Grading Ordinance, watering as required, and prompt paving of the access roads, would reduce dust generation. The contractor will be required to prepare an erosion control plan prior to receiving a grading permit.

Because the project would involve disturbance of more than five acres of total land area, an NPDES General Permit under DOH Chapter 55 (Hawaii Administrative Rules) for "Discharges of Storm Water Associated with Construction Activity" would be required. A second NPDES General Permit will be required for "Discharges Associated with Construction Activity Dewatering" Similarly, an NPDES General Permit will be required for "Discharges of Hydrotesting Waters" if such tests are employed.

Water Quality.

Impacts to surface and drinking water resources are of much greater concern at Kaau/Maunawili than at Koko Crater. Kaau Crater lies between two tributaries of Palolo Stream, and eroded soil particles would eventually make their way into this stream system. In addition, Kaau Crater is a drinking water source for Palolo and Kaimuki via the Palolo Tunnel. The State's general policy against water quality degradation and use interference (§11-54-01.1, HAR cited above) will be impacted by the reservoir.

The Kaau Crater/Maunawili Valley project would affect "inland, fresh" waters classified as streams (perennial and intermittent), springs and seeps, and elevated wetlands. Because both project areas are within Forest Reserves, the contained inland waters are in Class 1.a. From Chapter 54, HAR, "Water Quality Standards,":

> *It is the objective of class 1 waters that these waters remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. To the extent possible, the wilderness character of these areas shall be protected. Waste discharge into these waters is prohibited. Any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination in class 1 waters is prohibited;...*
>
> *The uses to be protected in class 1.a. waters are scientific and educational purposes, protection of breeding stock and baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other nondegrading uses which are compatible with the protection of the ecosystems associated with waters of this class;...*

The basic water quality criteria introduced in the Koko Crater sections also apply to these inland waters. Elevated wetlands have a pH criterion added, and streams have a suite of water quality parameters including nutrient and suspended solids concentrations.

In the case of Kaau Crater, the elevated wetland would be destroyed, and nonpoint source contaminants would enter stream waters during construction. In Maunawili Valley, a number of springs, seeps and streams would be covered or altered by the lower reservoir and downstream waters would receive sediments eroded during construction. While nonpoint source pollution may be controlled to acceptable levels, uses of waters covered by the development would be lost.

Land Tenure.

Kaau Crater is on lands owned by the City and County of Honolulu and controlled by the Board of Water Supply. The access road would pass over both state and city lands. The Maunawili Valley lands are owned by the state, but portions of the proposed project area are leased to the Luluku banana farmers displaced from Kaneohe by construction of the H-3 freeway. These farmers would have to be evicted again. Mitigation would involve finding suitable alternative sites and compensation for lost crops and improvements.

Recreational and Aesthetic Uses.

Construction of the upper reservoir in Kaau Crater would eliminate a destination for hikers and nature enthusiasts. Aesthetically, construction of the access road would have a greater impact than damming of the crater mouth. The access road, however, would provide easier access to the Koolau summit for hikers and hunters. While this would be a recreational benefit, it could result in the accelerated degradation of native habitat, including that of the endangered tree snails that are found along the upper elevation of the Koolau Ridge.

The Maunawili Valley project area is little used recreationally because of the restricted access maintained by the state. The area, however, is visible from the new Maunawili Demonstration Trail constructed as part of the Na Ala Hele Program of DLNR.

Views from the trail extend from the Koolaus to the ocean, and do encompass developed areas. Nevertheless, a dam, reservoir, electrical switchyard and additional power lines will degrade the wilderness character of the upper valley.

Biota.

Construction of the upper reservoir and access road would remove vegetation and habitat, including the wetland, known to be used by endangered waterbirds and snails.

The flora and fauna of the Maunawili area is not as distinguished as that of Kaau Crater, however, reduced water flows into Kawainui Marsh would affect endangered waterbird habitat.

Noise.

Development of the project sites would involve grubbing, grading, tunnel drilling, road paving, and the construction of the powerhouse and the switch yard. Construction operations can generate significant amounts of noise. Actual noise levels would depend on the methods of construction employed during each stage of the process. Earthmoving equipment such as bulldozers and diesel powered trucks would probably be the loudest equipment used during the construction. Back-up alarms, in particular, have proven especially disturbing to residents near construction sites. Because of the distance between the proposed project location and nearby residences, however, the noise from construction operations would not cause "unreasonable" or "excessive" noise as defined by "Chapter 43 - Community Noise Control for Oahu".(13) All construction equipment and on-site vehicles or devices requiring an exhaust of gas or air must be equipped with mufflers. Also, construction vehicles using trafficways will satisfy the noise level requirements adopted for Oahu for similar noise generation ("Chapter 42 - Vehicular Noise Control for Oahu").(14)

Traffic and Air Quality.

Traffic into and out of both Palolo and Maunawili Valleys would increase during construction due to delivery of equipment and materials and worker vehicles.

Short-term direct and indirect impacts to air quality could potentially occur due to project construction. There are two types of air pollutant emissions which could directly result in short-term air quality impacts during the construction phase: (1) fugitive dust (particulate matter) from vehicle movement and site excavation; and (2) exhaust emissions (primarily nitrogen oxides, but also carbon monoxide, sulfur oxides and hydrocarbons) from on-site construction equipment. Indirectly, there could also be short-term impacts from slow-moving construction equipment traveling to and from the project site and from a temporary increase in local automotive traffic caused by commuting construction workers. Carbon monoxide comprises the largest fraction of emissions from gasoline-powered vehicles.

Strict compliance with State of Hawaii Air Pollution Control Regulations (Section 11-60-5), Hawaii Administrative Rules (HAR) regarding establishment of a regular dust-watering program and covering of dirt-hauling trucks would be required to effectively mitigate fugitive dust emissions from construction activities. Twice-daily watering is estimated to reduce dust emissions by up to 50 percent. Soil transported onto paved roads by construction vehicles and activities should be promptly removed. Use of wind screens and/or limiting the area that is disturbed at any given time may be required in sensitive or dust-prone areas. Paving of designated areas, landscaping as early as possible in the construction sequencing, and rapid installation of the reservoir liner would reduce total fugitive dust emissions. Construction equipment should be properly maintained and tuned to minimize exhaust emissions (Section 11-60-4, HAR). Equipment should be shut down rather than left idling when not in use.(15)

Archaeological Resources.

Neither Kaau Crater nor the Maunawili Valley project have been surveyed adequately for archaeological resources. The sediments in Kaau Crater are of value in explaining ancient conditions and uses. In Maunawili, both habitation and agricultural sites and features could be expected in the project area. A portion of the Maunawili Ditch System, which is eligible for inclusion on the National Register of Historic Places, would be destroyed.

b. Operational Phase

Water Quality.

Unlike the Koko Crater project, the Kaau project is essentially "closed," that is, the fresh water would be recycled from lower to upper reservoir without significant discharge. Most potential water quality impacts would occur during construction while grading and perhaps through erosion of dam faces during construction.

Land Use.

Operation of industrial facilities in forest reserves may be perceived as incompatible uses. While Kaau Crater is not extensively used other than by hikers, the access road and reservoir with its attendant safety and security systems would permanently alter the wilderness character of the area.

Operation of the lower reservoir would disrupt the Maunawili Ditch System to some extent, and could alter stream flows into Kawainui Marsh. Certainly the banana farmers would have to be permanently relocated. According to the State Agriculture Plan, Maunawili Valley does not contain "prime" agriculture lands; all of the valley is classified "other agricultural lands."

Both reservoirs would tend to increase nearby residents' fears of the consequences of natural disasters, and might negatively affect property values.

Recreational and Aesthetic Uses.

The proposed Pumped Storage facility would have recreational, aesthetic and cultural impacts. The primary impacts to recreational use would result from reduced hiking opportunities into the Kaau Crater.

Aesthetic impacts would be significant. Koolau vistas would be altered by the visual intrusion of the access road and views from the Maunawili Demonstration Trail would be altered by the new water body, and the electrical switchyard.

Biota.

Operation of the upper reservoir would unavoidably eliminate the wetlands as a waterbird habitat. This would be, in effect, filling of a wetlands. Federal regulations (Sect. 404, CWA) require that there be no practical alternative. Where avoidance or minimization of wetlands destruction cannot be achieved, compensation is required. Generally, creation or restoration of a comparable acreage is required.

Sourcing of water for this system is addressed in Section III of this report. Existing regulations insure that minimum stream flow volumes be maintained in Maunawili Stream, and sufficient water must flow into Kawainui Marsh to maintain that ecosystem.

Lights should be shielded to prevent birds from becoming disoriented.

Noise.

Noise from the PSH facility would result from operation of the pumps and generator, and to some extent from the moving water itself. The combined pump house/generating station would be below grade, thereby greatly reducing ambient noise impacts, especially at higher frequencies. There may also be some noise associated with operations of the switchyard.

Air Quality.

Air quality effects would be minimal and would primarily be associated with the incremental increase in fuel consumption at established power plant sites during the PSH pumping operations.

The project itself would have no emissions of air pollutants; it would actually result in lower islandwide emissions because of its displacement of fossil-fuel generators for peak power production. Vehicular traffic to the site would not be significant.

EMF and RI.

Electrical switching gear and transmission lines generate ambient electro-magnetic fields (EMF). There appears to be no definitive linkage of EMF and human health or ecological risks at this time. Some localized radio interference (RI) could occur around the high voltage facilities. The Kaau Crater and the area adjacent to the lower reservoir already have above ground 138 KV transmission lines.

4. SOCIOLOGICAL/POLITICAL CONSIDERATIONS

a. Housing/Infrastructure

Direct impacts to housing would be minimal. Both project areas are in Forest Reserves, at some distance from residential neighborhoods. Indirectly, there would be somewhat more traffic in adjacent neighborhoods, but infrastructure would not be unduly stressed. The existing 138 KV electrical transmission line from the Pukele substation in Palolo Valley over Kaau Crater into Maunawili Valley would be connected to the proposed switchyard and would require no acquisition of residential properties for right-of-way.

b. Residential And Neighborhood Board Concerns

On January 24, 1994, members of the Palolo Neighborhood Board were briefed on the project. Major concerns which surfaced included: the opportunity to review a draft report prior to any public hearing; the necessity for a transmission line through Palolo to the Pukele substation; the impacts of building an access road into Kaau Crater; visual impacts of an access road; loss of recreational use of Kaau Crater; and, safety in terms of both hikers and dam failure. It was suggested that enhancement of public assess along the access road would be partial mitigation of recreational losses.

On February 8, 1994, the Environmental Subcommittee of the Kailua Neighborhood Board was briefed on the project. Primary concerns expressed were replacement of the wetlands acreage in Kaau Crater, impacts to Kawainui Marsh, impacts to archaeological sites in Maunawili Valley, loss of agricultural lands and visual impacts of the facilities.

5. REGULATORY REQUIREMENTS

The project would need permits and approvals at federal, state and county levels to proceed (Table II-2). The coordinating agency at the federal level would be the Army Corps of Engineers. Filling of a wetlands would require a Corps permit under Section 404 of the Clean Water Act (33 U.S.C. 1344). The need for a federal permit would trigger additional requirements. The magnitude of potential impacts would likely trigger a federal environmental impact statement (EIS) under the National Environmental Policy Act (NEPA).

Section 7 of the Endangered Species Act (ESA), 16 U.S.C. 1536, requires that each federal agency insure that any activity authorized, funded of carried out by it is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of any critical habitat for such species. Construction and operation of the Pump Storage facility would involve modification of the physical environment as well as potential impacts on living organisms. Accordingly, review of the project for endangered species impacts will form a part of the process of granting any federal permit or authorization for the project.

The Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661-666c, requires that federal permitting agencies give full consideration to conservation of wildlife resource values in the permitting process. This consideration is accomplished through consultations between the permitting agency and the affected state wildlife agency, the U.S. Fish and Wildlife Service Regional Director and the National Marine Fisheries Service Regional Director, as appropriate. The purpose of these consultations is, to the maximum practical extent, to avoid project-caused losses of wildlife resources, to compensate for unavoidable wildlife resource losses, and to enhance wildlife resource values.(16)

The project would take place entirely within Forest Reserve lands, which are outside Hawaii's defined coastal zone. Therefore, no Coastal Zone Management Consistency Certification (Section 307(c) of the Coastal Zone Management Act of 1972 (16 U.S.C. 1456 (c)) would be required.

The State Commission on Water Resource Management has designated Windward Oahu a water management area, and is in the process of inventorying existing uses of groundwater. No groundwater use permits are being granted until the inventory is complete.(27)

A state Water Quality Certification pursuant to Section 401 of the Clean Water Act is required by any applicant for a federal license or permit to conduct an activity in state waters that would include the construction and operation of facilities that may result in any discharge. As an emergency discharge from the facility might be required, a certification would be necessary.

Much of the proposed infrastructure for the project would be situated on lands classified Conservation by the state. Accordingly, a Conservation District Use Permit would be required from the Board of Land and Natural Resources. Use of Conservation District Lands would also trigger a state EIS under Chapter 343, HRS. Historic Site Review (Chapter 6A) would be undertaken as part of the EIS process. A revocable permit for use of state lands would be required from the Division of Land Management.

Construction of the dams and reservoirs would require permits from the BLNR. If a dam is judged to be of high hazard, an emergency preparedness plan would be required.

Because the project would involve disturbance of more than five acres of total land area, an NPDES General Permit under DOH Chapter 55 (Hawaii Administrative Rules) for "Discharges of Storm Water Associated with Construction Activity" would be required. A second NPDES General Permit will be required for "Discharges Associated with Construction Activity Dewatering" Similarly, an NPDES General Permit will be required for "Discharges of Hydrotesting Waters."

At the City and County level both discretionary and ministerial permits would be required. The Development Plan would require amendment, which may in turn trigger an

EIS requirement. A single EIS can be written to fulfill the requirements at federal, state and county levels.

A Zoning Waiver for Public Utilities may be granted by the Director of Land Utilization, and may be appropriate for the proposed project.

Ministerial permits would include a Building Permit, Certificate of Occupancy, and a Grubbing, Grading and Stockpiling Permit. The contractor will be required to prepare an erosion control plan prior to receiving a grading permit.

The permits and approvals necessary to develop the Kaau Crater site are listed in Table II-2.

TABLE 2
KAAU CRATER PERMITS AND APPROVALS

PERMIT OR APPROVAL	AGENCY OR ENTITY
Section 404 Permit (Clean Water Act)	U.S. Army Corps of Engineers (COE)
Section 7 (ESA) Consultation and Fish and Wildlife Coordination	COE with National Marine Fisheries Service (NMFS), Fish and Wildlife Service (FWS) and Hawaii Department of Land and Natural Resources (DLNR)
Environmental Impact Statement (NEPA)	COE, Office of Environmental Policy
Groundwater Use Permit	Hawaii Commission on Water Resource Management
Water Quality Certification	Hawaii Department of Health (DOH)
Conservation District Use Permit	Hawaii Board of Land and Natural Resources (BLNR)
EIS (Chapter 343, HRS)	Governor (through the Hawaii Office of Environmental Quality Control)
Historic Site Review (Chapter 6A, HRS)	DLNR, Division of Historic Preservation
Revocable Permit for Use of State Lands	DLNR, Division of Land Management
Dam Safety Approval	BLNR

NPDES Permits	DOH
Use of City Land	Honolulu City Council
Development Plan Amendment	Honolulu Department of General Planning (DGP) and Planning Commission
EIS (Chapter 25, ROH)	DLU and DGP
Zoning Waiver for Public Utilities	DLU
Building Permit	Honolulu Building Department (BD)
Certificate of Occupancy	BD
Grubbing, Grading and Stockpiling Permit	Honolulu Department of Public Works (DPW)

D. CONCLUSIONS ON PROJECT ENVIRONMENTAL AND LEGAL ISSUES

1. KOKO CRATER

- **Land Tenure** - Most of the lands to be used for the proposed project are owned by the City and County of Honolulu, and administered by the Department of Parks and Recreation, the Director of which is on the record as opposing any change in use of Koko Crater. It would likely be possible to negotiate with Bishop Estate a waiver of the existing deed restriction specifying recreational use only of Koko Crater, but monetary compensation, probably in the form of a percentage of revenues, may be required.

- **Land Use** - Existing uses of Koko Crater, including the botanical gardens and the stables could likely be relocated elsewhere. Uses of the remainder of Koko Head Park would be little impacted, except at the shoreline in the vicinity of the intake structure and breakwater.

- **Environmental Resources** - No protected native plant or animal species would be directly and significantly impacted, although Madagascan specimens in the botanical gardens and certain "exceptional trees" might be lost. Additional oceanographic, water quality and marine biological investigations would be necessary to insure that the resources of Hanauma Bay would not be impacted. Additional archaeological work would be necessary, although the extent of mitigation necessary to acquire Chapter 6E HRS. clearance is of course unknown in advance. Aesthetic impacts, especially degradation of the scenic coastal vistas, could be a significant impediment.

- **Regulatory Requirements** - Major permits would be necessary at city, state and federal levels. Justifications in terms of overall public benefits would be necessary where issues arise with respect to development plans, and special management and conservation district use areas. It is likely that a substantial list of conditions would be attached to permits, especially those concerned with the discharge waters.

- **Public Opinion** - Probably the most significant impediment to feasibility of the Koko Crater site will be public opposition. It is likely that a number of organized environmental groups would oppose the project, resulting in a long and expensive permitting process.

- **Summary** - While there are negative environmental impacts, none identified for the report appears to be insurmountable in that reasonable mitigating measures are likely to be available.

2. KAAU CRATER/MAUNAWILI RESERVOIR

- **Land Tenure** - Kaau Crater is owned by the City and County of Honolulu, and control resides with the Board of Water Supply. The Maunawili Valley project area is owned by the State, but a second relocation of the Luluku banana farmers would be necessary.

- **Land Use** - Kaau Crater is little used presently. Construction of the access road from Palolo Valley would improve recreational access to the crater, but jeopardize important habitat for protected and other native species. Construction of the lower reservoir in Maunawili Valley would likely reduce delivery of irrigation water to Waimanalo through the Maunawili Ditch System.

- **Environmental Resources** - Kaau Crater and the surrounding mountains harbor an impressive array of protected and native species. At a minimum, a unique higher elevation wetland with habitat for endangered waterbirds would be lost, and development of replacement habitat may be required as compensation. Candidate sites are not readily apparent.

  Although the biota of the Maunawili Valley site is less distinguished, the Maunawili Stream System is a candidate for preservation because of its important cultural and riparian resources. The necessity to maintain minimum stream flow into Kawainui Marsh, a major endangered waterbird habitat, and the apparent lack of significant developable groundwater resources in the valley, make sourcing of water for this project a major constraint. Archaeological and historical resources, including the Maunawili Ditch System itself, are also significant in Maunawili Valley, if not at Kaau Crater. Aesthetic impacts to both areas would be significant.

- **Regulatory Requirements** - Major permits would be necessary at city, state and federal levels. Justifications in terms of overall public benefits would be necessary where development plan and conservation district use guidelines may be violated. Windward Oahu is a designated Water Management Area, and water use plans would be subject to intense scrutiny. There is presently a moratorium on granting of new Groundwater Use Permits.

- **Public Opinion** - It could be expected that numerous environmental groups would actively oppose the project's impacts to protected species in and near Kaau Crater and the water resources of Maunawili Valley.

- **Summary** - Because of the significant negative impacts and the lack of mitigating solutions, the Kaau Crater project would appear to have very significant, if not insurmountable opposition to its becoming a reality.

E. RECOMMENDATIONS FOR FOLLOW-ON STUDIES

1. KOKO CRATER PROJECT

A full-scale inventory-level archaeological survey of the entire Koko Head Regional Park project area should be completed. The principal objectives of such an inventory-level survey would be fourfold: (a) to identify (find and locate) all sites and features present within the project area; (b) to evaluate the potential significance of all identified archaeological remains; (c) to determine the possible impacts of proposed development upon the identified remains; and (d) to define the scope of any subsequent archaeological mitigation work that might be necessary or appropriate.(4)

Required oceanographic and marine biological studies would include a species inventory, water quality measurements, analysis of facility construction and operation noise on protected species, and current measurements to determine effects of the discharge on Hanauma Bay. There should also be a survey for Pueo and prey species at the Koko Crater site.

2. KAAU CRATER/MAUNAWILI PROJECT

Before construction of the upper reservoir, a comprehensive survey for endangered tree snails near Kaau Crater should be completed. An additional bird survey for Elepaio in both Kaau Crater and Maunawili Valley should be done. Both floral and fauna surveys along the access road route should be completed.

Archaeological studies would be required in Kaau Crater and Maunawili Valley. Borings through the sediments in the crater should be taken and analyzed for information on the history and prehistory of Hawaii, in particular the composition of the native forest and its changes over time. Archaeological inventory surveys should be completed over the more than half of the Maunawili Valley project area which has not been surveyed in the past. Native Hawaiian groups should be consulted to ascertain traditional cultural values of the area.

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SECTION III. KOKO CRATER AND KAAU CRATER DESIGN

A. TECHNICAL DATA

1. General

This section summarizes the results of field work, literature surveys, and current utility analysis to expand the data base for realistic design concepts for the Pumped Storage Hydroelectric (PSH) projects. The projects could then be evaluated for technical, economic, and environmental feasibility. The following sections discuss geotechnical, hydrological, utility system analysis, and ocean engineering issues. (See Appendices E, F, and G technical reports for more detail.)

2. Geotechnical

a. Koko Crater (See Plate 1 of Appendix E for project location and plate 2 for Geologic description)

Borrow material: Considering the weak to moderately strong nature of the Koko Crater tuff, local borrow sites will likely yield earthfill-type material rather than rockfill material. The tuff derived earthfill material, however, will likely be highly erodible on embankments and some measures will be needed to prevent erosion and piping should seepage occur.

Construction: To reduce the amount of settlement the dam will experience, over-excavation of the alluvial materials at the crater gap will likely be required. Alluvium at the crater gap was observed to be at least 20 feet thick where exposed in the stream course draining the crater. The tuff and alluvium within the crater, in general, appear to be highly permeable and it is likely that lining of the reservoir will be needed to reduce the potential for large losses of water through infiltration. Tunnel excavation appears to be feasible using currently established methods; however, considering the nature of the tuff, the need for temporary crown support should be anticipated. Where tunneling extends below sea level, basal groundwater will be encountered and, due to the highly permeable tuff excavation, will require groundwater control measures such as grout curtains and dewatering. These measures will be particularly difficult for the powerhouse site because of the large underground openings required. Based on the performance of the existing road cuts along Kalanianaole Highway vertical rock faces should have very good standup time.

<u>Geological Hazards</u>: It does not appear that the project would adversely affect stability of the slopes in the area. The possibility of rockfall and rock sliding, however, will continue to exist on the steep slopes above the reservoir. The island of Oahu is not considered a highly active seismic area and the project would be designed to the prevailing code related to seismic zone 2A. Although Koko Crater is believed to be approximately 32,000 years old, many geologists would consider Koko Crater to be a potentially active crater. This potentiality should be tempered by the trend in volcanic activity in the Hawaiian Islands moving to the southeast, suggesting that the likelihood of volcanic activity on Oahu during the lifespan of the project is relatively low. Since the Koko Crater reservoir site is located sufficiently inland and at a high enough elevation the possibility of inundation of the reservoir by a tsunami is remote; however, the breakwater and other appurtenances on the ocean side of the project could suffer severe damage. Finally, ground subsidence resulting from the consolidation of soft sub-soils does not appear to be a consideration for the project.

b. Kaau Crater Project (See Appendix E Plate 3 for project location and Plate 4 for Geologic description)

<u>Borrow material</u>: Spur ridges in the Maunawili reservoir area appear to be potential sources of basalt rockfill material. Basaltic rock characteristics on the rim of the Kaau Crater should also have characteristics appropriate for use as rock fill. Deposits of low permeability material suitable for dam clay core or reservoir lining were not observed in any sufficient quantities. Silts and clays within the Kaau Crater may be suitable for use as liner material for the Kaau reservoir since these materials currently function to some extent as a natural liner in the crater contributing to its marshy surface condition. However, soft soil and shallow ground water conditions would present difficulties that would need to be overcome to process the silts and clays.

Construction: To reduce the amount of settlement the Maunawili dam will experience, over-excavation of the alluvial materials will likely be required. Once basalt rock foundation conditions are exposed, probing to detect possible voids may be required. With appropriate design and construction techniques basaltic rock at the dam abutments should provide adequate foundation support for dam construction. The alluvium and basaltic rock at the Maunawili site appear to have high permeability and lining of the reservoir should be anticipated.

Although silts and clays in the bottom of the Kaau Crater appear to have low permeability characteristics, the transition slopes around the perimeter of the crater floor may have high permeability. Lining of the reservoir will be needed to reduce the potentially large losses of water through leakage. The crater floor appears to be highly compressible and may experience significant settlement under reservoir loading.

Tunnel construction considerations for the Kaau project are similar to the Koko Crater project except for the major dike complex system that pervades the geological formation between the crater and the lower reservoir of the Kaau project. It is likely that abrupt changes in groundwater levels will be encountered during tunneling through the diked complex. Appropriate exploration and tunneling methods will need to be used to reduce the potential construction and safety problems associated with sudden, large volume flows of groundwater in zones of sheared rock. The presences of groundwater will require design and construction features for the underground power plant to assure positive control of groundwater infiltration.

Geological Hazards: Areas of debris flows and debris avalanches are located above both reservoir sites. The volumes of material involved are likely to be small; therefore, a significant impact on reservoir level is not anticipated. The seismic and volcanic conditions are similar to the Koko Crater description. The Kaau Crater and Maunawili reservoirs are sufficiently inland and at high enough elevations that the possibility of inundation by tsunami is non-existent; however, intense rainstorms can cause localized flash floods that may transport mud and rock debris into the reservoirs.

3. Ocean Engineering

a. General

Appendix F discusses the ocean environment and recommends design requirements for the salt water intake/outlet structure of the Koko Crater project. The structure is located about one-quarter mile southwest of the Blowhole near the shoreline below Kalanianaole Highway. Figure 2 of Appendix F depicts its location. The inlet/outlet structure must be designed to withstand forces created by wind driven waves during both the construction phase and when in operation.

This study considered two options for the inlet; a continuous tunnel out to deep water, and a near shore inlet protected by a breakwater that encloses a salt water reservoir. During operation the breakwater must be pervious to allow water flow in both directions. This feature will filter large objects from entering the inlet tunnel leading to the power plant.

Continuous Tunneling: In this option the inlet/outlet would be extended sufficiently offshore such that it would not be subject to large breaking waves. Based on the estimated bathemetry it would be necessary to extend the tunnel about 500 feet offshore to a bottom depth of 65 feet to provide a cover depth of about 30 feet over the tunnel. This location will avoid the affects of 30 foot design waves for the area. This option is depicted in figure 7a of appendix F.

Breakwater: This option requires the initial construction of a cofferdam so that the inlet/outlet structure can be constructed in the "dry". An offshore breakwater is also necessary to provide wave protection during construction and operation. The breakwater can be located relatively near shore; it is estimated that a location 150 feet offshore will be sufficient primarily to provide working space during construction of the inlet/outlet structure. The breakwater would be a rubblemound structure which would dissipate wave energy and serve as a "filter" for large objects. Figure 8 of Appendix F shows a conceptual typical section for the breakwater.

4. HECO System Analysis

The Generation Expansion Planning Program Study (GEPPS) and PROSCREEN:

GEPPS and PROSCREEN are computer programs used to model and simulate utility system operations and to perform screening of different basic plans of generating facilities and demand side programs. The computer programs were used as part of the IRP work, discussed above, as part of a complete generation expansion study. The identification of PSH as an economically feasible addition to the HECO generating system resulted from the GEPPS and PROSCREEN analysis.

Additional analyses were performed as part of the present study to utilize the most current load forecasts. Appendix G is the report on the results of the analyses. These results indicate that the inclusion of PSH in the mix of generating facilities in the year 2005 would result in fuel savings over mixes of generating facilities that did not have PSH. The study further showed that a daily operating cycle would have greater fuel savings than a weekly operating cycle.

The analysis concluded that the number of pumping hours should be about 8 and the number of generating hours should be up to 14, and the size of the PSH facility should be in the range of 100 to 180 MW. 180 MW is the upper limit so as not to increase spinning reserve requirements. (Spinning reserve is equal to the largest unit on the HECO system which is presently 180 MW.)

As a result of these analyses and the capacity of the Koko Crater project both Kaau and Koko Crater projects are based on a nominal 160 MW generating capacity.

5. Hydrogeology

Koko Crater: As noted above, any groundwaters encountered in the construction of this project are likely to be brackish due to the close proximity of the project to seawater. Because of the relatively dry nature of the area due to the low annual rainfall there are no perennial streams or other fresh water resources of concern for this project.

Kaau Crater/Maunawili Project: Unlike Koko Crater, the Kaau Crater project is significantly affected by the hydrological features of the area and related legal requirements; both current and anticipated in the future. The Kaau Crater/Maunawili project is affected by the following major issues:

- Source and availability of water to initially fill the reservoir
- Affect of diked waters on the routing and construction of shafts and penstocks
- Requirements to maintain stream water quality
- Requirements to maintain delivery of water to users
- Requirements to maintain in-stream flow

Each of these issues is discussed in the following sections preceded by a general description.

a. General Description of area

The area encompassing Kaau Crater and the Maunawili Valley is one of the wettest spots in East Oahu. The annual median rainfall pattern in this region shows the dominance of the topographic effects on rainfall. The principal rain-producing mechanism on Oahu is orographic lifting of trade winds along the Koolau slopes. These slopes terminate at the crest of the Koolau Range which divides Kaau Crater from the Maunawili Valley.

The geological structure separating these two features, as well as the area underlying the Valley, contains large quantities of dike impounded water. The dike-impounded water manifests itself as essentially continuous flow out of natural springs, seepage and manmade tunnels that feed the streams in the Valley. The effect the dike system has on ground water levels is depicted in Figure III-1. The flow quantities and the streams created by this groundwater are depicted in Figure III-2.

b. Reservoir Water Requirements

The amount of water required for the Kaau Crater project is about 1470 acre-feet or 485 million gallons. The possible sources for this water are the springs and tunnel feeding the Maunawili Stream, additional wells and tunnels into the dike impounded groundwater, and rainfall.

The dry weather water sources feed the Maunawili Stream at about 1 million gallons per day. Assuming a constant flow, it would require over a year to fill the reservoir; (evaporation is assumed to be equal to recharge by rainfall into the reservoir.) however, as shown on Figure III-1, some of the principal sources of water flowing into the stream will be covered as the reservoir fills thereby applying a back pressure on these sources. This backpressure would be expected to reduce the flow from these sources and increase the time for filling.

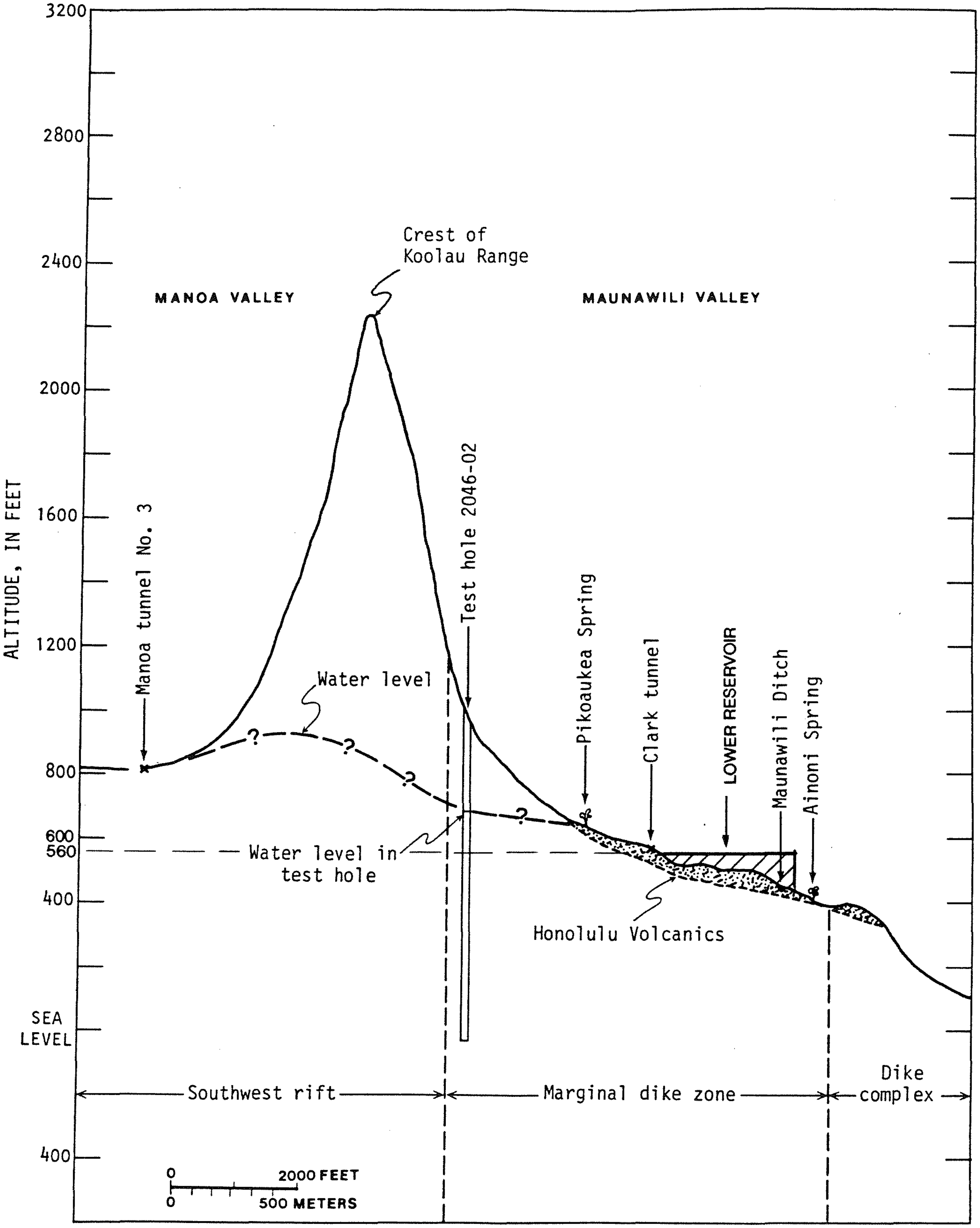
To accelerate reservoir filling it is conceivable to install wells to tap the marginal dike groundwater. As noted in "Water Resources of Windward Oahu",(Takasaki et. al. 1969) the basal water level of Maunawili Valley is at an elevation of 2 feet and the high level (diked) water is at 650 ft. These conclusions are based in part on a series of test wells drilled for the Honolulu Board of Water Supply during 1953-54 to investigate ground water resources in Maunawili Valley.

These wells (now identified by Well Nos. 2046-01, 2046-02, 2047-01 and 2047-02) encountered ground water at about 600 ft above sea level. The geological information presented in the report indicates that the test wells penetrated marginal dike complex formations and that the rocks have low to moderate permeability.

In general, the rocks of the marginal dike complex of the Koolau Volcanic Series have relatively low permeatabilities and do not freely yield water to wells. The available information indicated that, on the Windward side of Oahu, wells have specific capacities of less than about 50 gallons per minute per foot of drawdown. By comparison, wells tapping dike-free flows of the Koolau Volcanic series have specific capacities ranging from about 80 to 500 gallons per minute per foot of drawdown. (Takasaki et. al., 1969). To fill the reservoir from these sources in a period of from 3 to 6 months would require wells with a capacity of 2 to 4 Mgal per day. The low permeatabilities of the marginal dike complex essentially eliminated wells as a source of water to fill the reservoir.

The same report noted that further development of water flow by the addition of more horizontal tunnels in the marginal dike zone or anywhere in Maunawili Valley would not enhance the existing net water supply. The principal reason is that the base-flow discharge is too small and that the present tunnels are already effective in channeling nearly all base flow above the Maunawili Ditch.

The historical rainfall data suggests that in an average year the drainage area related to the lower reservoir could fill the reservoir in about 6 months (as compared to 12 month period of dry weather flow from the diked zones only). To capture this water



EVALUATION OF MAJOR DIKE-IMPOUNDED GROUND WATER RESERVOIRS, ISLAND OF OAHU

GEOLOGICAL SURVEY

FIGURE III-1

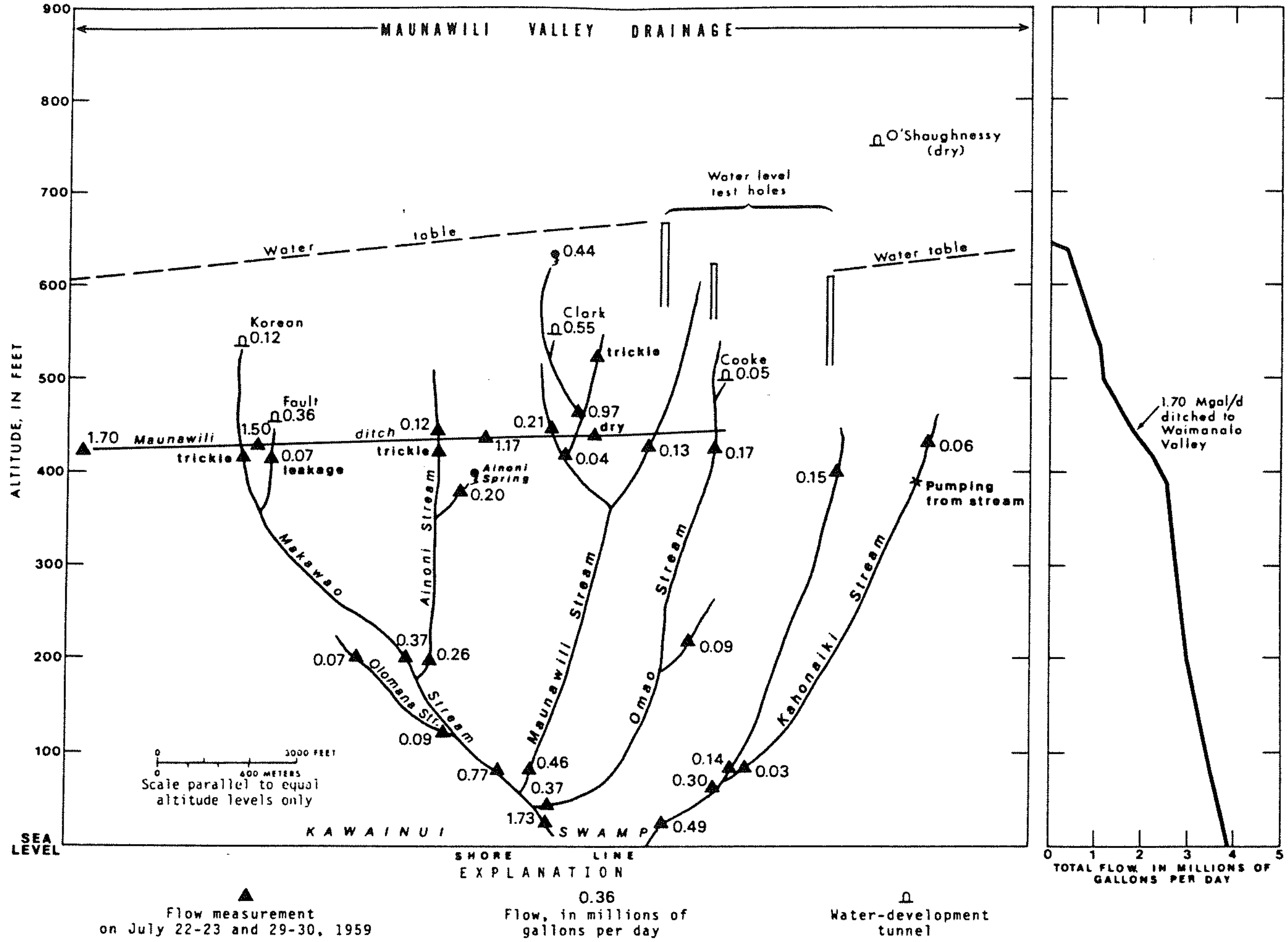


Figure 30. Relative altitudes of water levels in wells, water-level gradient of dike-impounded water, tunnels, and base-flow measuring points in streams in Maunawili Valley.

would essentially eliminate the contribution of water flowing to the Waimanalo Ditch as well as the Kawainui Marsh during the filling cycle.

c. Affect of diked/perched water on Penstock routing and construction

The diked water is in the path of the waterways between the upper and lower reservoirs. In Figure III-1, it can be seen that the groundwater level (based on test wells) is at 800 to 600 feet above sea level as the Koolaus are traversed. Since the inlet to the lower reservoir is at about 500 feet a significant length of the underground waterway will traverse through ground water regions. This condition will impose water intrusion control procedures that will add significantly to the cost of construction.

The amount of water encountered may be reduced by routing the penstock from the upper reservoir (its base is at elevation 1540 ft) at a shallow slope toward the Maunawili Valley thereby maintaining the tunnel above the maximum water level in the Koolau's.

d. Water Quality

Many laws and regulations, both federal and State, require that the water quality of the streams that drain the Maunawili valley be maintained and that pollutants that would affect in- stream habitat, the Kawainui Marsh, or agricultural lands be eliminated. During construction of the lower reservoir it is almost certain that a change in the nature of the nutrients and other elements flowing into the streams will result from excavation and any subsequent erosion due to rain. The excavation alone will undoubtedly disrupt or destroy insect, mammal, and bird populations and habitats resulting in a major change in the flow of organic as well as inorganic material into the streams. It is unclear that it is possible to maintain water quality should construction of the Kaau crater project go forward.

e. Water Quantity

Maunawili Ditch: The Maunawili Stream and its tributaries currently contribute about 1 million gallons of water a day to the Maunawili Ditch. This ditch provides irrigation water to the Waimanalo Irrigation System. The February 1992 draft report on the State Water Projects Plan indicates that the supply of water for irrigation is expected to increase and continue for the foreseeable future. (The report has projections out to the year 2010).

III B. PUMPED STORAGE TECHNOLOGY

"Hydroelectric pumped storage...is widely recognized as the most mature and efficient energy storage technology available. There are more than 180 pumped storage plants in operation worldwide with a total installed capacity exceeding 70,000 MW."

This quotation from a 1993 paper presented by Mr. R. S. Koebbe of L. B. Industries at the Waterpower '93 Conference supports the validity of considering PSH technology for use with the HECO utility system. As an established technology there is no research to be undertaken and there are a variety of firms, foreign and domestic, to produce the necessary machinery and numerous contractors available with the required construction knowhow. Table IIIB-1 is a summary of pumped storage hydroelectric facilities worldwide.

Pumped storage facilities generally use fresh water as the pumping fluid; so essentially all the experience is limited thereto. The only major salt water plant is a unit currently under construction in Okinawa. This unit is a 30MW plant that is expected to be completed in 1998. (Construction was delayed by phased government funding). Even with the salt water application the machinery is based on proven design concepts; the major difference from a fresh water plant is in the materials of construction for the impellers/runners. Appendix I provides more detail on the Okinawa project.

Installed capacity of pumped-storage plants by country

Data are based on the surveys "The world's hydro resources" and "The world's pumped-storage plants" in the *Water Power & Dam Construction* Handbook 1991. The numbers of plants exclude pumping only plants at pumped-storage projects.

Turbining capacity of pumped-storage plants in operation, under construction and planned, by country

	In operation		Under const.		Planned			In operation		Under const.		Planned	
Country	Number of plants	Total capacity (GW)	Number of plants	Total capacity (GW)	Number of plants	Total capacity (GW)	Country	Number of plants	Total capacity (GW)	Number of plants	Total capacity (GW)	Number of plants	Total capacity (GW)
Argentina	2	0.862[a]	0	0	0	0	Italy	20	6.15	1	0.338	1	1
Australia	6	2.565	0	0	0	0	Japan	38	17.004	8	5.48	440[d]	329
Austria	17	2.081	0	0	5	2.28	Korea (Rep of.)	2	1.032	1	0.6	0	0
Belgium	2[b]	1.211	0	0	0	0	Luxembourg	1	1.096	0	0	0	0
Brazil	4	0.191	0	0	0	0	Mexico	0	0	0	0	8	2.8
Bulgaria	2	0.535	1	0.864	n/a	n/a	Morocco	0	0	0	0	1	0.333
Canada	1	0.122	0	0	0	0	Norway	7	1.239	1	0.6	3	n/a
Chile	1	0.029	0	0	0	0	Philippines	1	0.31	0	0	1	0.31
China	2	0.033	3	1.55	2	2.6	Poland	5	1.37	2	0.927	n/a	n/a
China (Mainland)	1	1.028	1	1.6	1	1.2	Portugal	4	0.414	0	0	1	0.136
China (Taiwan)	3	0.031	0	0	0	0	Romania	6	0.084	0	0	1	1
Czechoslovakia	8	1.349	1	0.65	2	1.7	South Africa	2	1.4	0	0	1	1
Finland	0	0	0	0	1	0.45	Spain	22	4.831	3	1.32	11	n/a
France	22	4.9	0	0	1	0.5 +	Sweden	3	0.427	0	0	0	0
Germany	38	5.129	0	0	0	0	Switzerland	12	1.178	1	0.003	n/a	n/a
Greece	1	0.315	1	0.3	0	0	Thailand	1	0.18	1	0.18	2	0.775
Hungary	0	0	0	0	1	1.2	Tunisia	0	0	0	0	1	0.3
India	4[c]	1.389	3	1.333	0	0	UK	5	3.023	0	0	0	0
Iran	0	0	1	1	0	0	USA	37	17.09	3	1.975	49	18.69
Ireland	1	0.292	0	0	0	0	USSR	1	0.225	3	5	4	11
Israel	0	0	0	0	1	0.5	Yugoslavia	3	1.3	0	0	0	0

(a) Los Reyunos: capacity to be increased from 112 MW to 224 MW; (b) Coo-Trois Ponts 1 and 2 are counted as one plant in total; (c) only one of the completed plants (Kadamparai, 400 MW) has operated in the pumping mode; and, (d) timescale for the development of Japan's planned schemes is not available.

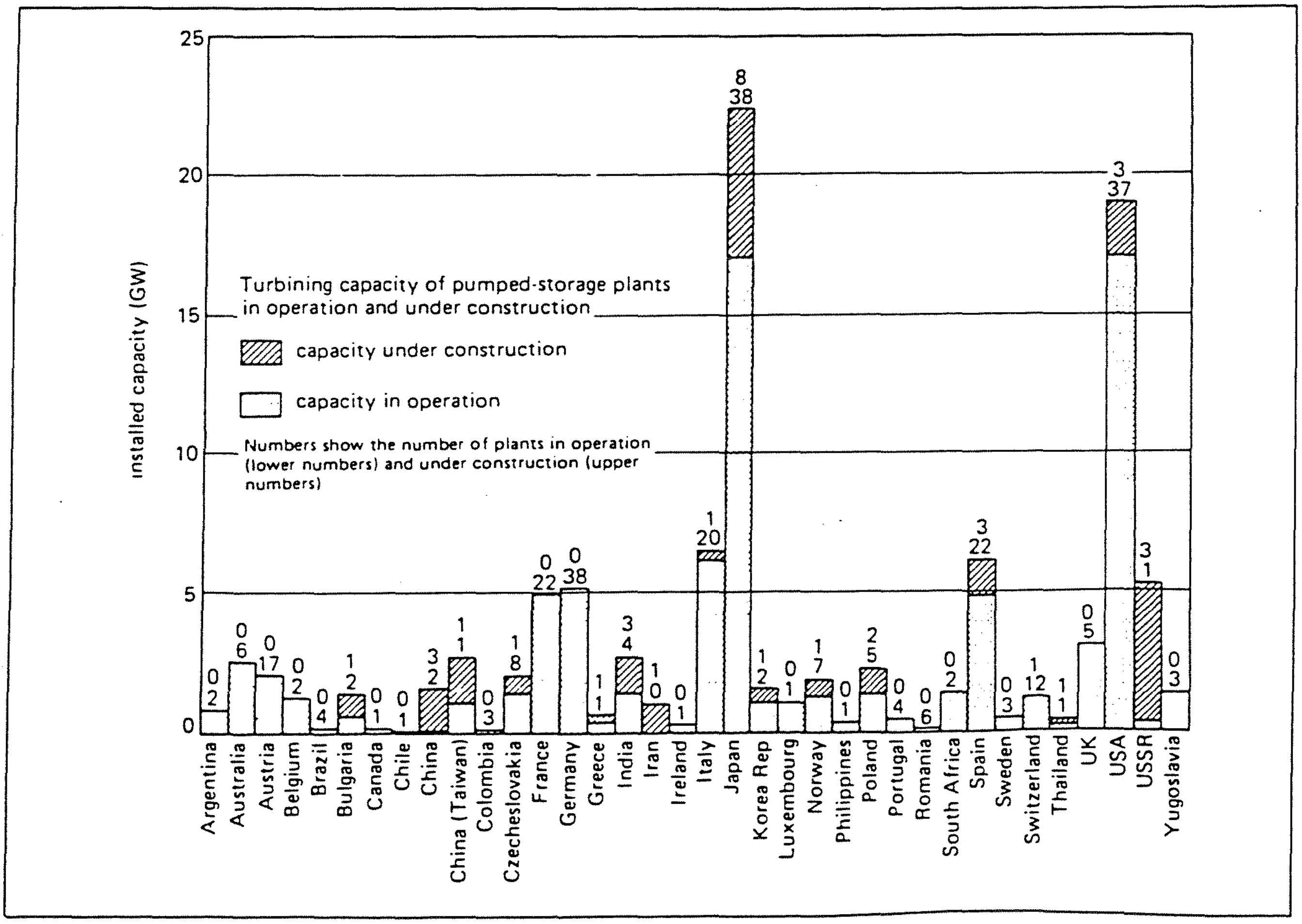


TABLE IIIB-1

C. KOKO CRATER PUMPED STORAGE POWER PROJECT

The Koko Crater site is located on the south-east coast of Oahu just east of Hawaii Kai as shown on Figure III-3. Proposed features of major components of the hydroelectric facility are shown on the following page.

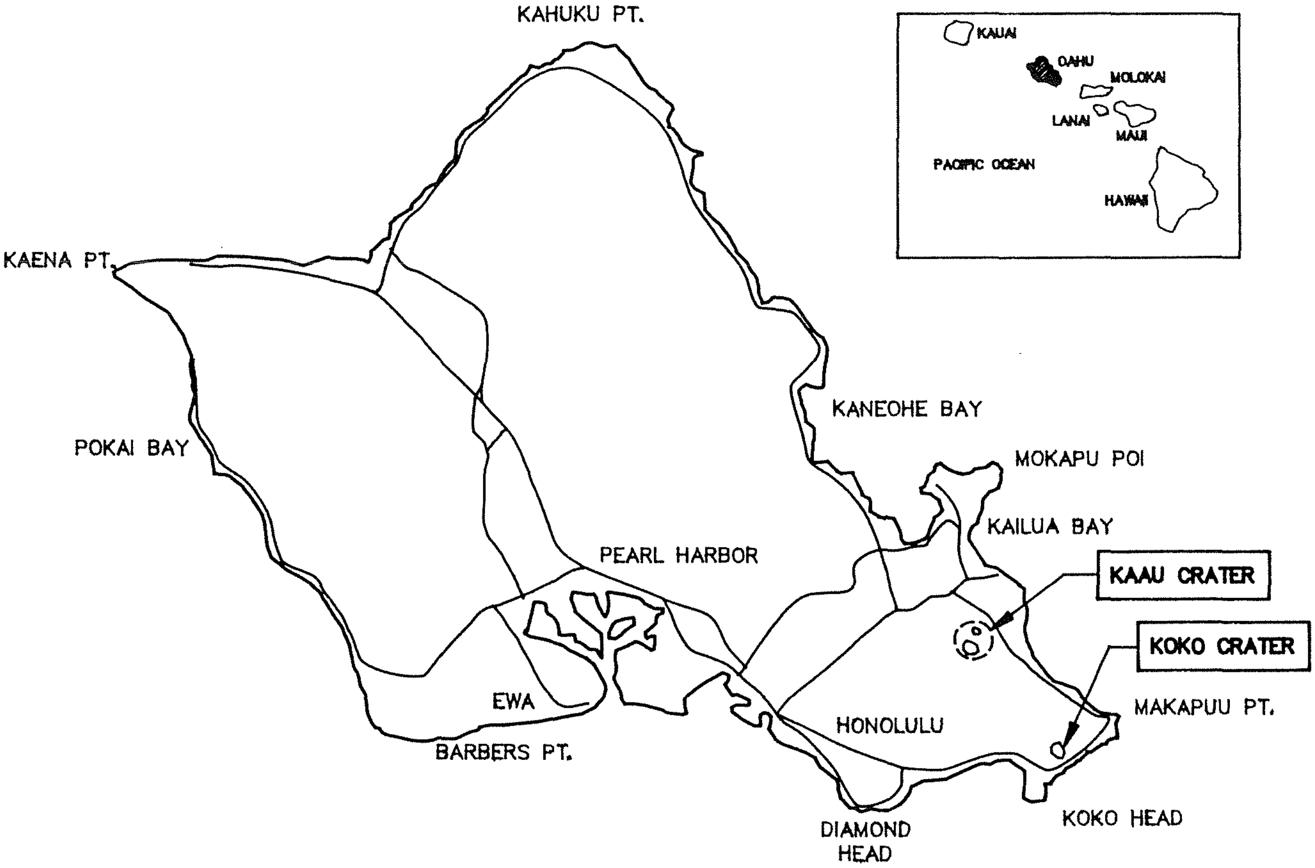
The environmental impact of the Project would be minimized by locating underground most of the power structures, and locating in the Koko Crater the upper reservoir. Furthermore, maximum emphasis and care taken to ensure minimal disturbance of the Project area by minimizing the effect of noise, vibration and visual impact..

Preliminary plans and profiles of the project showing the major components are provided on Figures III-4 to III-9. Principal features of the Koko Crater are shown in the following:

Upper Reservoir		
Maximum water level	feet	370
Minimum water level	feet	280
Reservoir bottom elevation	feet	240
Water surface area at Max. water level	acres	50
Water surface area at Min. water level	acres	21
Total storage at Max. water level	ac-ft	3,745
Storage at Min. water level	ac-ft	550
Effective storage	ac-ft	3,195
Available drawdown	feet	90
Dam Type	Earth fill with rubber liner	
Dam crest elevation	feet	380
Dam height	feet	150
Crest length	feet	675
Gross head		
Maximum	feet	370
Minimum	feet	280
Average	feet	340

Design Discharge (Max.)		
Generating mode	cfs	6,440
Pumping mode	cfs	4,830
Head loss		
Generating mode	feet	10
Pumping mode	feet	7
Effective head		
Generating at avg. head	feet	330
Max. pumping height	feet	377
Generating power (Max.)	kW	160,000
(Avg.)	kW	158,000
Pumping power (Max.)	kW	160,000
Installed capacity	MW	160
Number of units	unit	2
Hours of generation	hr	6
Hours of storage	hr	8
Energy storage	MWh	948
Intake-Outlet	Concrete structure of Morning-glory type	
Headrace tunnel		
Length	feet	1,075
Diameter	fee	25
Area	sq. ft.	491
Penstock		
Length	feet	450
Diameter	feet	25
Area	sq. ft.	491
Bifurcation		1
Penstock		
Length	feet	200
Line	No.	2
Diameter	feet	18-15
Area	sq. ft.	254 - 177

Powerhouse		
Type	Underground	
Center of turbines elevation	ft	-165
Turbine	Vertical type of Francis Reversible Pump-Turbine	
Draft Tunnel		
Length	feet	200
Line	No.	2
Tailrace tunnel		
Length	feet	890
Line	No.	1
Diameter	feet	25
Area	sq. ft.	491
Outlet-Inlet	Concrete structure of Horizontal type with Rubblemound Breakwater	
Design seismic intensity	0.15 g	



ISLAND OF OAHU
NOT TO SCALE

PROJECT SITE LOCATION

FIGURE III-3

Koko Crater reservoir

Koko Crater would serve as the upper reservoir for the pumped storage facility. The reservoir would be formed by constructing a earthfill-type dam across the northeast portion of the crater rim. The crest of the dam would be at an elevation of 380 feet and the dam would have a maximum height of approximately 150 feet. The crest elevation and inner dimensions of the reservoir were selected so that the volume of earthwork would be balanced inside the crater. Surface alluvium layer of the crater would be excavated by 15 feet deep at minimum. The inner slope gradient of the reservoir is to be 1:3.0 and rubber sheet lining is to be provided to protect the reservoir from seawater seepage. The crest of the dam is to have a free-board of ten feet above the high water level. A spillway and spillway channel are considered unnecessary, because any excess water could be discharged through the water conductor system leading to the powerhouse and sea.

The minimum and maximum operating levels for the reservoir would be 280 feet and 370 feet, respectively. The active storage capacity would be about 3,200 acre-feet.

The surface runoff water in the basin is to be caught in the side gutter of the inspection road and not be allowed to flow into the reservoir. Infiltration and sea water leakage from the reservoir are to be collected through the inspection gallery, where a leakage detection system is also provided, and returned to the reservoir by pump.

A reinforced concrete inlet/outlet structure would be constructed within the crater to direct generation and pumpback flows between the reservoir and the low pressure tunnel. It is to be provided at the southernmost end of the reservoir to shorten the length of the pressure tunnel. A form of the structure is to be a morning glory type of diameter of 90 feet and height 25 feet, which is designed for the maximum hydraulic capacity in both generating and pumping modes.

Powerhouse

A concrete-lined underground powerhouse could be located between the upper reservoir and Kalanianaole Highway 72. The powerhouse and tunnel are located underground to ensure the existing natural scenery is retained. The powerhouse would be of mushroom type sized to accommodate two vertical, reversible pump/turbines directly coupled to motor/ generators. The powerhouse also would have sufficient space for an equipment laydown area for maintenance purposes and for the auxiliary mechanical and electrical equipment. The unit step-up transformers would be placed beside the equipment laydown area.

The setting level of the pump/turbine distributors would be 165 feet below mean sea level to provide the submergence depth required for pumpback operations.

Access to the powerhouse would be by an access tunnel of 0.4 miles and access road 500 feet in length from an above-ground plant substation, which is located in close proximity to an existing sewage disposal facility. A breakwater/outlet access tunnel would be also provided from the powerhouse. In addition, a drainage tunnel would be provided around the powerhouse cavern in order to reduce the leakage of seawater to the cavern by means of grout curtains and drain holes.

Water conductors

A headrace system would extend from the Koko Crater inlet/outlet structure to the powerhouse to convey generation and pumpback flows between Koko Crater Reservoir and the hydroelectric units. The headrace system would consist of a low pressure tunnel, an inclined penstock, and individual unit penstocks.

The low pressure tunnel would extend from the Koko Crater reservoir inlet/outlet structure for a distance of 950 feet to the intersection with the inclined penstock. The penstock would extend downward for a distance of 460 feet to a bifurcation, where individual penstocks would convey discharges to each unit. The penstock and tunnels would have a finished inside diameter of 25 feet. The individual unit penstocks would be reduced to 15 feet in diameter. The penstocks would likely be fiberglass reinforced plastic lined to prevent corrosion and seawater seepage. Furthermore, water conductor drainage systems would collect all the seawater leakage flows.

The tailrace tunnel is to have an inside diameter of 25 feet and the length is to be 890 feet from the bifurcation located 200 feet downstream from the turbine center, and a special coating will be provided at the inner surface of the concrete to minimize adhesion of marine organisms.

Ocean outlet/inlet structure

The reinforce concrete outlet structure is to be constructed at the south side of Highway 72. (Kalanianaole Highway) A curved section is to be provided in the tailrace tunnel at the part where the tailrace tunnel crosses with Highway 72 so that the waterway axis line will be perpendicular to the shoreline.

A rubblemound breakwater is to be provided to protect the outlet structure and suppress water surface fluctuations. It should be constructed prior to other outlet concrete structures, so that a less fluctuating water surface level can be maintained inside.

The invert level of the outlet is to be -50 feet below sea level. The crest elevations of the revetment and breakwater are to be 22 feet and 15 feet, respectively, while the crest width of the breakwater is to be 40 feet.

Special emphasis would be made on the water velocity, of which less than 3.3 feet/sec will be preferable, at the outlet/inlet structure, to protect coral and marine life from the inflow and outflow.

Pump/turbine-motor/generators

Two vertical, single stage, Francis reversible pump/turbine units of 80 MW each would pump water and generate power. However, an alternative of three units of 55 MW each should be studied in the next stage in consideration of the low and variable head, and large discharge. The pump/turbines would be directly coupled to vertical shaft, three-phase, 60 hertz, ac synchronous motor/generators. Corrosion- and salinity-resistant marine materials suitable for seawater application would be used for the pump turbine units. It should be planned to adopt a modified variety of austenite type stainless steel. Emphasis would be placed on minimizing the effects of noise and vibration.

Substation/transmission line

The plant substation would be located at ground level adjacent to an existing sewage treatment plant. An existing HECO 46 kV transmission line should be improved to that of 138 kV to the interconnection at Koolau or Pukele substation, so as to transmit power that is generated and to receive power needed to pump seawater to the upper reservoir.

Project operations

The Project would be operated as a conventional pumped storage hydroelectric facility with the generation cycle occurring during on-peak electrical demand periods and the pumpback cycle occurring during off-peak periods.

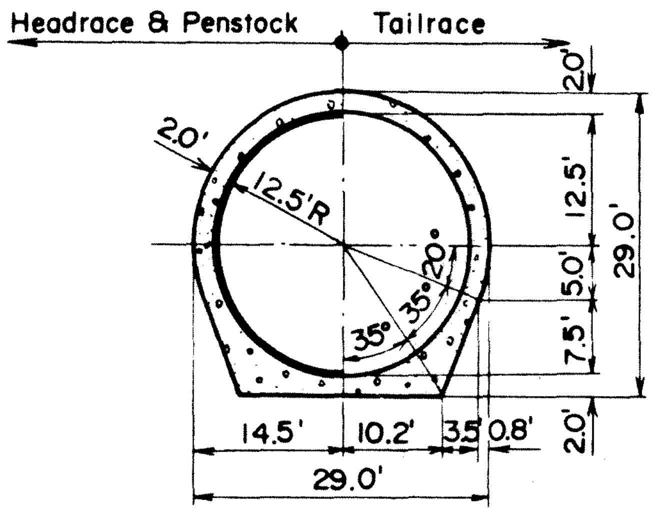
The normal daily operating cycle would begin with the upper reservoir at maximum operating level. During the on-peak generation cycle, the hydro units would function as turbine-generators, and water would be conveyed from the upper reservoir to the ocean through the pump-turbines and water conductor system. During the off-peak pumpback cycle, the units would function as pump-motors, and water would be conveyed from the ocean to refill the upper reservoir.

During the daily generating cycle, average plant output would be 158 MW for a period of six hours. During the pumpback cycle, an average of approximately 160 MW plant input would be required for a period of eight hours to refill the upper reservoir. Cycle efficiency is expected to be about 75 percent.

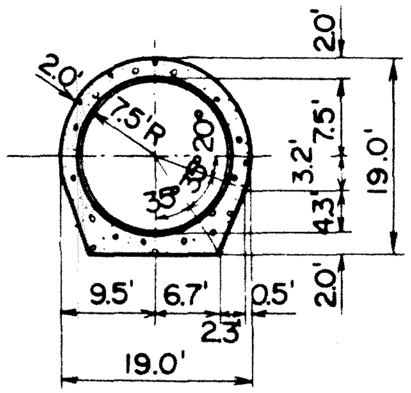
Operation

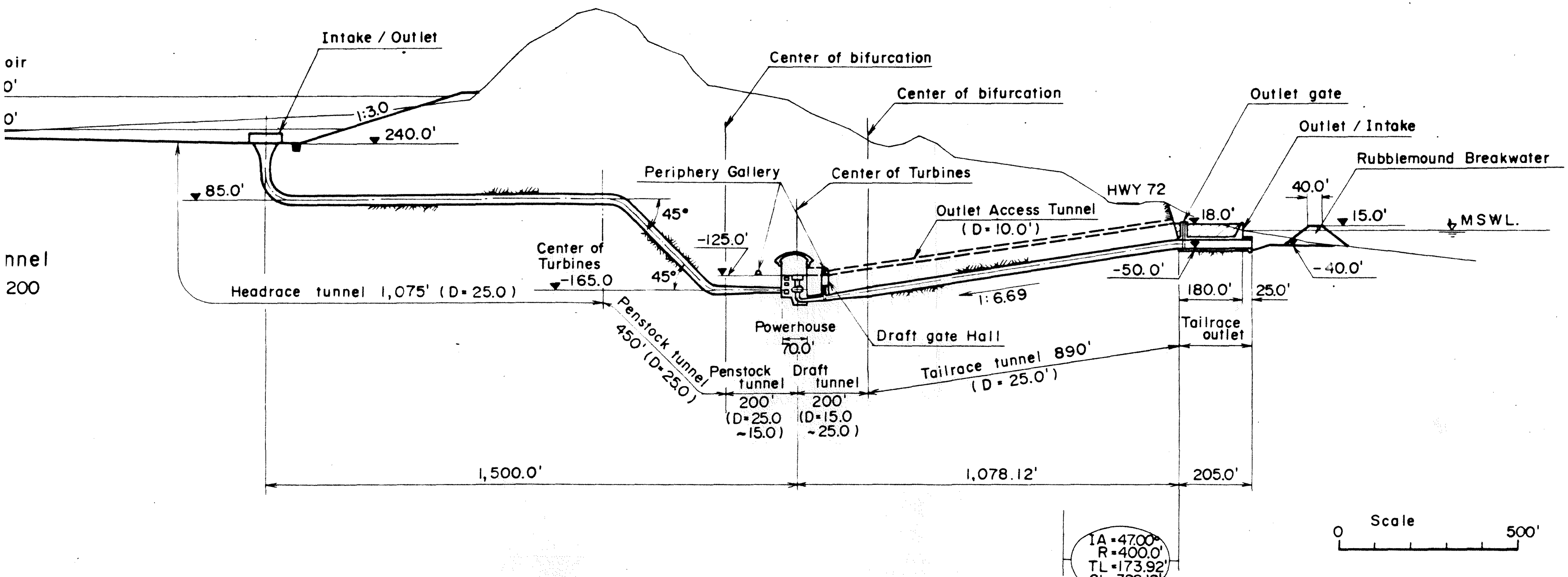
The PSH facility is proposed to be operated from the switchyard and will have a staff of 15 people to provide operation and maintenance 24 hour, 7 days a week.

Typical Section of Headrace & Tailrace Tunnel (For reference) S=1:200



Typical Section of Penstock & Draft Tunnel (For reference) S=1:200





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REFERENCE DRAWINGS

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FIGURE III-4

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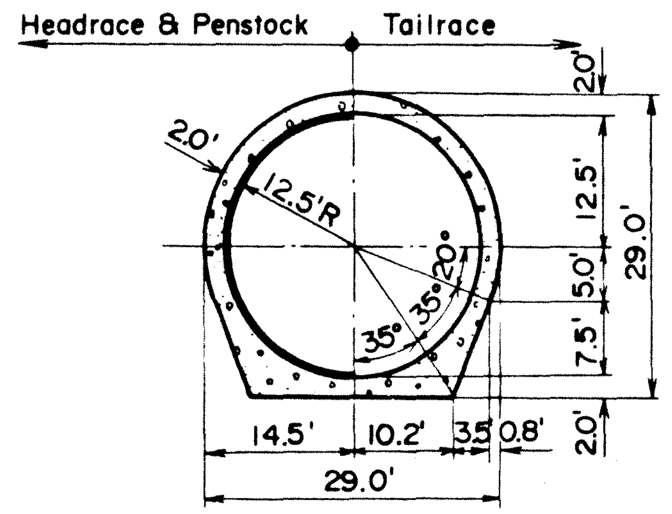
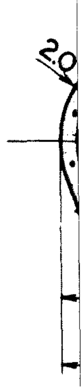
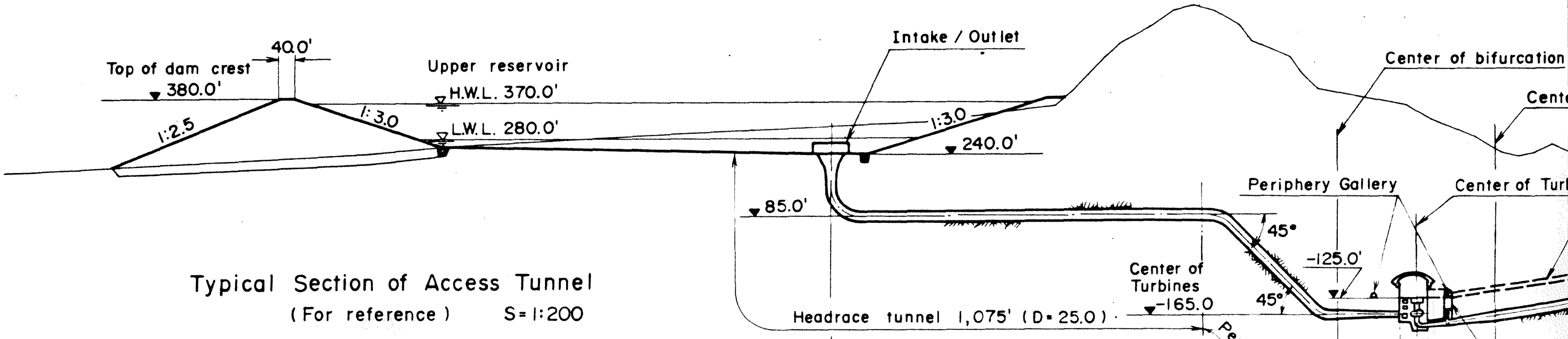
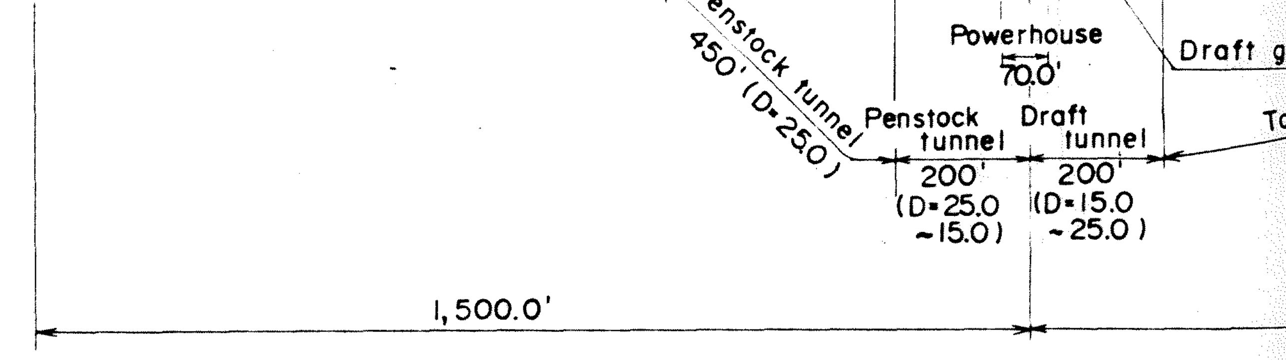
Typical Section of Headrace & Tailrace Tunnel (For reference) S=1:200



Typical Secti
Draft Tunnel

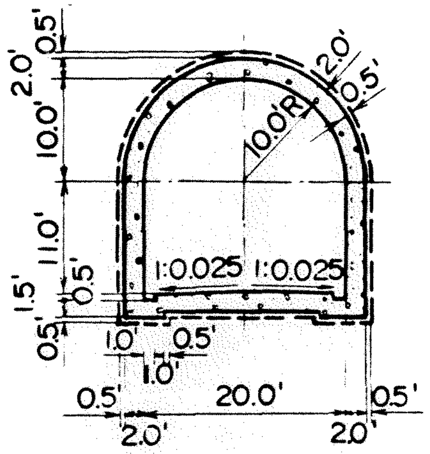






Typical Section of Access Tunnel

(For reference) S=1:200



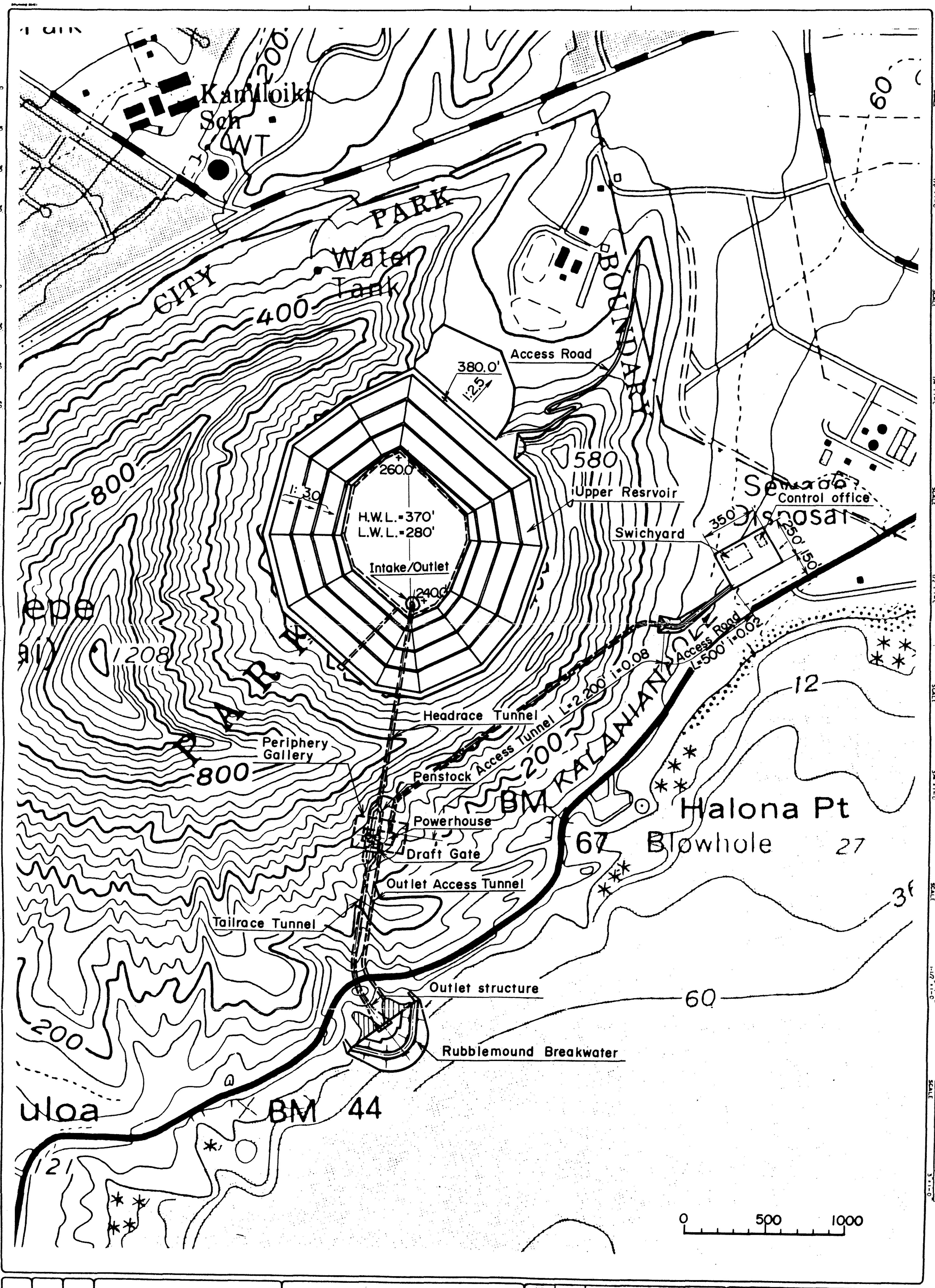


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FIGURE III-5

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470 N. NIMITZ HWY. SUITE 219
HONOLULU, HAWAII 96817
TEL: (808) 524-1224

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SCALE 1/8" = 1'-0"

SCALE 1/4" = 1'-0"

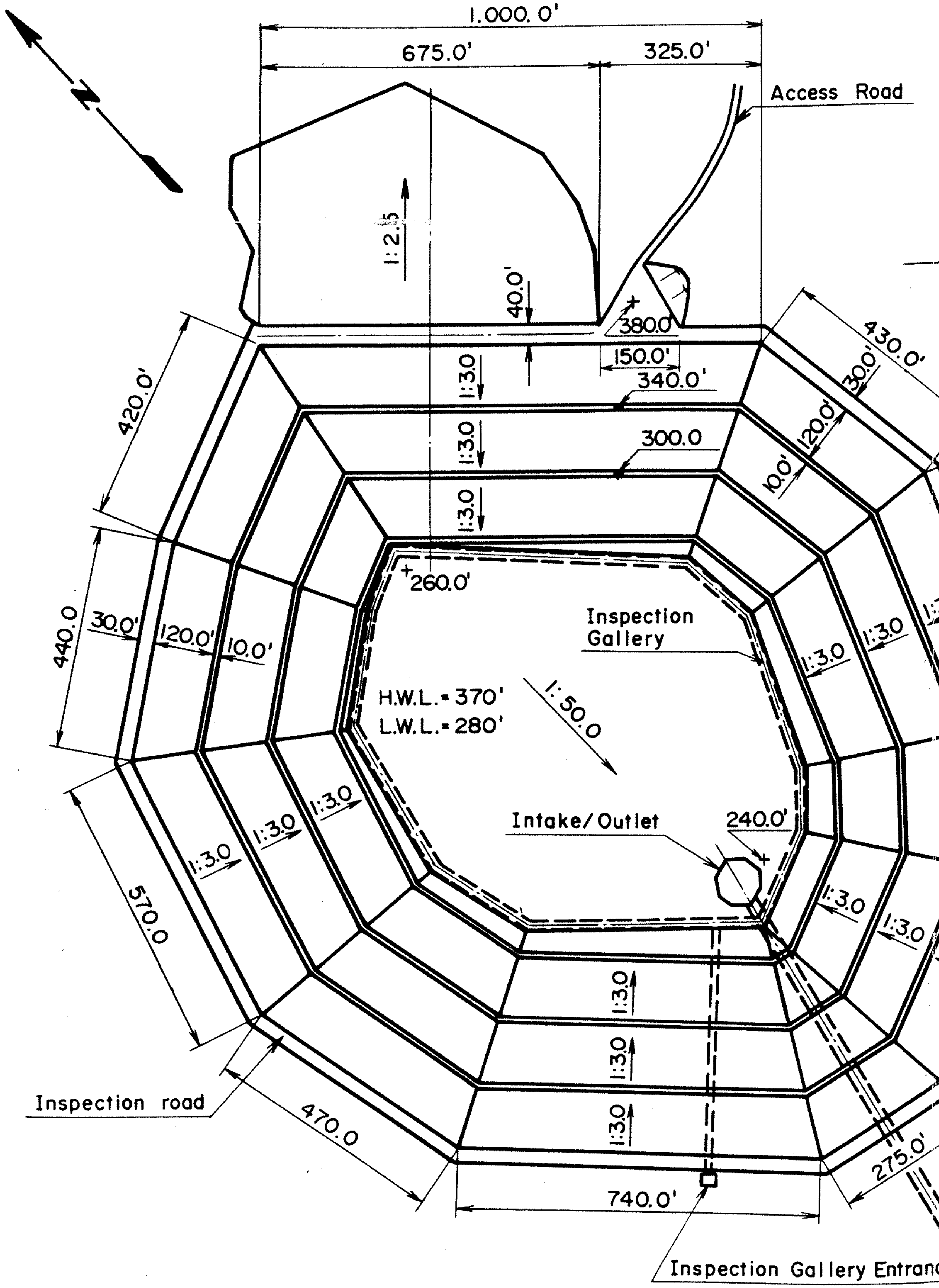
SCALE 1/2" = 1'-0"

SCALE 3/4" = 1'-0"

SCALE 1-1/2" = 1'-0"

SCALE 3" = 1'-0"

Plan of Upper Reservoir S = 1: 3.000



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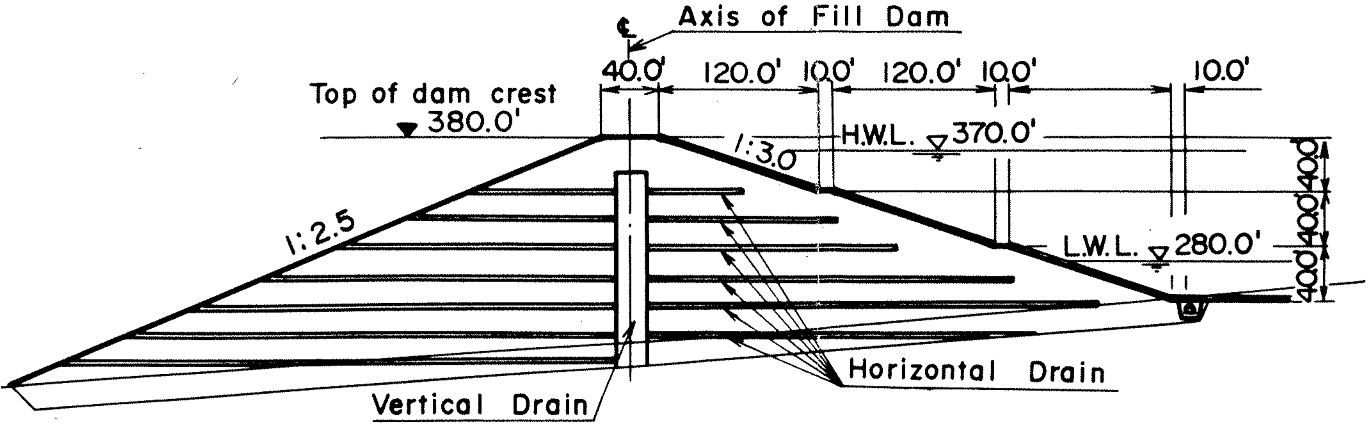
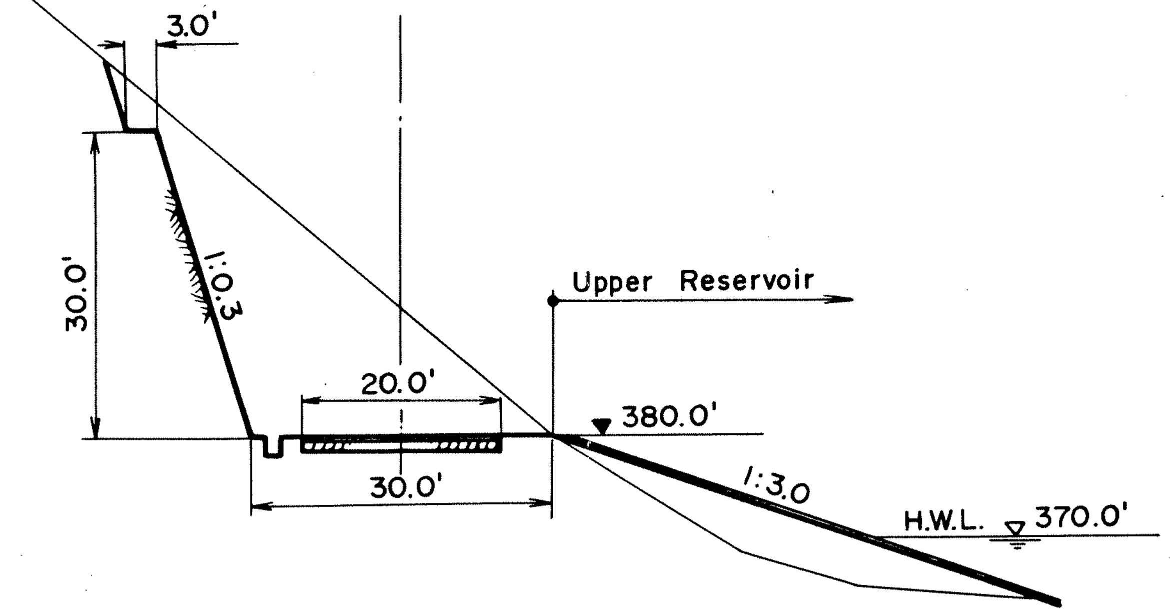
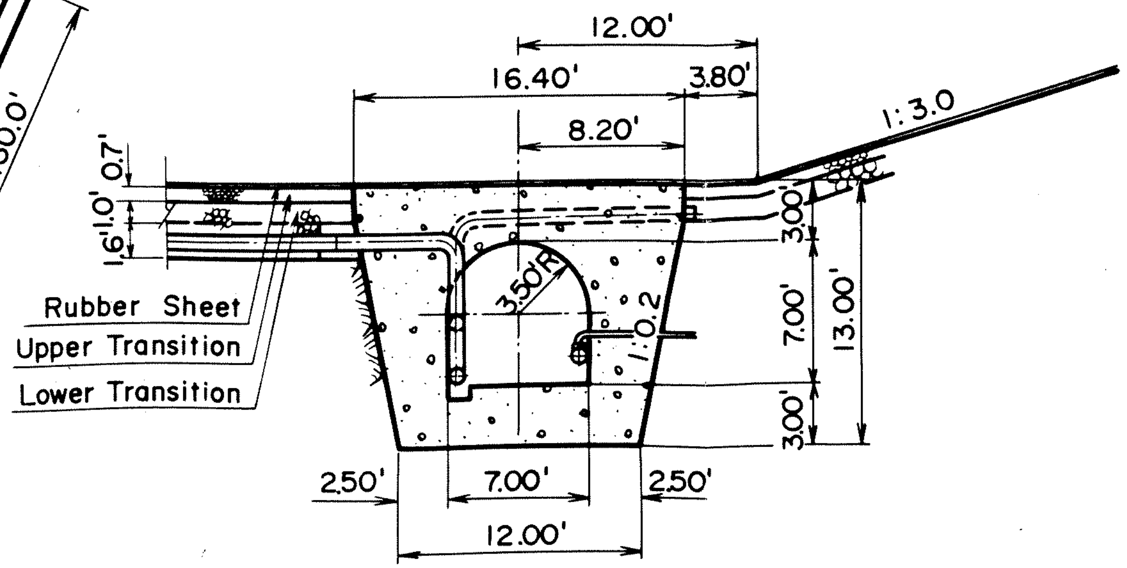


Typical Section of Inspection Road S = 1: 200



Section of Inspection Gallery S = 1: 100



SCALE 1" = 10'

SCALE 1" = 20'

SCALE 1" = 40'

SCALE 1" = 100'

SCALE 1" = 200'

REVISIONS

NO	DATE	DWN	CHK

REFERENCE DRAWINGS

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HILO, HAWAII 96720
TEL: (808) 961-5527

470 N. NIMITZ HWY SUITE [illegible]
HONOLULU, HAWAII [illegible]
TEL: (808) [illegible]

FIGURE III-6

DRAWING NO

SHEET NO

REVISION

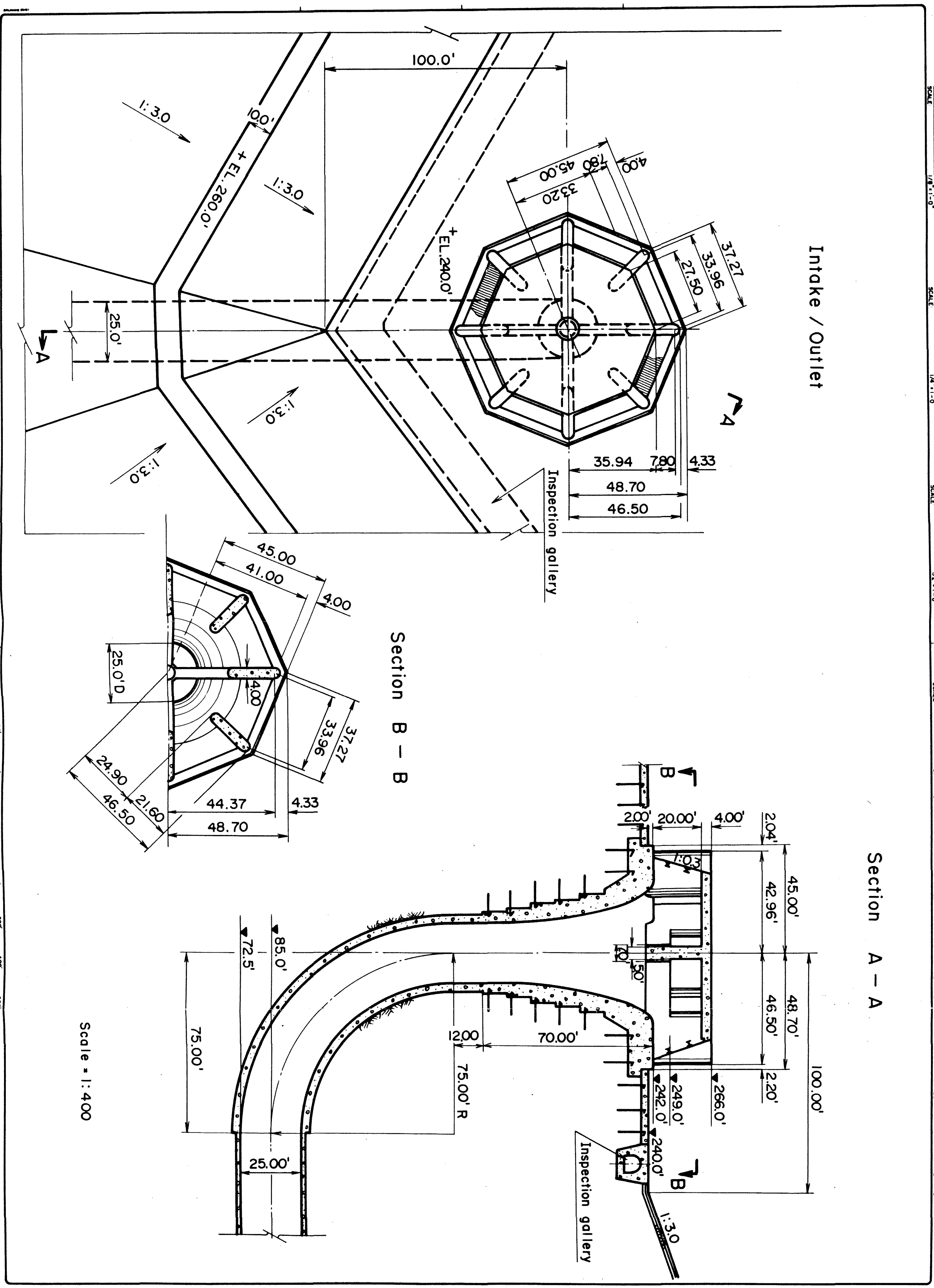

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FIGURE III-7

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HONOLULU, HAWAII 96817
TEL: (808) 524-1224

NO	CO.	REFERENCE DRAWINGS	NO	DATE	DWN	CHK	REVISIONS

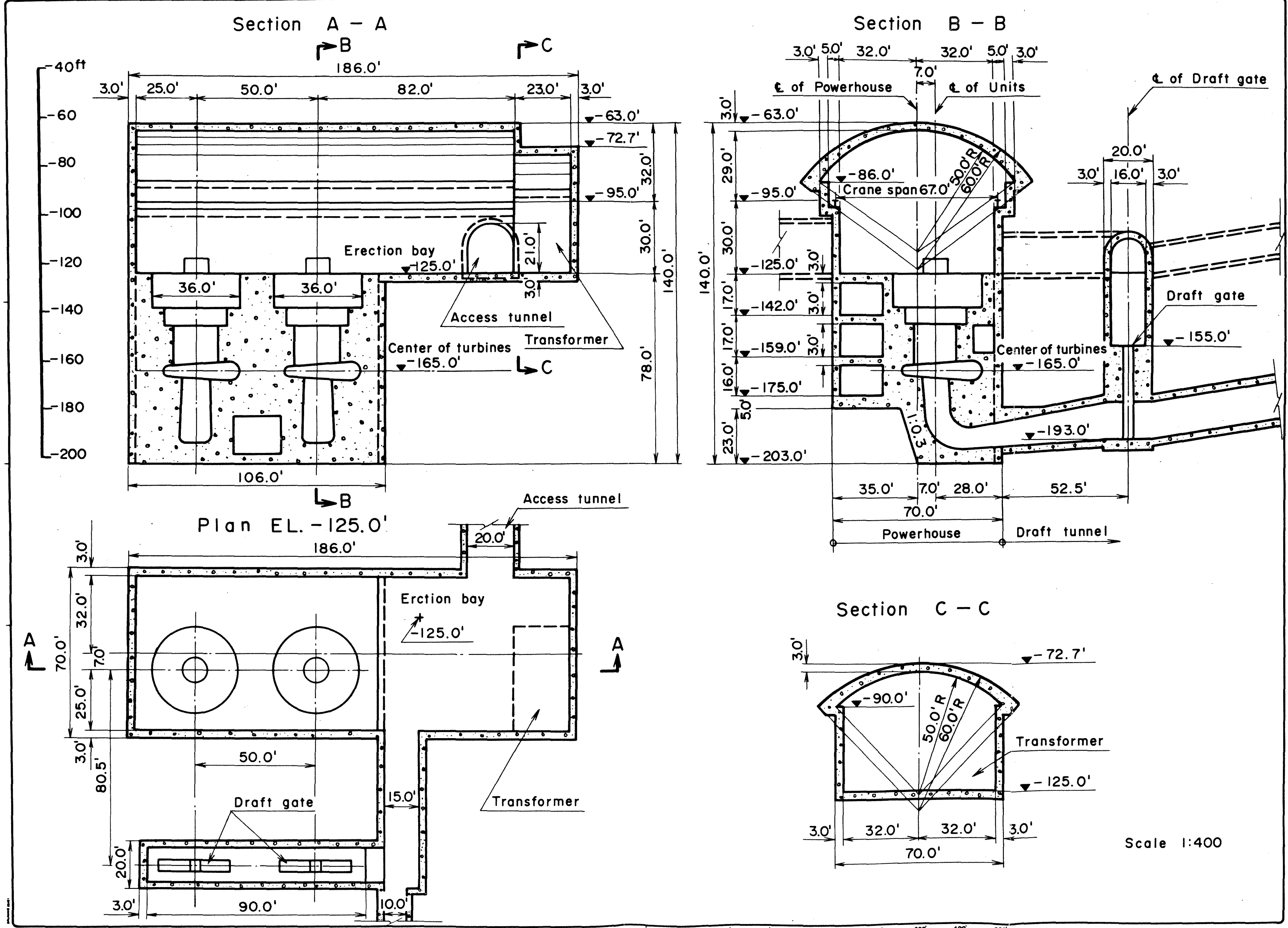

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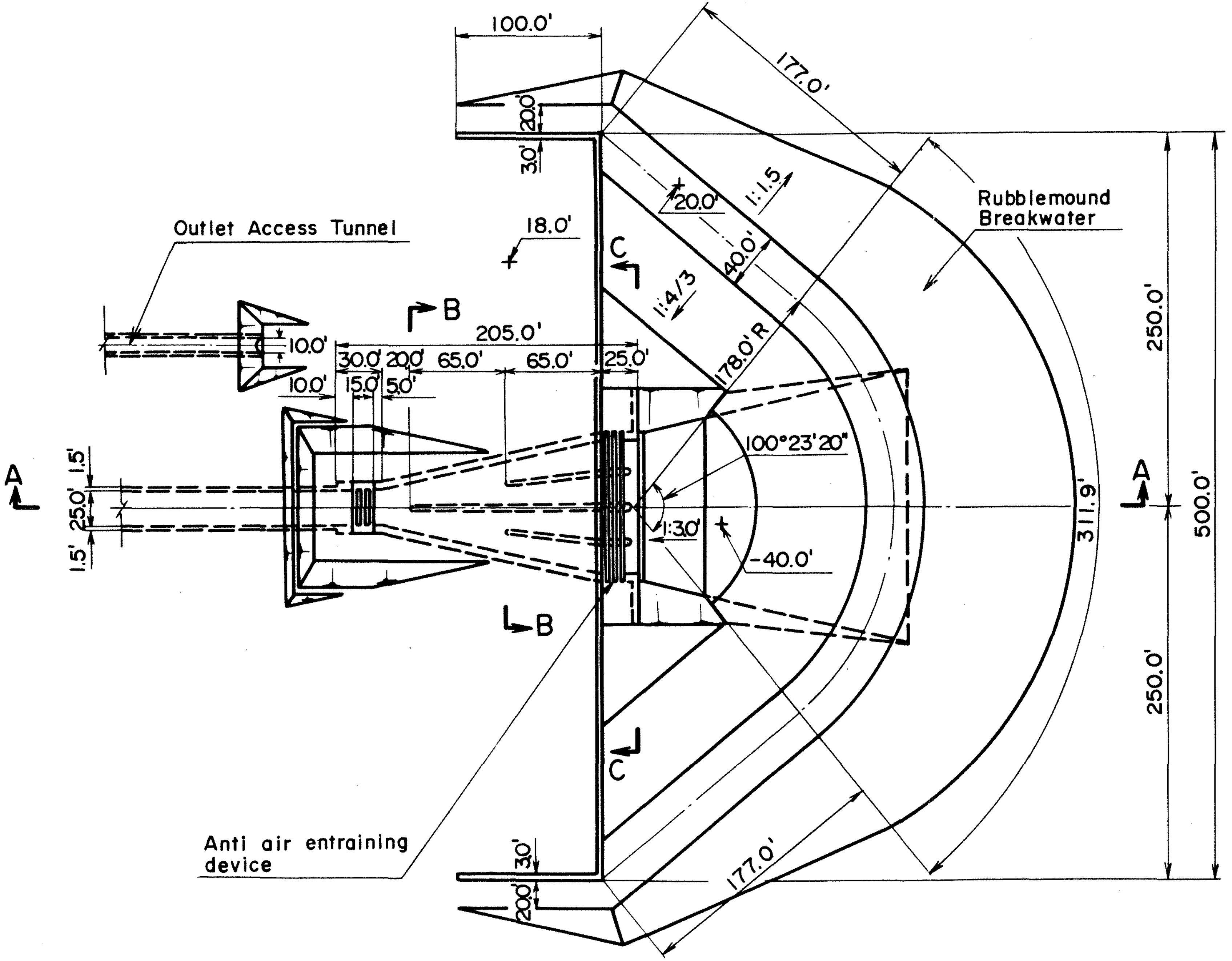
FIGURE III-8

SCALE 1/8" = 1'-0" SCALE 1/4" = 1'-0" SCALE 1/2" = 1'-0" SCALE 3/4" = 1'-0" SCALE 1-1/2" = 1'-0" SCALE 3" = 1'-0"

Plan of Outlet / Intake Structure

S = 1:1,000



Section B – B

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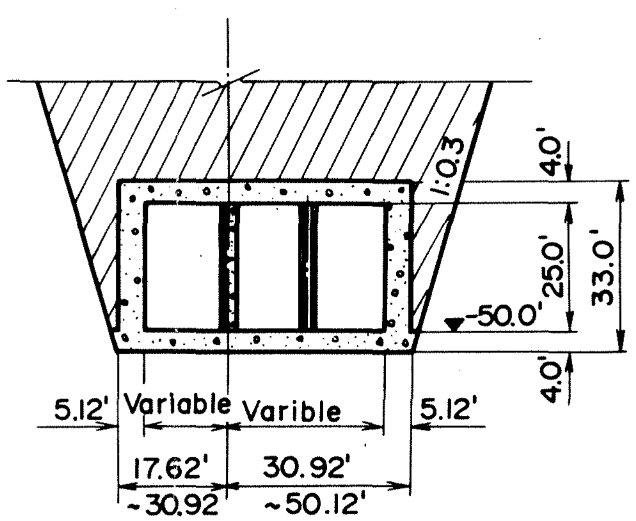
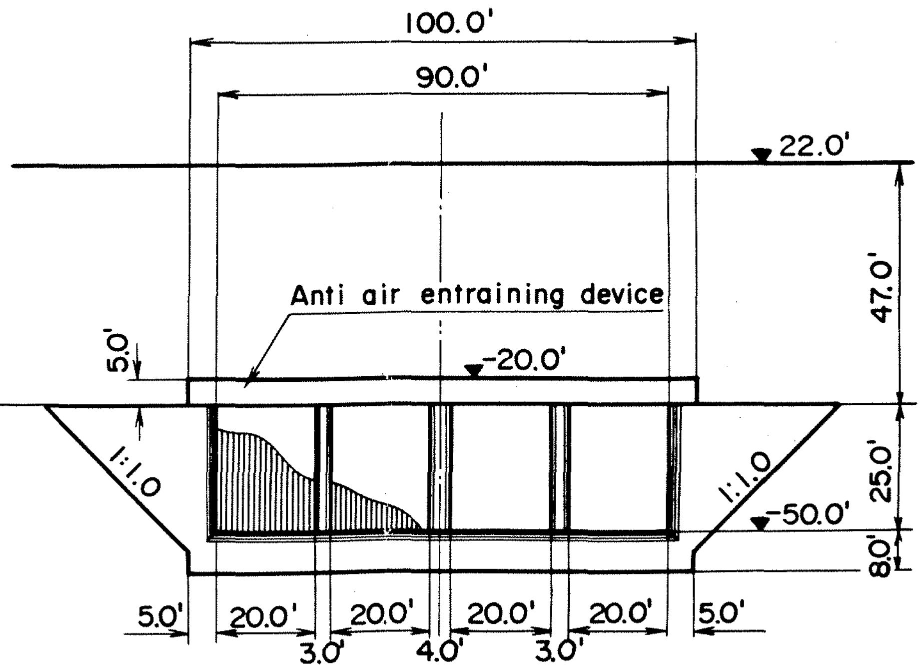
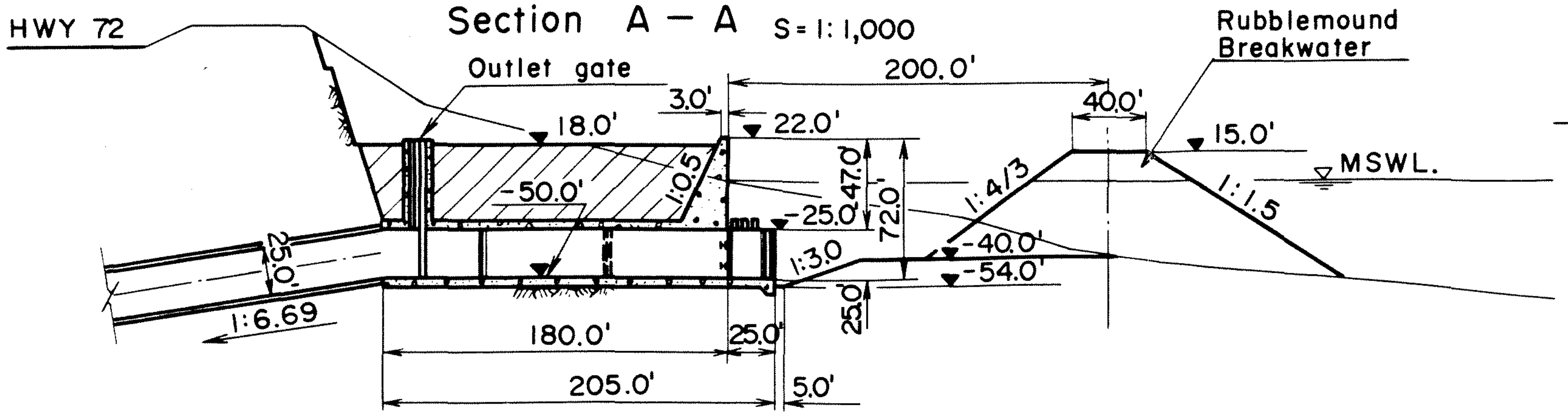


Section C – C

S = 1:400



Section A – A S = 1:1,000



SCALE 1" = 10' SCALE 1" = 20' SCALE 1" = 40' SCALE 1" = 100' SCALE 1" = 200'

6

REVISIONS

NO	DATE	DWN	CHK

REFERENCE DRAWINGS

NO	CO

Okahara & Associates Inc.
CONSULTING ENGINEERS

200 KOHOLA STREET
HILO, HAWAII 96720
TEL: (808) 961-5527

470 N. NIMITZ HWY. SUITE 221
HONOLULU, HAWAII 96817
TEL: (808) 524-1224

FIGURE III-9

DRAWING NO

SHEET NO

REVISION

△

D. KAAU CRATER PUMPED STORAGE POWER PROJECT

Kaau Crater, the upper reservoir site, is located inland at the upper end of Palolo Valley on Oahu; the lower reservoir site is in Maunawili Valley about 1 mile north of the Kaau Crater, as shown on Figure III-3.

The tunnels and powerhouse of the project will be located underground to ensure the existing natural condition be retained, and emphasis will also be placed on minimizing the effects of noise and vibration.

However, an access road of about 3.5 miles long should be provided from the Palolo Valley side to the upper reservoir, which will serve for transportation of materials and facilities during construction as well as maintenance of the upper reservoir. In addition, it would take six months from December to May in the average year to impound the lower reservoir, on the assumption that the downstream requirement of Maunawili Valley could be met by the release of 311.8 x 10^6 gallons after impounding 531.2 x 10^6 gallons of water in the reservoir. Discharge data are shown on Table III - A and III - B.

Preliminary plans and profiles of the Kaau Crater Pumped Storage Project showing the major project components are provided on Figures III - 10 to III 14. Principal features of major project components of the proposed hydroelectric facility are shown in the following:

Principal features of major project components

Upper Reservoir		
Maximum water level	feet	1,560
Minimum water level	feet	1,520
Reservoir bottom elevation	feet	1,500
Water surface area at Max. water level	acre	34
Water surface area at Min. water level	acre	22
Total storage at Max water level	ac-ft	1,350
Effective storage	ac-ft	1,130
Available drawdown	feet	40
Lower Reservoir		
Maximum water level	feet	550
Minimum water level	feet	500
Reservoir bottom elevation	feet	460
Water surface area at Max. water level	acre	30
Water surface area at Min. water level	acre	15
Total storage at Max. water level	ac-ft	1,470
Effective storage	ac-ft	1,130
Available drawdown	feet	50
Dam		
Upper Reservoir Dam		
Dam Type	Fill dam with rubber liner	
Dam crest elevation	feet	1,570
Dam height	feet	70
Crest length	feet	600
Lower Reservoir Dam		
Dam Type	Fill dam with rubber liner	
Dam Crest	feet	560
Dam Height	feet	140
Crest length	feet	1,700
Gross head		
Maximum	feet	1,060
Minimum	feet	970
Average	feet	1,015

Design Discharge (Max.)			
Generating mode		cfs	2,190
Pumping mode		cfs	1,660
Head loss			
Generating mode		feet	30
Pumping mode		feet	20
Effective heads			
Generating at avg. head		feet	985
Max. pumping height		feet	1,080
Generating power (Max.)		kW	160,000
Generating power (Avg.)		kW	160,000
Pumping power (Max.)		kW	162,000
Installed capacity		MW	160
Number of units		unit	2
Hours of generation		hr	6
Hours of storage		hr	8
Energy storage		MWh	960
Intake-Outlet	Concrete structure of Morning-glory type		
Headrace tunnel			
Length		feet	2,310
Diameter		feet	14
Area		sq. ft.	153.9
Surge-tank	Concrete structure of restricted-orifice type		
Penstock Tunnel			
Length		feet	1,430
Diameter		feet	14 - 6
Area		sq. ft.	153.9 - 28.3
Bifurcation			1
Powerhouse			
Type	Underground		
Center of turbines		ft (elev.)	320
Turbine	Vertical type Francis Reversible Pump-Turbine		

Draft Tunnel		
Length	feet	170
Line	No.	2
Tailrace tunnel		
Length	feet	2,090
Line	No.	1
Diameter	feet	14
Area	sq. ft.	153.9

Out-Inlet Concrete structure of Inclined type

Design seismic intensity 0.15 g

Kaau Crater reservoir

Kaau Crater would serve as the upper reservoir for the pumped storage facility. The reservoir would be formed by constructing a small fill dam across the southeast portion of the crater rim, and excavating the surface layer of silt and clay in the floor of the crater. The crest of the dam would be at an elevation of 1,570 feet, and the dam would have a maximum height of approximately 70 feet. The reservoir would be lined with a rubber sheet to conserve water. The runoff surface water in the basin is to be caught in the side gutter of the inspection road and not allowed to flow into the reservoir. Infiltration water and leaked water from the reservoir are to be collected through the inspection gallery and returned to the reservoir by pump. A spillway would not be necessary in the upper reservoir of this type of pump-storage project.

The minimum and maximum operating levels for the reservoir would be 1,520 feet and 1,560 feet, respectively. The active storage capacity would be about 1,130 acre-feet.

A reinforced concrete inlet/outlet structure would be constructed within the crater to direct generation and pumpback flows between the reservoir and the low pressure tunnel. The structure is to be of the morning glory type, of diameter approximately 50 feet and height 20 feet for the maximum hydraulic capacity of the project in generating and pumping modes.

Maunawili reservoir

A lower reservoir would be constructed within the Maunawili Valley just north of the Koolau Range escarpment and Mt. Olympus. The reservoir would be formed by constructing a fill-type dam with a crest length of about 1,700 feet and a maximum height of about 140 feet, and improving the present topography by excavation and embankment. The reservoir would be lined with a rubber sheet to conserve water. The crest of the dam would be at an elevation of 560 feet. The minimum and maximum operating levels for the reservoir would be 500 feet and 550 feet, respectively. The active storage capacity would be 1,130 acre-feet, corresponding to the active capacity of Kaau Crater Reservoir.

A reinforced concrete inlet/outlet structure of inclined type would be constructed within the lower reservoir to direct generation and pumpback flows between the reservoir and the tailrace tunnel. The inlet/outlet structure would be designed for the maximum hydraulic capacity of the pumped storage project in both generating and pumping modes.

A small dam of crest length approximately 400 feet is to be provided in a stream approximately 2,500 feet south of the reservoir, and an auxiliary regulating pond is to be made connecting to the reservoir with a horizontal tunnel, or water supply and drainage tunnel of 10 feet in diameter. It will serve to increase the catchment area of the reservoir during initial water impounding, and be converted to an uncontrolled overflow spillway tunnel to pass the discharge in the event of overfilling during the power plant operation.

The inflow water from the basin of the reservoir is to be caught in the side gutter of the inspection road and is to be run down by a shaft to the drainage tunnel.

Powerhouse

The powerhouse is located in the Koolau basalt zone. It would be concrete-lined of an underground type sized to accommodate two vertical, reversible pump/turbines directly coupled to motor/generators. The powerhouse also would have sufficient space for an equipment laydown area for maintenance purposes and for the auxiliary mechanical and electrical equipment. The unit set-up transformer would be located beside the equipment laydown area. The setting level of the pump/turbine distributors would be 180 feet below the minimum operating level within the lower reservoir to provide the submergence depth required for pumpback operations.

Access to the powerhouse would be by an access tunnel approximately 0.60 miles in length from the lower reservoir site, and a power cable tunnel will be provided between the powerhouse and the plant substation, which is sited in the western area of the lower reservoir at an elevation of approximately 600 feet. A drainage tunnel would be provided around the powerhouse cavern in order to reduce the leakage of water to the cavern by means of grout curtains and drain holes.

Water conductors

The water conductors would include headrace and tailrace systems. The headrace system would extend from the Kaau Crater inlet/ outlet structure to the powerhouse to convey generation and pumpback flows between Kaau Crater Reservoir and the hydroelectric units. The headrace system would consist of a low pressure tunnel, a inclined penstock and individual unit penstocks.

The low pressure tunnel would extend with an 8.3 percent downward slope from the Kaau Crater inlet/ outlet structure for a distance of 2,260 feet to the intersection with the inclined penstock. The penstock would then extend downward with an angle of 48 deg. for a distance of about 1,290 feet, where individual penstocks would convey discharges to each unit. The penstock and low pressure tunnel would have a finished inside diameter of approximately 14 feet on the average and either would be lined with concrete or concrete encased steel. The individual unit penstocks would be approximately 10 feet in diameter on the average and would have concrete encased steel liners.

The tailrace tunnel would extend from the unit draft tubes to the lower reservoir inlet/outlet structure to convey generation and pumpback flows between the powerhouse and the lower reservoir. The tailrace tunnel would be approximately 1,920 feet in length and would have a finished inside diameter of 14 feet. The tailrace tunnel would be concrete lined.

A headrace surge tank of restricted orifice type with inside diameter of 24 feet is to be provided at a location 2,180 feet in horizontal distance from the intake, and another surge tank of the same scale (inside diameter 24 feet) as the headrace is to be provided at a location 350 feet from the turbine center in the tailrace tunnel. These features will release the water hammer pressure and regulate the water discharge in the tunnel according to the change of load.

Pump/turbine - Motor/generators

Two vertical, single stage, Francis reversible pump/turbine units of 80 MW each would pump water and generate electricity. The pump/turbines would be directly coupled to vertical shaft, three-phase, 60 hertz, ac synchronous motor/generators.

Substation/transmission line

The plant substation would be located at ground level adjacent to the power cable tunnel portal just west of the lower reservoir in Maunawili, however, the unit step-up transformers could be located in an underground cavern. A 138 kV transmission line would extend from the plant substation to the interconnection with an existing HECO 138 kV transmission line which is located nearby.

Project operations

The project would be operated as a conventional pumped storage hydroelectric facility with the generation cycle occurring during on-peak electrical demand periods and the pumpback cycle occurring during off-peak periods. The normal daily operating cycle would begin with Kaau Crater Reservoir at maximum operating level and the lower reservoir at minimum operating level. During the on-peak generation cycle, the hydro units would function as turbine-generators, and water would be conveyed from the Kaau

Crater Reservoir to the lower reservoir through the pump-turbines and water conductor system. During the off-peak pumpback cycle, the units would function as pump-motors, and water would be conveyed from the lower reservoir to Kaau Crater Reservoir.

During the daily generating cycle, average plant output would be 160 MW for a period of six hours. During the pumpback cycle, an average of approximately 162 MW plant input would be required for a period of about eight hours to refill Kaau Crater Reservoir. Cycle efficiency is expected to be about 75 percent.

Operation

The PSH facility is proposed to be operated from the switchyard and will have a staff of 15 people to provide operation and maintenance (i.e. 24 hour, 7 days a week).

Kaau Crater Pumped Storage Power Project
Maunawili Monthly Discharge
Water impounding period: 6 months (December to May)

	Station No. 16254000 Drainage area 2.04 mile^2 (A)	Proposed Maunawili dam site 1.29 mile^2 (B)	Proposed Maunawili dam site 1.29 mile^2 (C)	Proposed Maunawili dam site 1.29 mile^2 (D)	Proposed Maunawili water impounding (E)	Downstream release (A) - (E)	Downstream release (A) - (E)
	cf/s	cf/s	acre-feet	x 10^6 gallon	acre-feet	cf/s	x 10^6 gallon
October	92.4	58.2	115.4	37.5	-	92.4	59.5
November	166.9	105.1	208.4	67.7	-	166.9	107.4
December	219.6	138.3	274.3	89.0	274.3	81.3	52.3
January	253.6	159.8	316.9	102.9	316.9	93.8	60.4
February	215.2	135.6	268.9	87.3	268.9	79.6	51.2
March	241.9	152.4	302.3	98.1	302.3	89.5	57.6
April	209.8	132.2	262.2	85.1	262.2	77.6	49.9
May	169.7	106.9	212.0	68.8	212.0	62.8	40.4
June	101.8	64.1	127.1	41.3	-	101.8	65.5
July	82.2	51.8	102.7	33.3	-	82.2	52.9
August	75.3	47.5	94.2	30.6	-	75.3	48.5
September	64.8	40.8	89.9	26.3	-	64.8	41.7
	1,893.2 (1,218.6 x 10^6 gallon)	1,192.7	2,374.3	767.9	1,636.6	1,068.0	687.3

- Adjusted annual evaporation at Station No. 787.10 (1976 - 84):
  49.8 ≈ 50 inch/year (4.17 feet/year)

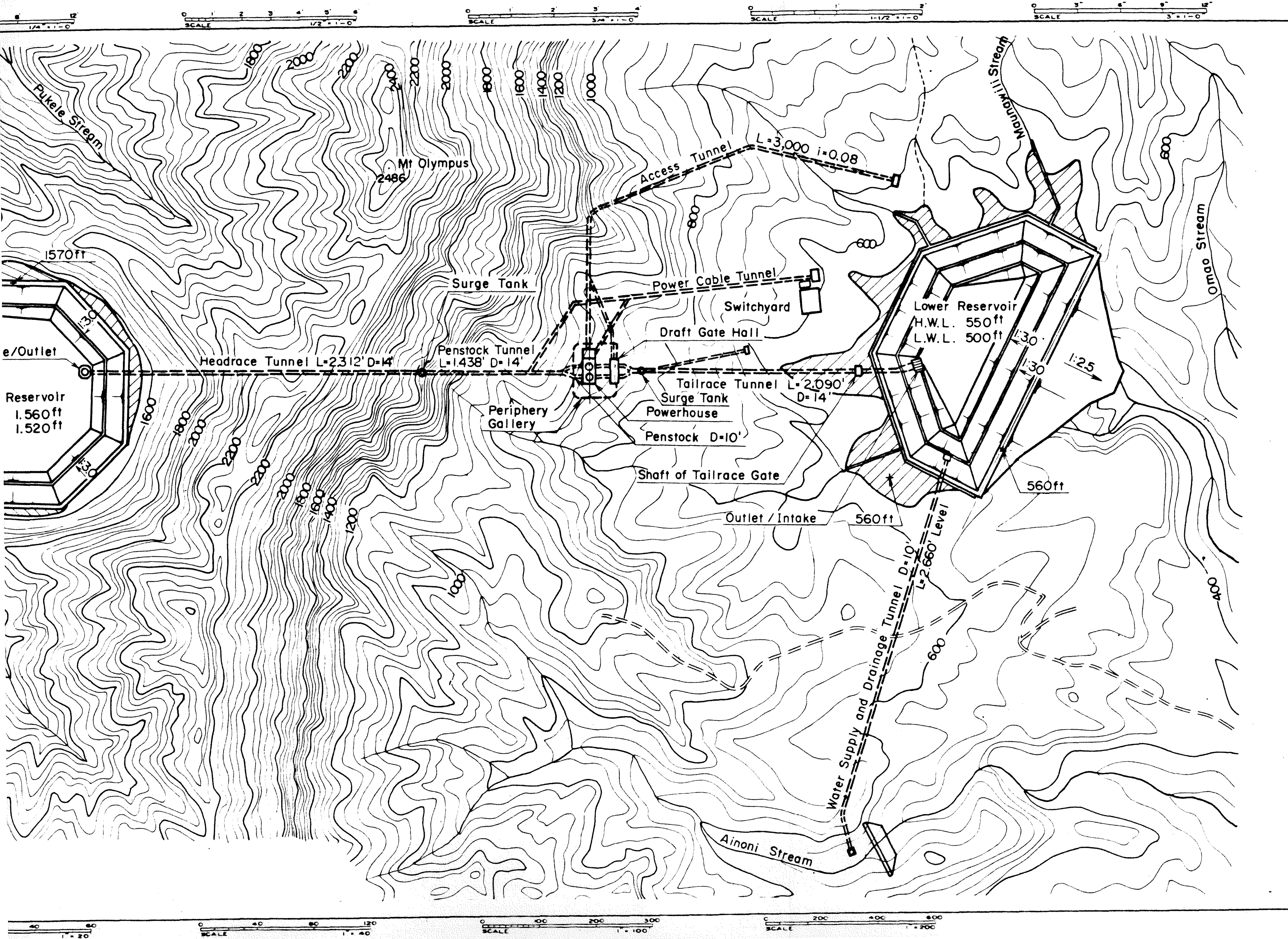
- Evaporation at lower reservoir
  {4.17 feet/year x 1/2 = 2.09 feet/6 month} x 25 acre = 52.3 acre-feet

- Lower reservoir water impounding capacity: 1,470 + 52.3 acre-feet = 1,522.3 acre-feet

STATION NO. 16254000, MAKAWAO STREAM NEAR KAILUA, OAHU, HI STREAM SOURCE AGENCY USGS
LATITUDE 212149, LONGITUDE 1574602, DRAINAGE AREA 2.04, DATUM 80.00, STATE 15, COUNTY 003,
DISCHARGE, CUBIC FEET PER SECOND, MONTHLY TOTAL OF DAILY MEAN VALUES

No.	Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
1	1958 - 1959	172.2	142.6	113.4	241.1	140.9	78.4	67.9	49.4	41.9	38.9	83.3	50.2
2	1959 - 1960	42.8	57.6	63.2	66.6	94.9	554.5	144.3	129.6	70.3	62.9	46.6	40.6
3	1960 - 1961	62.6	44.4	86.5	242.5	172.1	109.3	86.8	56.1	46.9	45.6	37.2	33.5
4	1961 - 1962	74.8	248.5	142.3	132.9	162.1	289.5	139.8	233.2	69.3	55.5	45.4	40.1
5	1962 - 1963	38.6	29.8	75.2	343.2	221.5	670.3	941.5	508.4	193.6	122.7	81.8	68.2
6	1963 - 1964	70.5	59.8	168.0	198.8	89.9	242.3	157.6	99.8	72.4	97.9	73.6	32.8
7	1964 - 1965	116.3	207.3	476.0	233.7	502.7	225.0	271.8	457.2	169.3	137.3	78.7	77.3
8	1965 - 1966	261.4	1,145.6	549.9	303.3	377.1	231.6	157.0	154.8	86.1	85.1	76.6	66.7
9	1966 - 1967	151.3	291.1	203.9	196.6	163.7	348.3	223.8	183.4	109.0	120.0	211.3	192.0
10	1967 - 1968	151.3	136.7	828.8	394.2	256.6	680.7	682.2	185.1	109.2	86.1	70.9	67.0
11	1968 - 1969	73.9	103.8	354.6	437.7	529.1	457.2	203.3	142.0	97.6	103.1	74.5	75.0
12	1969 - 1970	67.6	72.9	129.9	355.6	117.9	81.3	83.8	74.7	60.8	60.6	51.7	47.4
13	1970 - 1971	69.6	453.9	240.5	378.9	249.1	120.8	206.0	121.9	115.6	75.0	55.9	48.0
14	1971 - 1972	46.0	47.9	76.7	255.7	227.0	229.1	256.7	104.7	68.7	54.1	45.6	35.6
15	1972 - 1973	35.5	34.5	38.0	38.4	49.0	44.6	46.4	43.3	34.5	47.3	36.9	31.3
16	1973 - 1974	36.5	64.6	144.2	314.6	276.7	151.0	117.9	109.7	74.2	55.8	47.5	40.5
17	1974 - 1975	54.0	100.9	61.9	220.3	336.8	119.2	94.2	67.5	51.8	46.2	38.5	30.1
18	1975 - 1976	32.8	149.2	66.2	48.7	114.1	218.4	88.9	73.8	53.8	49.7	41.5	42.3
19	1976 - 1977	67.3	46.1	40.8	38.8	34.2	45.7	170.2	337.0	86.6	59.0	48.7	39.7
20	1977 - 1978	36.2	38.5	37.9	47.1	31.2	38.7	76.4	165.8	105.1	71.9	65.8	50.0
21	1978 - 1979	167.8	282.2	223.1	373.4	760.6	248.3	120.7	86.3	61.6	52.1	46.5	37.4
22	1979 - 1980	40.9	51.8	218.9	607.9	164.2	155.0	200.7	238.4	203.4	150.7	114.5	76.4
23	1980 - 1981	64.3	63.5	168.6	126.2	119.7	81.4	122.7	534.3	111.9	67.9	81.8	52.0
24	1981 - 1982	60.5	177.2	537.3	867.0	296.6	489.1	475.0	167.3	339.0	206.6	264.0	174.8
25	1982 - 1983	180.8	184.3	254.3	169.6	114.7	93.3	79.6	85.0	70.0	70.3	60.9	60.9
26	1983 - 1984	60.7	64.2	83.6	94.3	96.7	82.1	86.8	62.9	47.8	47.0	36.6	32.3
27	1984 - 1985	33.0	61.7	97.3	123.8	436.7	118.7	81.0	75.5	60.8	57.8	55.7	57.7
28	1985 - 1986	155.1	152.8	102.8	70.1	63.5	212.3	104.1	83.0	72.6	66.4	68.0	125.0
29	1986 - 1987	122.9	396.7	158.2	156.7	158.4	107.6	107.2	146.7	110.3	127.5	77.1	76.0
30	1987 - 1988	84.8	129.9	1,077.8	884.0	323.8	270.4	186.3	385.1	106.7	76.9	103.3	63.5
31	1988 - 1989	86.4	102.7	236.3	175.5	209.4	369.8	926.1	233.3	295.7	162.5	115.4	84.0
32	1989 - 1990	131.0	79.1	83.7	223.5	194.4	365.7	164.8	130.4	93.4	85.6	78.3	68.1
33	1990 - 1991	67.2	329.2	192.9	153.0	125.8	614.2	194.5	122.9	92.1	71.1	64.5	60.2
34	1991 - 1992	224.3	121.9	135.3	107.3	104.5	80.8	68.0	121.5	80.8	77.0	81.9	125.4
	Monthly Average Total Discharge (1958 - 1992)	92.4	166.9	219.6	253.6	215.2	241.9	209.8	169.7	101.8	82.2	75.3	64.8
	Monthly total for Drainage Area of 1.29 mile^2, Area ratio 1.29/2.04 = 0.63												
	Cubic feet/sec	58.2	105.1	138.3	159.8	135.6	152.4	132.2	106.9	64.1	51.8	47.5	40.8
	Acre-feet	115.4	208.4	274.3	316.9	268.9	302.3	262.2	212.0	127.1	102.7	94.2	89.9

R = 2374.3
(Acre-feet)

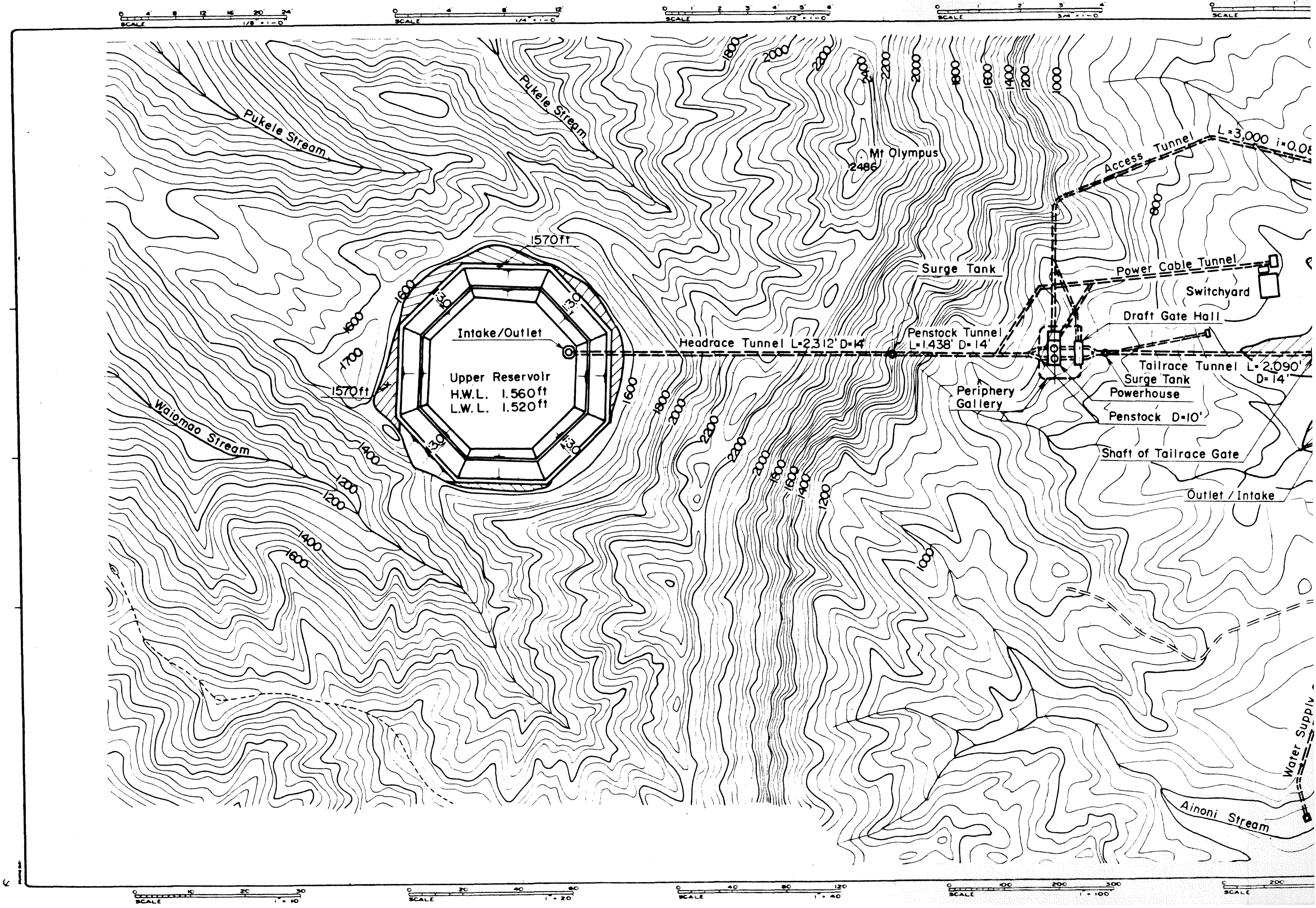


Note: Maunawili Ditch roughly follows the 420~430 feet contour.

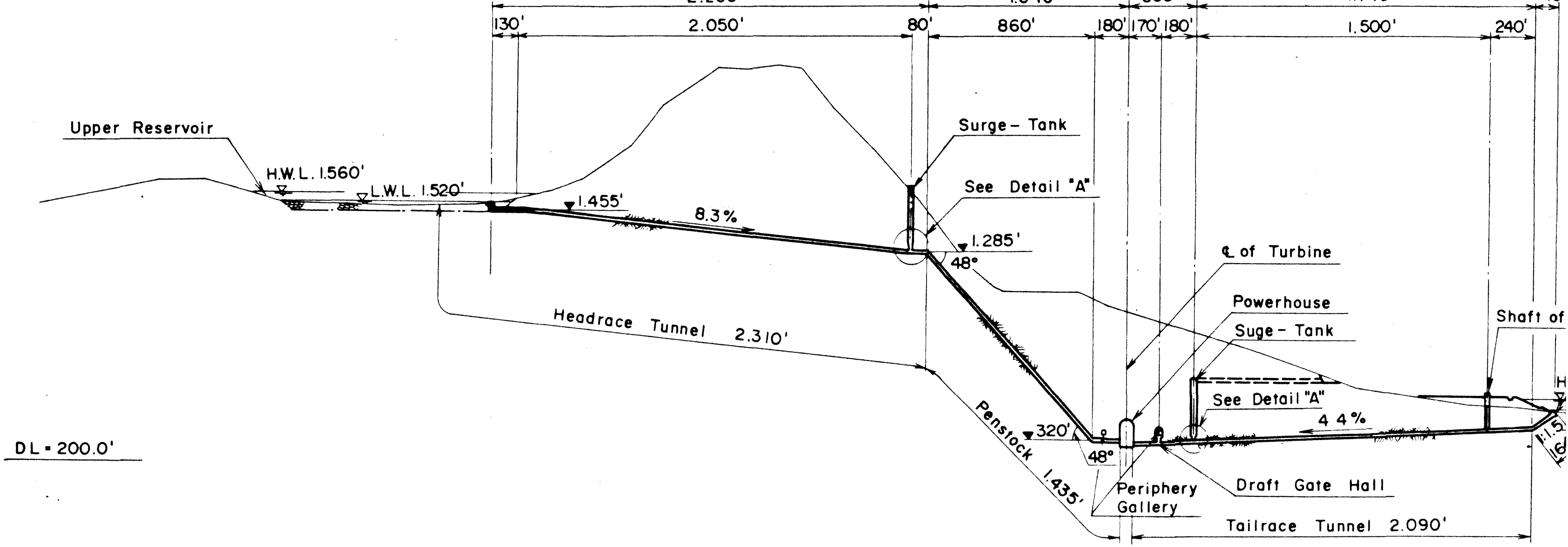
Okahara & Associates Inc.
CONSULTING ENGINEERS

FIGURE III-10

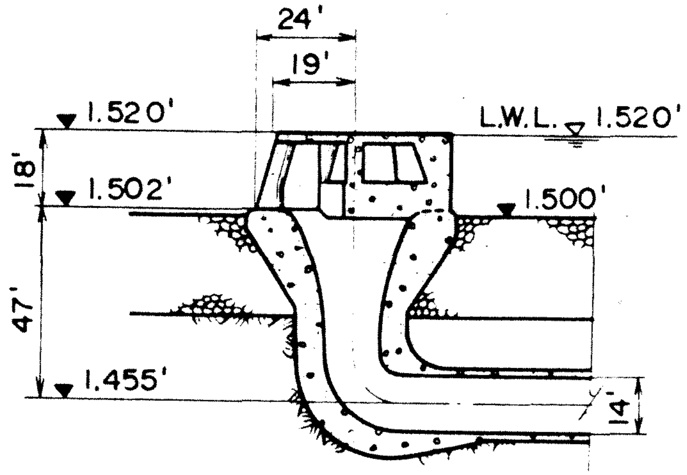
REVISIONS
DRAWING NO
SHEET NO
REVISION


Pukele Stream
Pukele Stream
Mt Olympus
2486
1570ft
1570ft
Intake/Outlet
Upper Reservoir
H.W.L. 1.560ft
L.W.L. 1.520ft
Waiomao Stream
Headrace Tunnel L=2.312' D=14'
Penstock Tunnel L=1.438' D=14'
Surge Tank
Access Tunnel
L=3,000 i=0.08
Power Cable Tunnel
Switchyard
Draft Gate Hall
Tailrace Tunnel L=2.090' D=14'
Surge Tank
Powerhouse
Penstock D=10'
Periphery Gallery
Shaft of Tailrace Gate
Outlet / Intake
Ainoni Stream
Water Supply
1000
1200
1400
1600
1700
1800
2000
2200
2400
800
130
SCALE 1/8" = 1'-0
SCALE 1/4" = 1'-0
SCALE 1/2" = 1'-0
SCALE 3/4" = 1'-0
SCALE
SCALE 1" = 10
SCALE 1" = 20
SCALE 1" = 40
SCALE 1" = 100
SCALE

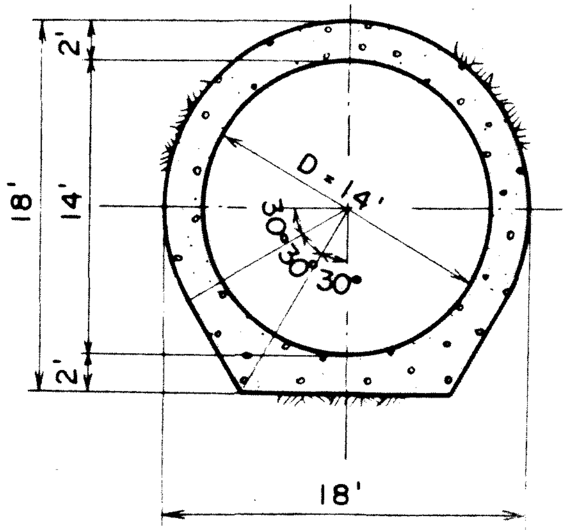
General Profile
S = 1: 6,000



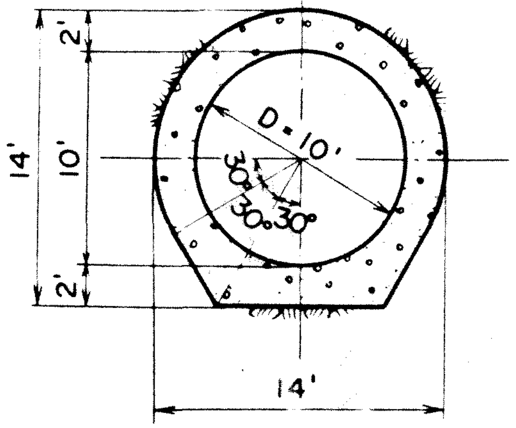
Section of Intake/Outlet
S = 500



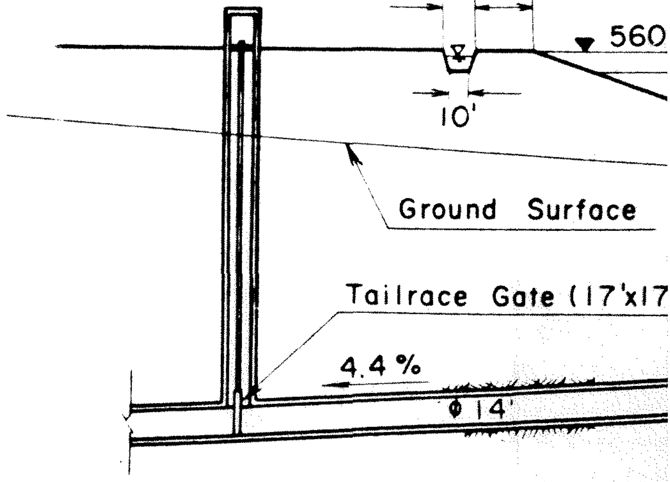
Headrace Tunnel
Tailrace Tunnel
Penstock Tunnel
S = 1:100



Penstock (Horizontal Area)
S = 1:100

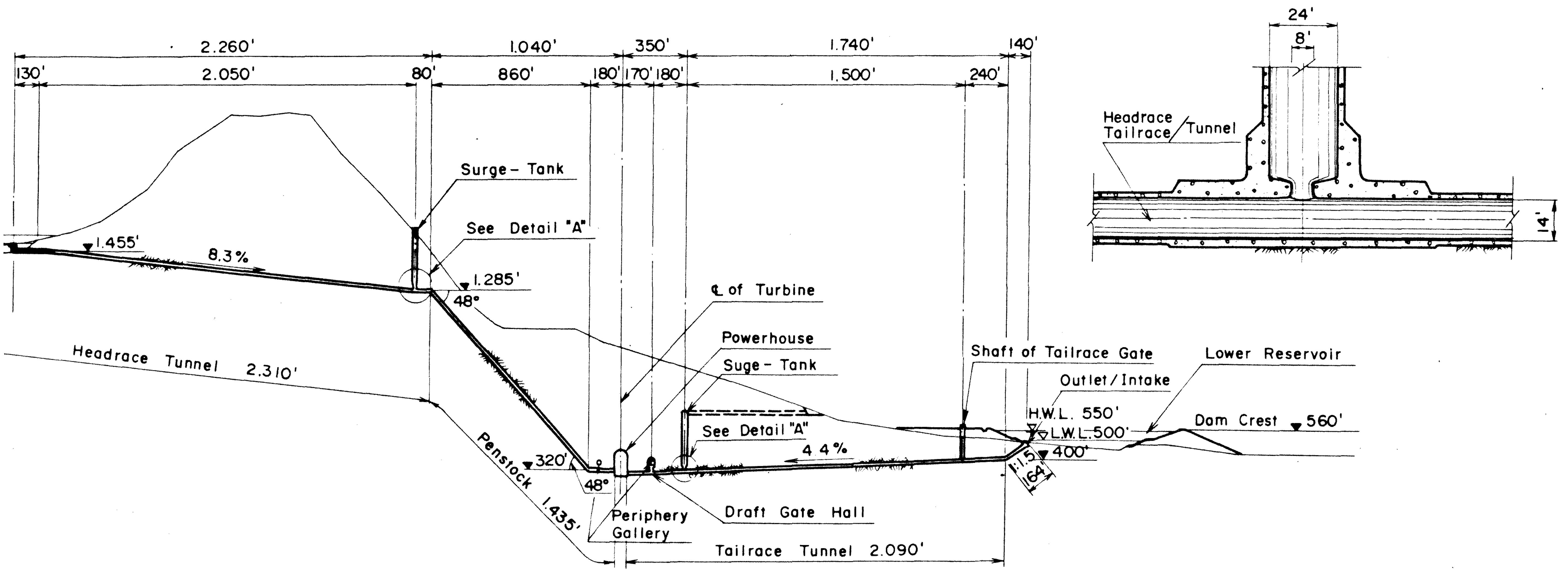


Section of Tailra



General Profile

S = 1: 6,000

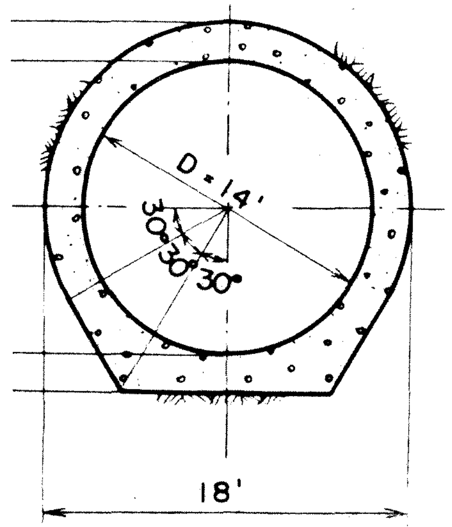


Detail "A"

S = 1:400

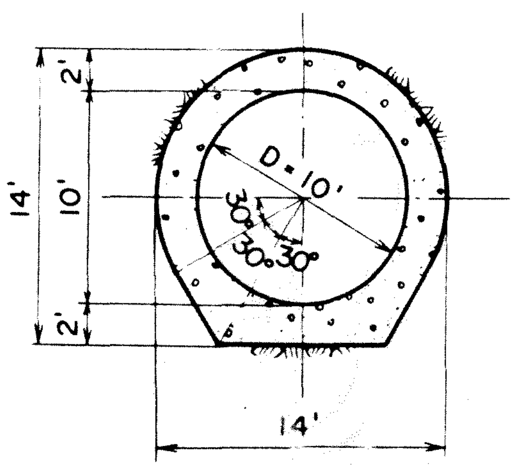
Headrace Tunnel
Tailrace Tunnel
Penstock Tunnel

S = 1:100



Penstock (Horizontal Area)

S = 1:100



Section of Tailrace Outlet

S = 1: 1,000

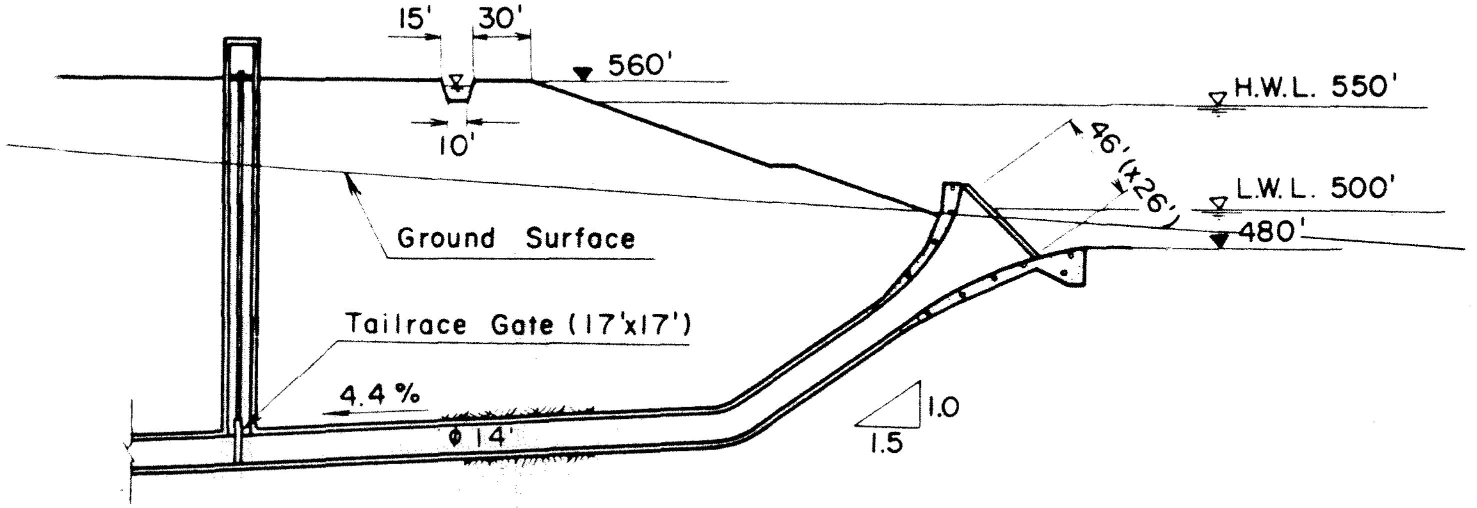


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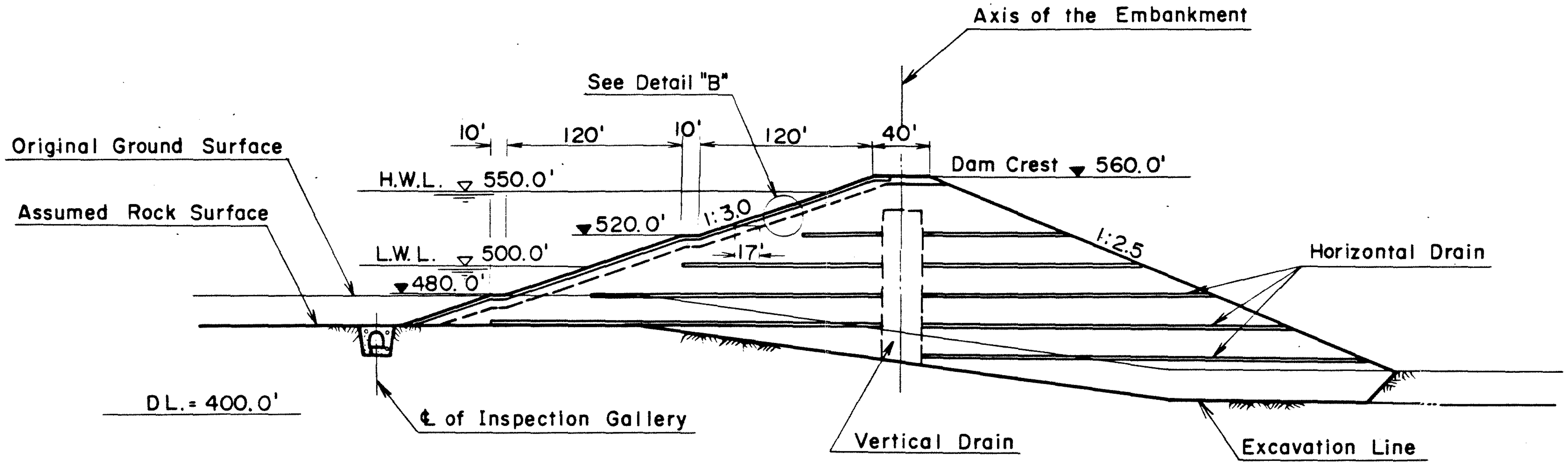
FIGURE III-11

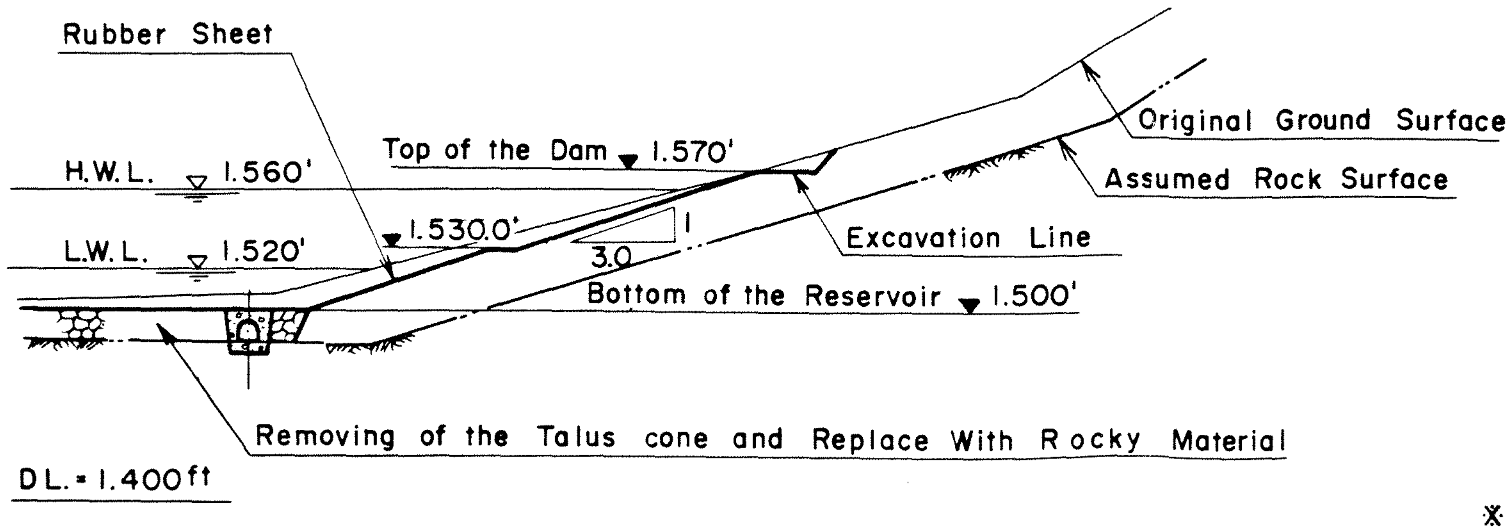
Typical Section of Lower Reservoir Dam

S= 1: 1,000



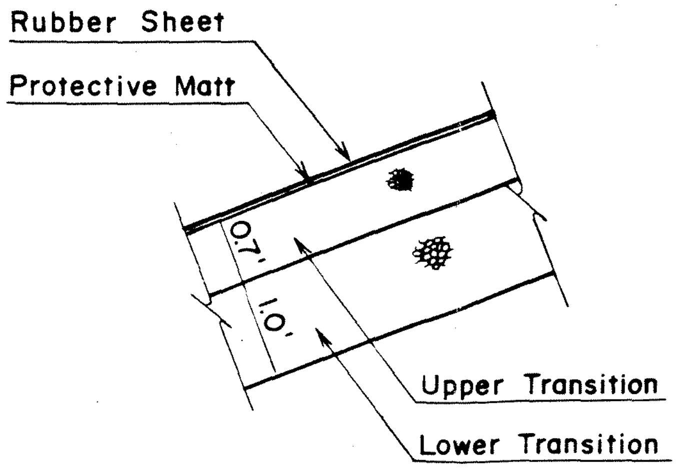
Typical Section of Upper Reservoir

S= 1: 1,000



Detail "B"

S= 1: 20



※ This detail shall be applicable to the upper reservoir of the Koko crater site.

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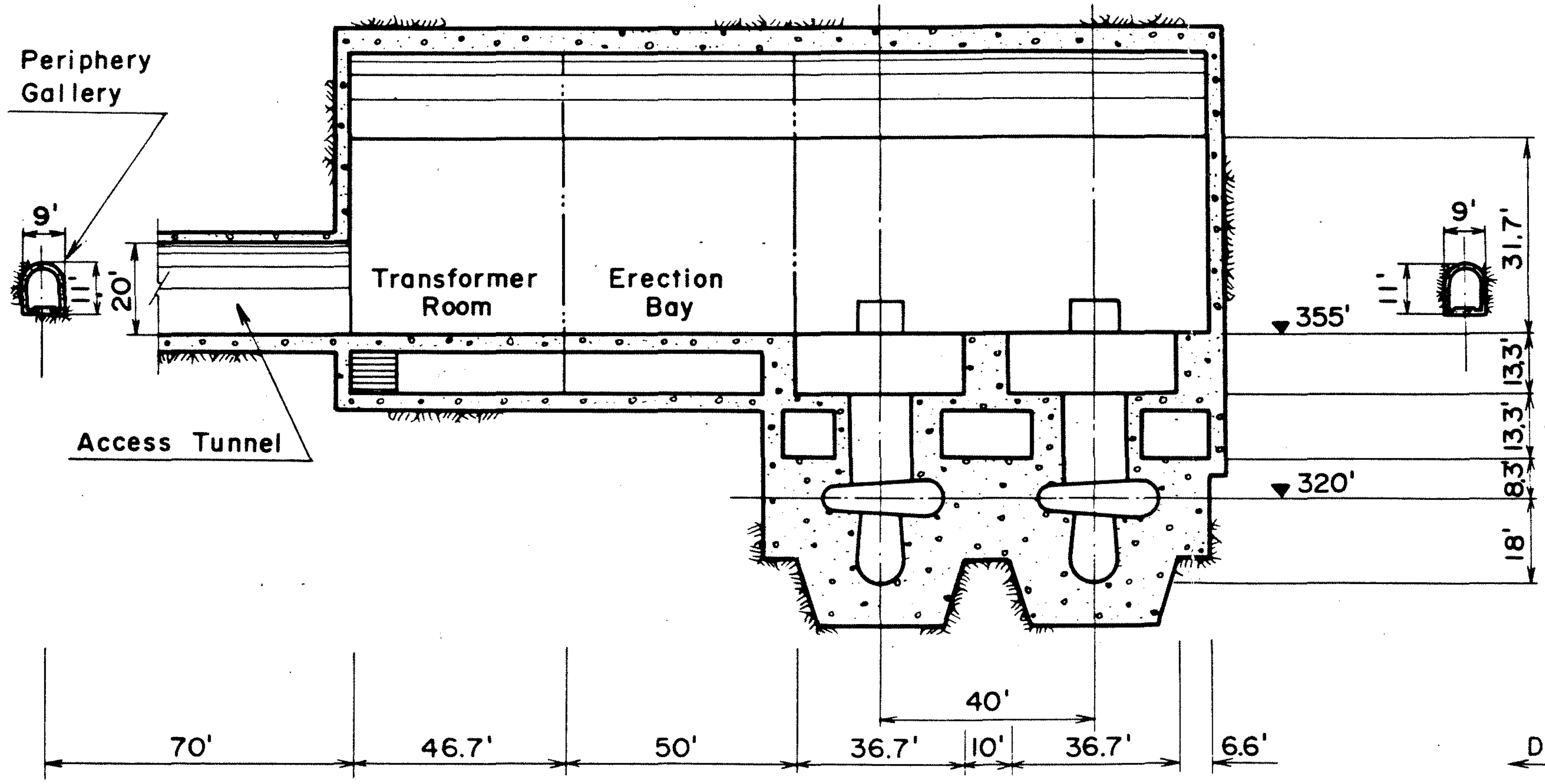
FIGURE III-12

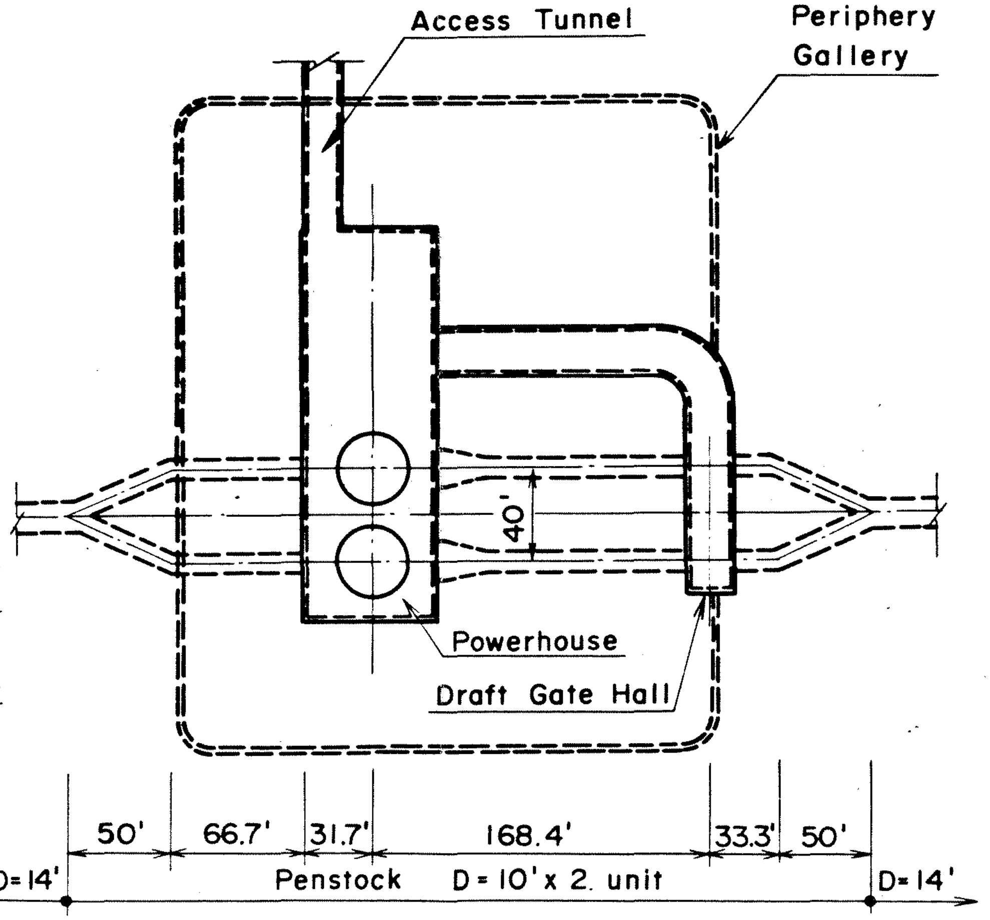
Longitudinal Section

S = 1:400



Plan of Powerhouse

S = 1:1.000



REVISIONS

NO	DATE	DWN	CHK
△			

REFERENCE DRAWINGS

NO	CO.

Okahara & Associates Inc.
CONSULTING ENGINEERS

200 KOHOLA STREET
HILO, HAWAII 96720
TEL: (808) 961-5527

470 N. NIMITZ HWY, SUITE [illegible]
HONOLULU, HAWAII [illegible]
TEL: (808) [illegible]

FIGURE III-13

DRAWING NO

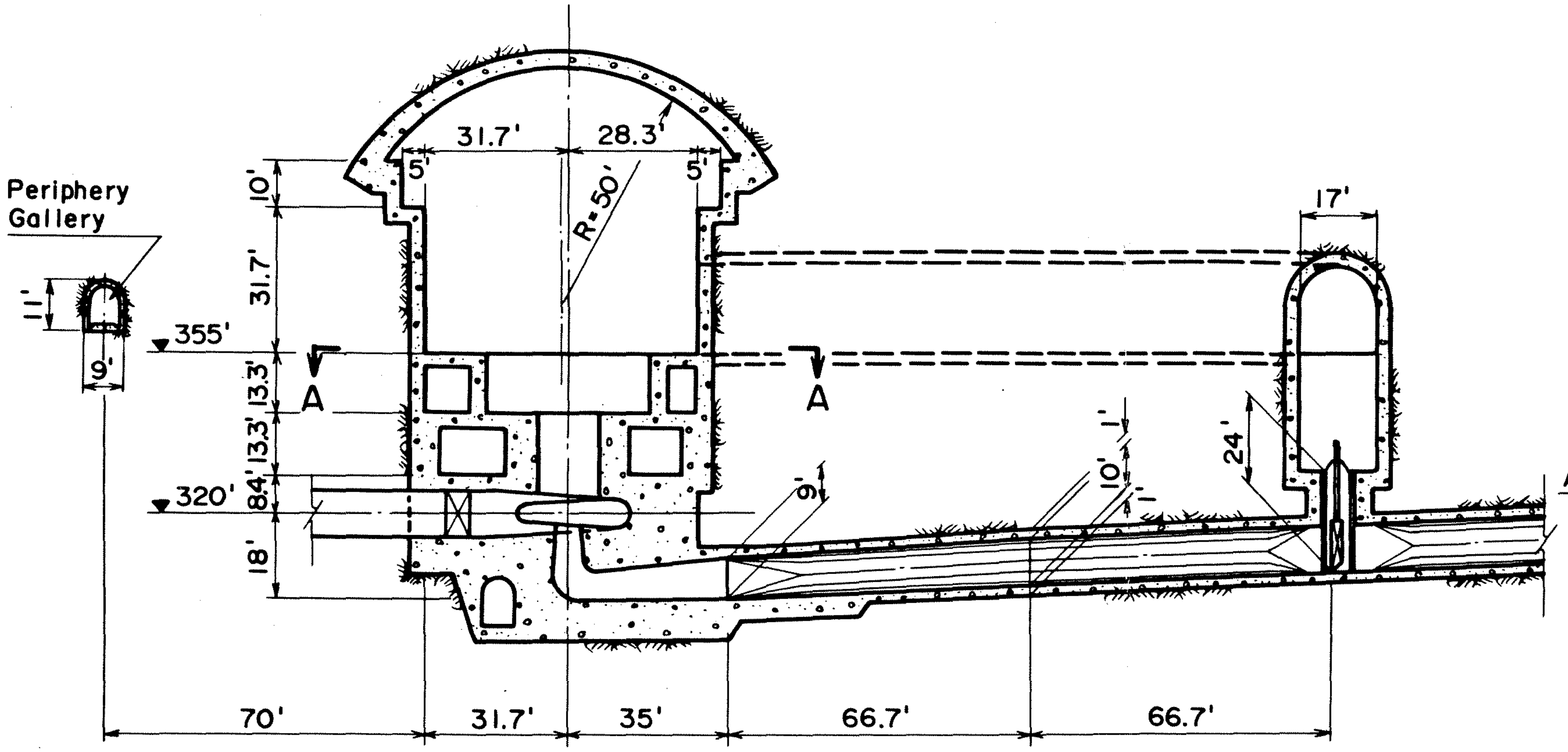
SHEET NO

REVISION

△

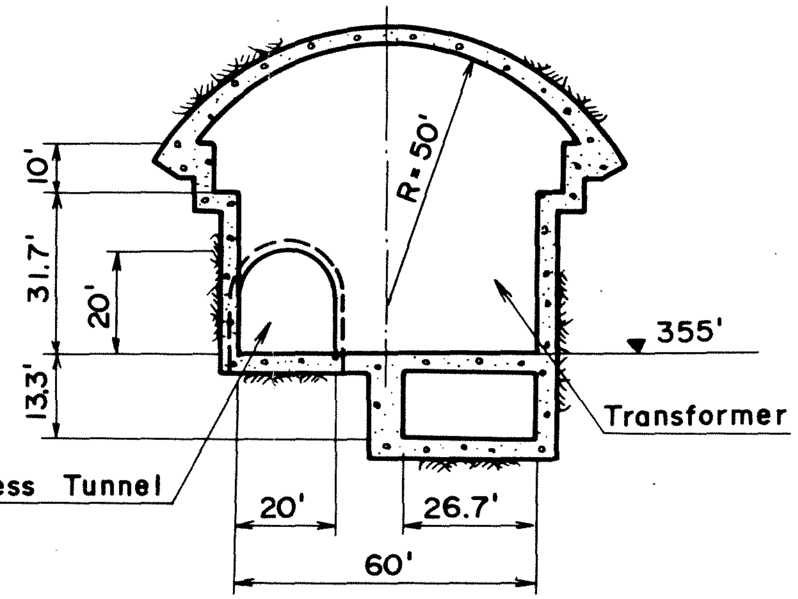
Section of Powerhouse and Draft Gate Hall

S = 1:400



Transformer Room Section B – B

S = 1:400



Powerhouse Plan A – A

S = 1:400

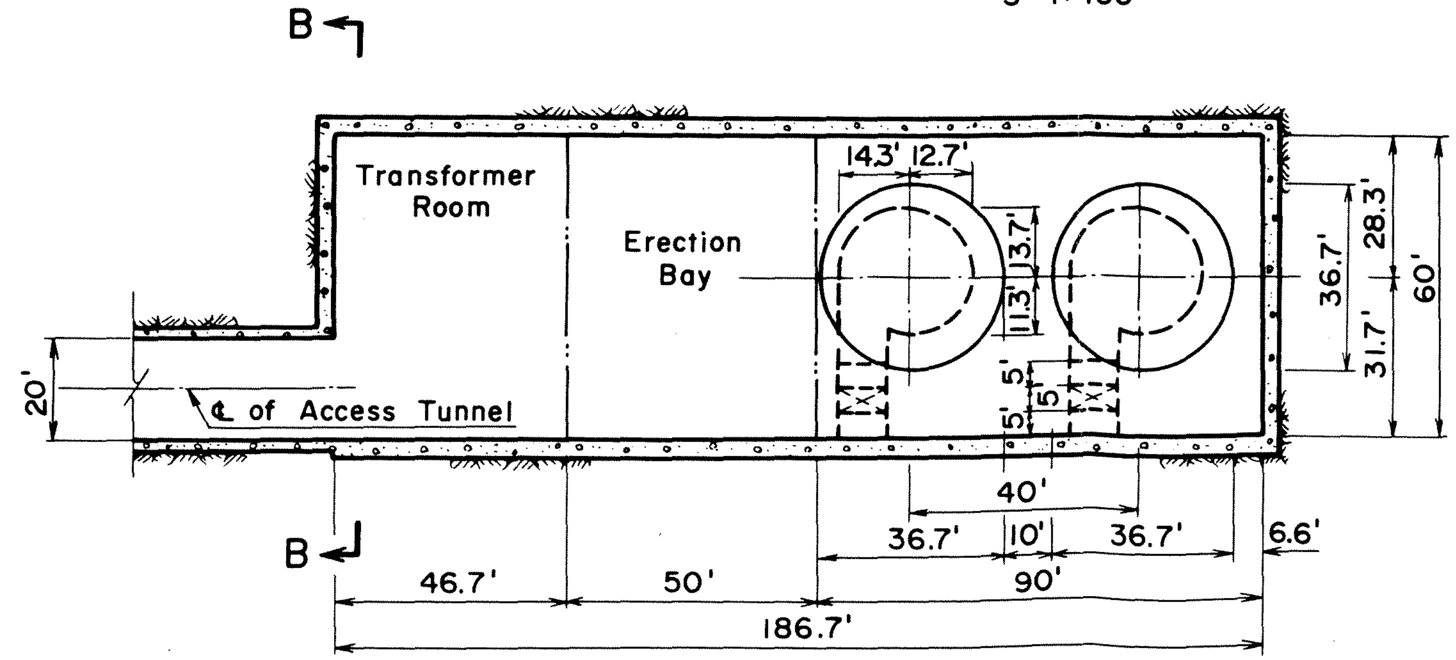


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FIGURE III-14

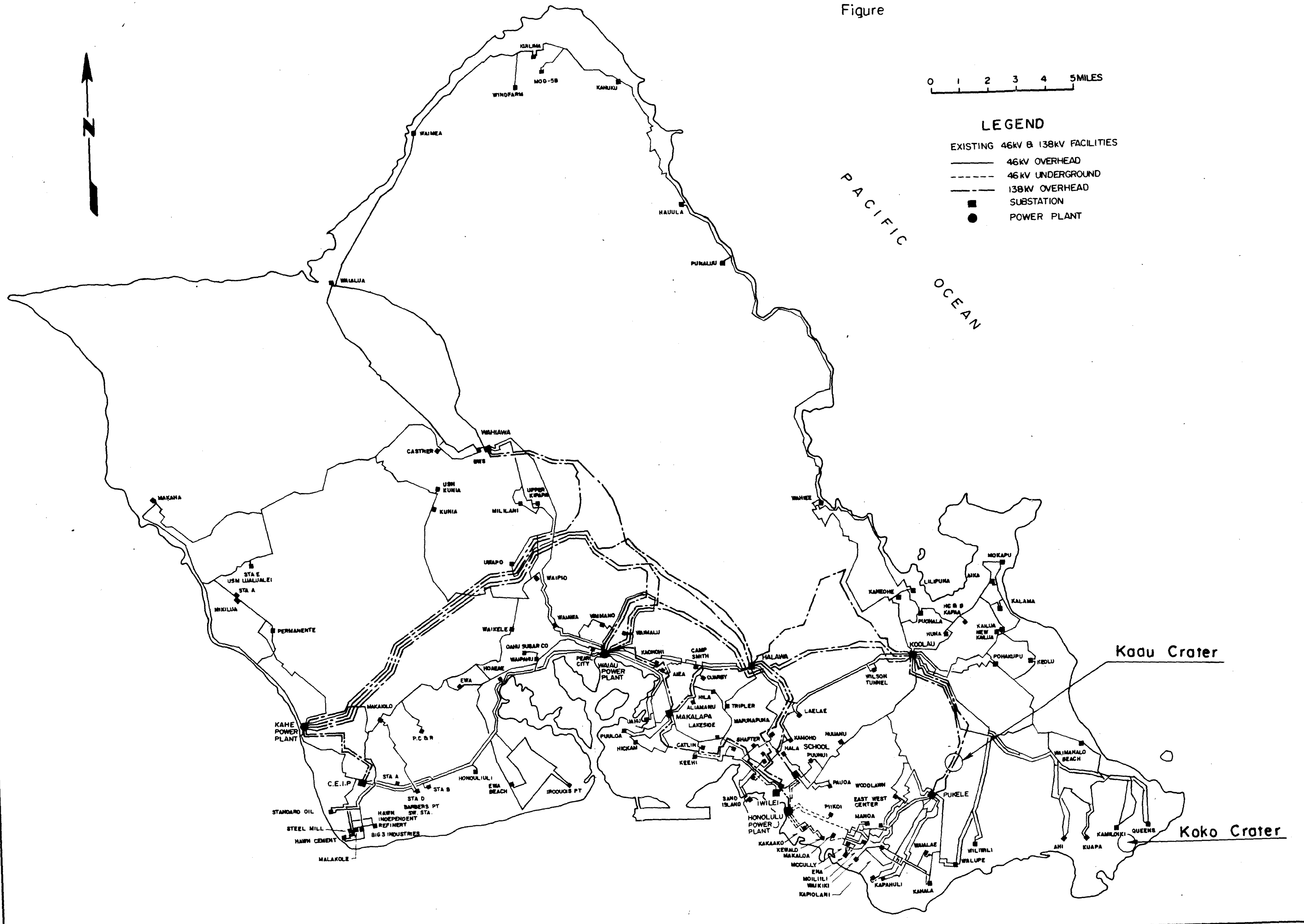
III E. TRANSMISSION LINES

The current electrical transmission system on Oahu consists of 138kV and 46kV overhead and transmission lines as shown on Figure III-15. Both the Koko Crater and the Kaau Crater projects will require extension of the existing transmission system and substations to interface with the power plants. The following information was developed by the Tramsmission and Distribution Planning Department of HECO.

Koko Crater: East Honolulu is currently serviced by 46kV transmission lines. This voltage level is too low to handle the 160MW of power that will be associated with Koko Crater project. This project will therefore require the installation of approximately nine miles of 138 kV transmission line extending from the existing Pukele-Koolau line to a substation in or near the new switchyard adjacent to the Hawaii Kai sewage treatment plant and a new switchyard on the Pukele-Koolau right of way. The 138kV line will be overhead (with 46kV underbuilt) where it traverses the rough mountainous terrain and mostly accessible only by helicopter. The alignment will need to be further developed before the full impact and cost of the transmission line can be determined. Figure III-16 is the proposed single line diagram for the transmission line additions.

Kaau Crater: This project will require the installation of approximately one mile of 138kV transmission line connecting from the nearby existing 138kV transmission line to the project's switchyard. The routing of the additional line will be mostly accessible by truck and will all be overhead as the existing lines are. Figures III-17 and 18 provide alternatives A and B, respectively, for the provisioning of switchyards. Alternative A provides one switchyard near the lower reservoir and close to the existing 138kV line. Alternative B provides an additional switchyard adjacent to the project's powerhouse switchyard. Additional study is required to select the more feasible alternative.

Figure



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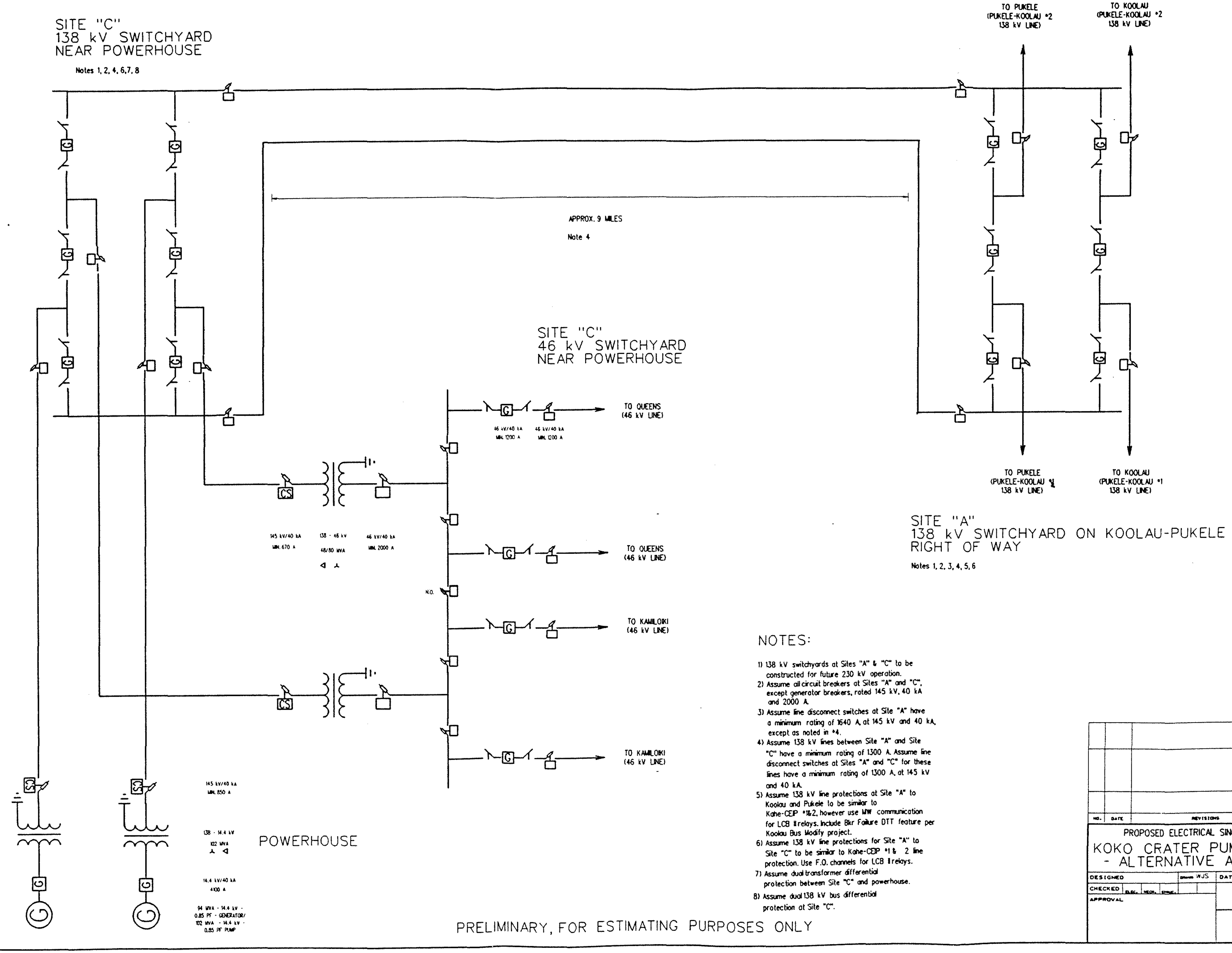
CONSULTING ENGINEERS

FIGURE III-15

pxtwskoko.sld



NOTES:

1) 138 kV switchyards at Sites "A" & "C" to be constructed for future 230 kV operation.
2) Assume all circuit breakers at Sites "A" and "C", except generator breakers, rated 145 kV, 40 kA and 2000 A.
3) Assume line disconnect switches at Site "A" have a minimum rating of 1640 A, at 145 kV and 40 kA, except as noted in •4.
4) Assume 138 kV lines between Site "A" and Site "C" have a minimum rating of 1300 A. Assume line disconnect switches at Sites "A" and "C" for these lines have a minimum rating of 1300 A, at 145 kV and 40 kA.
5) Assume 138 kV line protections at Site "A" to Koolau and Pukele to be similar to Kahe-CEIP •1&2, however use MW communication for LCB II relays. Include Bkr Failure DTT feature per Koolau Bus Modify project.
6) Assume 138 kV line protections for Site "A" to Site "C" to be similar to Kahe-CEIP •1 & 2 line protection. Use F.O. channels for LCB II relays.
7) Assume dual transformer differential protection between Site "C" and powerhouse.
8) Assume dual 138 kV bus differential protection at Site "C".

PRELIMINARY, FOR ESTIMATING PURPOSES ONLY

NO.	DATE	REVISIONS	BY	CHK'D	APP'D

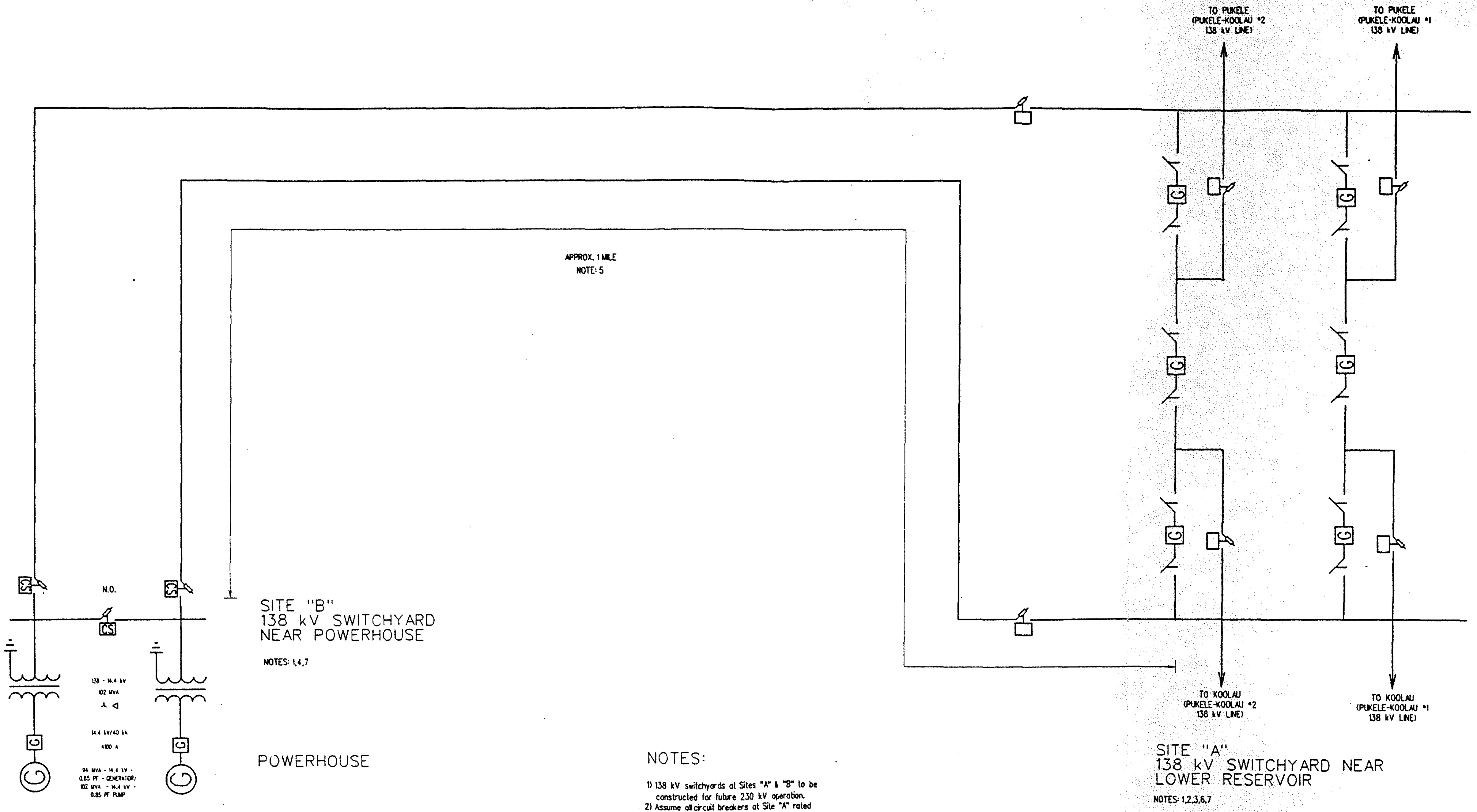
PROPOSED ELECTRICAL SINGLE LINE DIAGRAM
KOKO CRATER PUMPED STORAGE
- ALTERNATIVE A

DESIGNED
DRAWN WJS
DATE 01/11/1994
SCALE Not to scale
CHECKED ELEC. MECH. STRUC.
APPROVAL
DRAWING NUMBER
REV

11-JAN-1994 13:40 wshemley /usr/wshemley/dgn/pxtwskoko.sld

FIGURE III-16

pxtwskaau.sld



NOTES:

1) 138 kV switchyards at Sites "A" & "B" to be constructed for future 230 kV operation.
2) Assume all circuit breakers at Site "A" rated 145 kV, 40 kA and 2000 A.
3) Assume line disconnect switches at Site "A" have a minimum rating of 1640 A, at 145 kV and 40 kA except as noted in #5.
4) Assume circuit switchers at Site "B" have a minimum rating of 850 A, at 145 kV and 40 kA.
5) Assume 138 kV lines between Site "A" and Site "B" have a minimum rating of 850 A. Assume line disconnect switches at "Site "A" for these lines have a minimum rating of 850 A, at 145 kV and 40 kA.
6) Assume 138 kV line protections at Site "A" to Koolau and Pukele to be similar to Kahe-CEIP #1&2, however use MW communication for LCB II relays. Include Bkr Failure DTT feature per Koolau Bus Modify project.
7) Assume 138 kV line protections for Site "A" to Site "B" to be similar to new Koolau-Pukele #1&2 line protection. Include DTT from Site "B" to Site "A".

PRELIMINARY, FOR ESTIMATING PURPOSES ONLY

NO.	DATE	REVISIONS	BY	CHK'D	APP'D

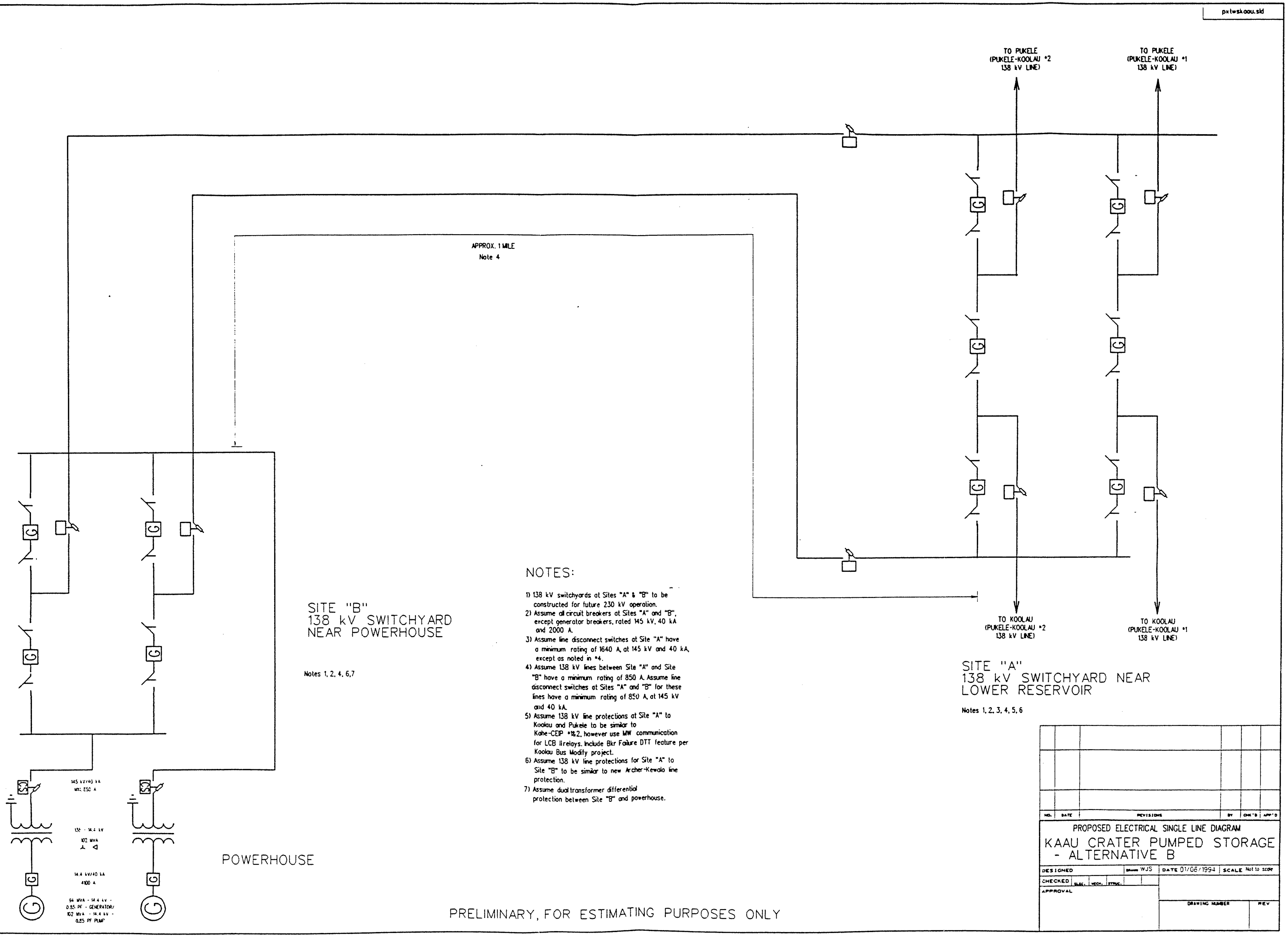
PROPOSED ELECTRICAL SINGLE LINE DIAGRAM

KAAU CRATER PUMPED STORAGE
- ALTERNATIVE A

DESIGNED | DRAWN WJS | DATE 01/06/1994 | SCALE Not to scale
CHECKED | ELEC. | MECH. | STRUC.
APPROVAL
DRAWING NUMBER | REV

06-JAN-1994 13:09 wshemley /usr/wshemley/dgn/pxtwskoau.sld

FIGURE III-17



NOTES:

1) 138 kV switchyards at Sites "A" & "B" to be constructed for future 230 kV operation.
2) Assume all circuit breakers at Sites "A" and "B", except generator breakers, rated 145 kV, 40 kA and 2000 A.
3) Assume line disconnect switches at Site "A" have a minimum rating of 1640 A, at 145 kV and 40 kA, except as noted in *4.
4) Assume 138 kV lines between Site "A" and Site "B" have a minimum rating of 850 A. Assume line disconnect switches at Sites "A" and "B" for these lines have a minimum rating of 850 A, at 145 kV and 40 kA.
5) Assume 138 kV line protections at Site "A" to Koolau and Pukele to be similar to Kahe-CEIP *1&2, however use MW communication for LCB llrelays. Include Bkr Failure DTT feature per Koolau Bus Modify project.
6) Assume 138 kV line protections for Site "A" to Site "B" to be similar to new Archer-Kewalo line protection.
7) Assume dual transformer differential protection between Site "B" and powerhouse.

NO.	DATE	REVISIONS	BY	CHK'D	APP'D

PROPOSED ELECTRICAL SINGLE LINE DIAGRAM

KAAU CRATER PUMPED STORAGE
- ALTERNATIVE B

DESIGNED
DRAWN WJS
DATE 01/06/1994
SCALE Not to scale
CHECKED ELEC. MECH. STRUC.
APPROVAL
DRAWING NUMBER
REV

06-JAN-1994 13:16 wshemley /usr/wshemley/dgn/pxtwskaou.sld

FIGURE III-18

III F. COST ESTIMATE AND CONSTRUCTION PLANNING

The estimated cost for each project was developed based on the designs described in the previous sections. The estimates are based on quantity take-offs from these designs and unit prices for Hawaii cost and productivity. There are some obvious limitations in the accuracy in the estimates since the designs are conceptual in nature; however, all the major construction elements have been costed. In addition, realistic overhead and profit percentages have been included based on the type of construction involved.

Table III-C and III-D are summaries of the costs for Koko Crater and Kaau Crater projects. Appendix J provides greater cost detail and a breakdown of the summaries.

Some of the assumptions used for the estimates are as follows;

-Drill and blasting techniques will be used to form the underground tunnels, penstocks and powerhouse on 3 shifts per day. Blasting will not be used to grade the reservoirs.

-Cut and fill will be balanced and there will be essentially no hauling. Excavated rock and soil will be processed on site.

-Material excavated from underground will be processed and used on site.

-Transmission lines will be above ground along the Koolaus. Portions of the Koko Crater transmission line will be underground between the Koolaus and the switchyard.

Schedule:

Figures III - 19 and III - 20 depict the schedule for construction of the Koko Crater and the Kaau Crater projects, respectively. These schedules are based on the experience of a similar project in Okinawa. The critical path is 1-excavation of the access tunnels, 2-excavation of the power house, 3-installation of the turbines and 4-installation of the generators. Current experience allows 18 - 20 months for lead time in procurement of large electrical machinery; this time has been included in developing the schedules. These schedules assume all the necessary planning, environmental and land use permits have been previously obtained.

Economic analysis

The estimated construction and operating costs were analyzed by Hawaiian Electric Co. to determine if the two projects were cost effective when compared to alternative generating schemes developed in the IRP. The analysis is detailed in Appendix K. The results indicate that both the Koko Crater and Kaau Crater projects have costs higher than the alternative schemes. These higher cost differences, which range from $18 to $34 millions (0.3% to 0.5%) over a period of 20 years, are not enough to eliminate the PSH projects from consideration and both projects are considered cost effective. The alternative generating schemes were the least cost plan and the preferred plan developed from the IRP.

FILE : 1194BA

TABLE III - C

REV. NO. 0 29-Mar-94

PROJECT : KOKO CRATER - PUMPED STORAGE

ITEM : PROJECT SUMMARY

SHEET 1 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
SUMMARY DIRECT COST CONSTRUCTION								
A. MOBILIZATION				1,180,000		350,000		1,530,000
B. SPECIAL PLANT				320,000		10,000		330,000
1. UPPER RESERVOIR				18,541,000		11,630,000		30,171,000
2. INTAKE STRUCTURE				1,787,000		1,068,000		2,855,000
3. i) PENSTOCK TUNNEL				7,144,000		5,673,000		12,817,000
ii) DRAFT TUBE TUNNEL				887,000		1,034,000		1,921,000
iii) TAILRACE TUNNEL				2,625,000		2,965,000		5,590,000
4. POWERHOUSE				5,677,000		7,040,000		12,717,000
5. DRAFT GATE HALL				2,253,000		740,000		2,993,000
6. OUTLET STRUCTURE				12,596,000		6,231,000		18,827,000
7. POWERHOUSE ACCESS				5,591,000		6,209,000		11,800,000
8. OUTLET ACCESS TUNNEL				949,000		2,263,000		3,212,000
9. POWERHOUSE EQUIPMENT (#1)				40,290,000				40,290,000
10. SWITCHYARD				14,348,000				14,348,000
11. TRANSMISSION LINE (#2)				7,861,000				7,861,000
TOTAL DIRECT COST				122,049,000		45,213,000		167,262,000
CONTRACTORS OH	15.00%							25,089,000
SUBTOTAL								192,351,000
CONTRACTORS CONTINGENCY & FEE	15.00%							28,853,000
SUBTOTAL								221,204,000
BOND & HAWAII G.I. TAX	4.50%							9,954,000
DESIGN / CM	6%							13,869,000
TOTAL PROJECT 1994 DOLLARS								245,027,000
OWNERS CONTINGENCY	5%							12,251,000
MITIGATING MEASURES	1%							2,450,000
TOTAL CONSTRUCTION 1994 DOLLARS								259,728,000
LAND AQUISITION (#3)								TO BE DETERMINED

(#1) INCLUDES PRIMARY TRANSFORMERS

(#2) ALLOWS $ 2,000,000 FOR UNDERGROUND PORTION OF TRANSMISSION LINE

(#3) VALUE BASED ON CURRENT TAX ASSESSMENT OF $1,200 / ACRE

FILE : 1194B8

TABLE III - D

REV. NO. 0 29-Mar-94

PROJECT : KAAU CRATER – PUMPED STORAGE

ITEM : PROJECT SUMMARY

SHEET 1 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
SUMMARY DIRECT COST								
A. MOBILIZATION				1,230,000		375,000		1,605,000
B. SPECIAL PLANT				380,000		10,000		390,000
1. UPPER RESERVOIR				12,427,000		5,573,000		18,000,000
2. UPPER RESERVOIR ACCESS ROAD				924,000		308,000		1,232,000
3. INTAKE STRUCTURE				476,000		223,000		699,000
4. WATER CONDUCTORS								
i) PENSTOCK TUNNEL				6,648,000		7,579,000		14,227,000
ii) DRAFT TUBE TUNNEL				434,000		453,000		887,000
iii) TAILRACE TUNNEL				2,767,000		2,875,000		5,642,000
5. POWERHOUSE				5,545,000		7,124,000		12,669,000
6. SURGE TANK				1,725,000		2,050,000		3,775,000
7. DRAFT GATE HALL				1,207,000		713,000		1,920,000
8. TAILRACE GATE SHAFT				1,781,000		1,555,000		3,336,000
9. LOWER RESERVOIR				8,865,000		9,430,000		18,295,000
10. OUTLET STRUCTURE				375,000		297,000		672,000
11. CONNECTED POND				7,439,000		5,901,000		13,340,000
12. POWERHOUSE ACCESS TUNNEL				9,110,000		10,068,000		19,178,000
13. POWERHOUSE CABLE TUNNEL				2,144,000		2,310,000		4,454,000
14. ACCESS TUNNEL FOR SURGE TANK				1,950,000		1,377,000		3,327,000
15. POWERHOUSE EQUIPMENT (#1)				35,000,000				35,000,000
16. SWITCHYARD				7,246,000				7,246,000
17. TRANSMISSION LINE				507,000				507,000
TOTAL DIRECT COST				108,180,000		58,221,000		166,401,000
CONTRACTORS OH	15.00%							24,960,000
SUBTOTAL								191,361,000
CONTRACTORS CONTINGENCY & FEE	15.00%							28,704,000
SUBTOTAL								220,065,000
BOND & HAWAII G.I. TAX	4.50%							9,903,000
DESIGN / CM	6%							13,798,000
TOTAL PROJECT 1994 DOLLARS								243,766,000
OWNERS CONTINGENCY	5%							12,188,000
MITIGATING MEASURES	1%							2,438,000
TOTAL CONSTRUCTION 1994 DOLLARS								258,392,000
LAND AQUISITION (#2)								TO BE DETERMINED

(#1) INCLUDES PRIMARY TRANSFORMERS

(#2) VALUE BASED ON CURRENT TAX ASSESSMENT OF $1,200 / ACRE

Koko Crater - Pumped Storage Project Schedule

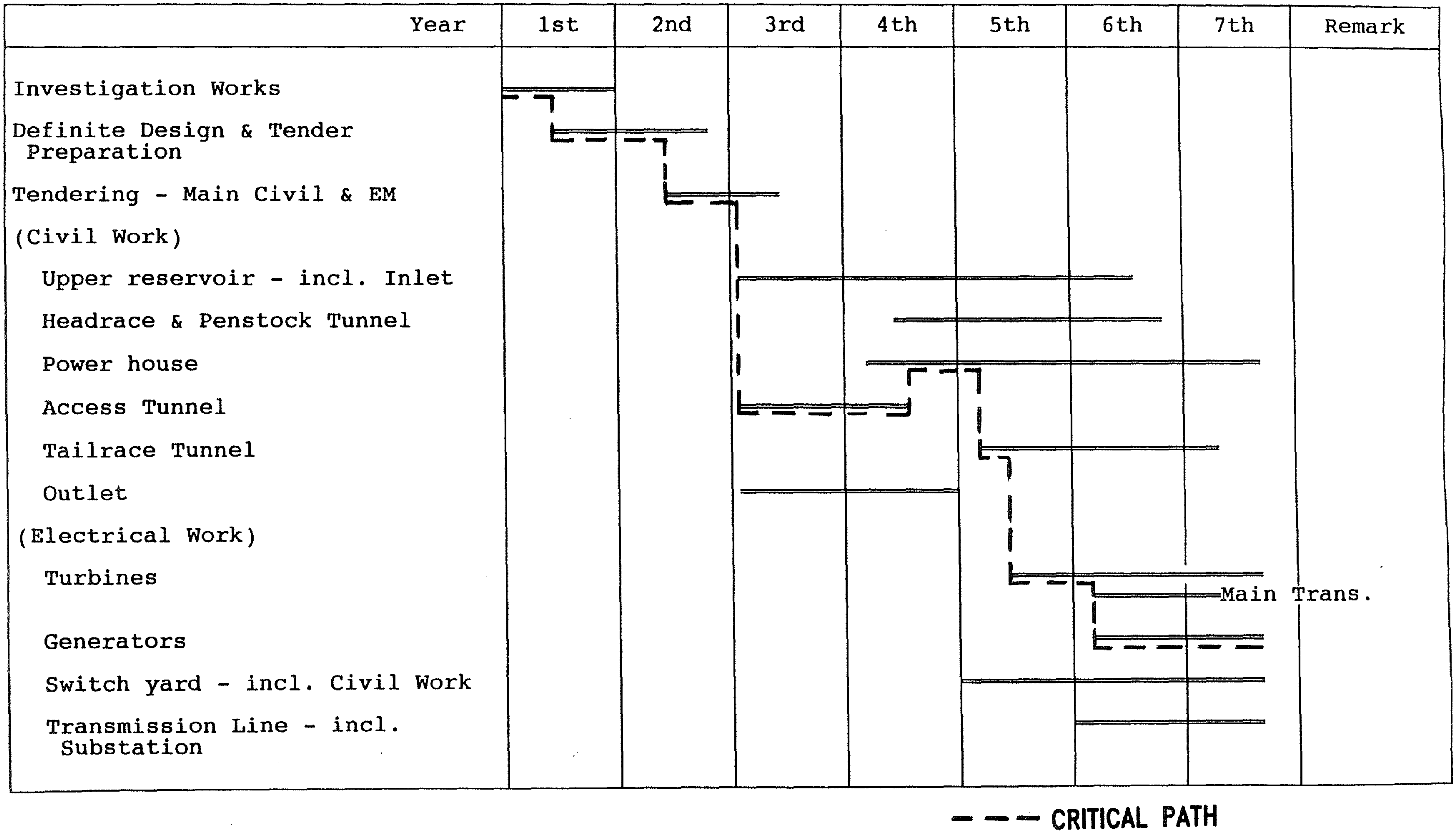


FIGURE III-19

Kaau Crater - Pumped Storage Project Schedule

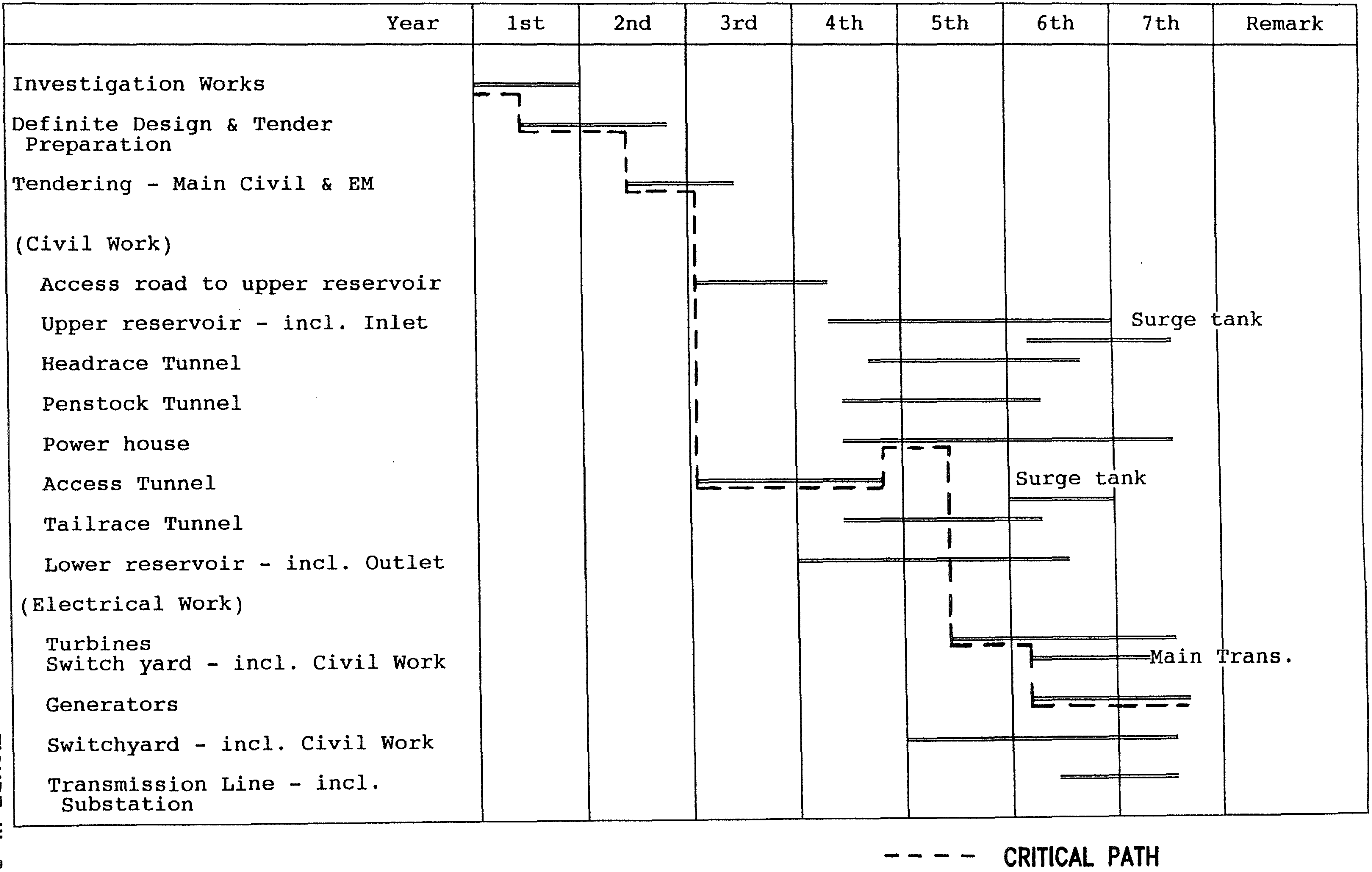


FIGURE III-20

REFERENCES

1. "Water Resources of Windward Oahu", Hawaii 1969. USGS
K. J. Takasaki, G. K. Hirashima, E. R. Lubke

2. "Evaluation of Major Dike-Impounded Ground-Water Reservoirs, Island of Oahu". 1985. USGS K. J. Takasaki and J. F. Mink.

3. "State Water Projects Plan" Review draft, February 1992.

IV. CONCLUSIONS AND RECOMMENDATIONS

Koko Crater Conclusions:

The Koko Crater project appears to be technologically, environmentally, and economically feasible and could provide a significant source of peaking power for the HECO system on or about the year 2005. Although this project will have significant environmental impacts, reasonable mitigation measures appear to be available for consideration. The following issues will need to be addressed:

1. The residents in the area will need to be assured of the safety of the dam.

2. The breakwater will have a negative visual impact and affect the recreational and commercial use of the area. These impacts will need to be addressed in the detail design. Features should be included to allow fishing and diving from the sea side of the breakwater. Such efforts could actually increase the current recreational use of the area.

3. The Botanical Garden which contains non-native plants will need to be relocated or otherwise compensated. Other mitigating measures may be necessary for loss of certain exceptional trees.

4. The appearance of the reservoir dam will need to be addressed in the design to mitigate any negative visual impacts.

5. There are currently no known endangered species or archeological sites that would be affected; however, a complete archeological survey of the site is required to confirm this.

6. Additional oceanographic, water quality, and marine biological investigations will need to be conducted to minimize impacts to marine resources, especially Hanauma Bay.

7. The effect of water borne sound on marine mammals will need to be evaluated.

8. The routing of the transmission line will need to be developed to determine the extent and impacts of right-of-way aquisition.

Kaau Crater Conclusions

The Kaau Crater project has significant environmental and technical issues that will need to be addressed if this project is to continue to be evaluated. The significance of the issues becomes apparent when it is noted that there are no evident mitigation measures to overcome the following:

1. The Kaau Crater wetlands will be displaced by a fresh water reservoir and will require replacement under current Federal Regulations.

2. The stream flow into the Kawainui Marsh and the Maunawili Ditch will be interrupted during construction and perhaps permanently.

3. The habitat in Maunawili Valley will be adversely affected both during and after construction.

4. The farmers who were recently relocated to the Maunawili agriculture reserve would need to be relocated again.

5. The lower reservoir will inhibit the current flow of springs and seepage

from the marginal dike area resulting in unknown effects on these sources of fresh water.

The above environmental and technical issues associated with the Kaau Crater project makes the feasibility of this project questionable.

In addition to the above issues the following environmental and technical issues will need to be addressed:

1. The 3.5 mile access road to the Kaau Crater will need to be evaluated for its visual impact and affect on biota and habitat.

2 The source of water for initial filling of the lower reservoir will require extensive evaluation before the full impact on existing streams, dike impounded water, and habitat can be assessed.

3. While no significant archeological resources were identified, a complete field survey will be required to confirm that none exist.

Recommendations:

The significant technical and environmental issues related to the Kaau Crater project lead to the recommendation that this project be eliminated from further consideration as a PSH facility. The Koko Crater project, however, does not appear to have insurmountable (although formidable) environmental and technical issues to overcome. Therefore, the Koko Crater project is considered feasible within the limits of the scope of this study.

The completion of this report represents a significant step toward the development of Pumped Storage Hydroelectric on Oahu. This report however, still provides only an elementary understanding of the construction, environmental and economic issues related to PSH on Oahu. To improve this understanding, it is recommended that the following be accomplished:

1. A complete Environmental Assessment should be undertaken to provide a full understanding of the issues with input from governmental agencies and public groups. The material prepared for this report represents a significant step in that direction and the required EA and preparation notice could easily be prepared. The next major step would be an EIS which would address in depth the environmental issues both on shore and off shore.

2. Exploratory geotechnical work should be performed to confirm the selection of sites and construction methods for the reservoir, dam, tunnels and powerhouse.

3. Offshore underwater bathymetric and geotechnical surveys should be performed to confirm the design and construction methods proposed for the seawater inlet and breakwater.

4. Additional studies should be performed to optimize the design to reduce construction cost, improve efficiency, and to evaluate safety of the dam.

5. Continued analysis to define the specific utility system related issues that effect the feasibility of PSH. These issues include system reliability and transmission line routing.

LIST OF APPENDICES

A. "Preliminary Report of Bird Surveys for Pumped Storage Hydroelectric Power Plant." Dr. Leonard A. Freed. December 30, 1993.

B. "O'ahu Tree Snails in the vicinity of Ka'au Crater." Dr. Michael G. Hadfield. October 26, 1993.

C. "Botanical Survey of Ka'au Crater and Maunawili Valley Sites." Char and Associates. October 29, 1993.

D. "An Archaeological Review of Maunawili Valley, Kailua, Ko'olaupoko, O'ahu, TMK: 4-02-10:01, Ka'au Crater, Palolo Valley, Waikiki, O'ahu, TMK:3-4-22:06, Koko Crater, Maunalua, Kona, Oahu, TMK:3-9-12:01 - HECO Proposed Pumped Storage Hydroelectric Power Plant." Carol T. Kawachi. January, 1994.

E. "Preliminary Geologic Reconnaissance Pumped Storage Projects, Koko Crater and Kaau Crater Sites, Oahu, Hawaii." GeoLabs-Hawaii. October 22, 1993.

F. "Pumped Storage Hydroelectric Study, Oahu, Hawaii. Ocean Engineering Considerations for the Inlet/Outlet Structure at the Koko Crater Site." E.K.Noda and Associates, December , 1993.

G. "Pumped Storage Hydro Feasibility Study" Debbie Fujikami, November 1, 1993. Interoffice Correspondence.

H. "Pumped Storage Hydroelectric Project Transmission and Substation Cost Estimates." A. Seki and D. Lau, February 11, 1994.

I. "Demonstration Test of Sea Water Pumped Storage Power Plant

J. Koko Crater and Kaau Crarter Summary and Detail Cost Estimates.

K. PROSCREEN Analysis Oahu Pumped Storage Hydroelectric Updated Cost Estimates. HECO IOC May 23,1994

Preliminary Report of Bird Surveys for Pumped Storage Hydroelectric Power Plant

December 30, 1993

Leonard A. Freed
639 Akoakoa St.
Kailua, HI 96734

APPENDIX A

INTRODUCTION

Brief on-site surveys for birds were conducted at Kaau Crater, Maunawili Valley, and Koko Crater. The goal of the surveys was to determine the actual or potential existence of endangered or threatened species or of species whose abundance on Oahu has been declining. At the time of the surveys, the following bird species were listed by the U.S. Fish and Wildlife Service (USFWS 1983) and by the State of Hawaii (DLNR 1986) as endangered or threatened on Oahu, and were known or suspected to exist on the island (Pratt et al. 1987, Hawaii Audubon Society 1989):

American Coot	(*Fulica americana alai*)
Common Moorhen	(*Gallinula chloropus sandvicensis*)
Black-necked Stilt	(*Himantopus mexicanus knudseni*)
Hawaiian Duck	(*Anas wyvilliana*)
Oahu Creeper	(*Paroreomyza maculata*)
Newell's Shearwater	(*Puffinus newelli*) (threatened only)

In addition the State of Hawaii recognizes the following as endangered or threatened on the island of Oahu:

Iiwi	(*Vestiaria coccinea*)
Short-eared Owl	(*Asio flammeus sandwichensis*)
White Tern	(*Gygis alba rothschildi*) (threatened only)

The following subspecies is recognized as declining on Oahu (Williams 1987):

Elepaio	(*Chasiempis sandwichensis gayi*)

METHODS

The Kaau Crater site, Maunawili Valley site, and Koko Crater sites were investigated on October 3,10, and 17, 1993, respectively. Approximately 2-3 hours were spent identifying birds by sight and sound and inspecting habitat. No attempt was made to conduct a comprehensive survey.

In addition, biologists at the Bishop Museum, USFWS, Division of Forestry and Wildlife, and University of Hawaii were consulted. Data on the distribution and abundance of native birds were gathered from the literature.

RESULTS

No endangered, threatened, or declining species were seen or heard at any of the 3 sites. However, the Black-necked Stilt, Hawaiian Duck, and American Coot have been known to occur in Kaau Crater in the past (Shallenberger 1977), the Short-eared Owl has been known to occur in Maunawili Valley (Eric VanderWerf, University of Hawaii) and Koko Crater (Carolyn Mostello, University of Hawaii), and the White Tern has nested at Koko Head (Ord 1961). In addition, the Oahu Elepaio has been known to occur near Maunawili Valley on the new trail off the Pali Highway (Bob Pyle, Bishop Museum), and dead Newell's Shearwaters have been found near the Pali Tunnels (Harrison 1990).

Other native bird species were detected or known to have occurred at the 3 sites. These are listed in the following table:

	Site		
Species	Kaau Crater	Maunawili Valley	Koko Crater
Common Amakihi	+	+	#
White-tailed Tropicbird	+		+
Pacific Golden-Plover			+
Apapane	#		

(+ = current survey)
(# = Shallenberger 1977)

DISCUSSION

The survey was far too limited in time and coverage to conclude that some significant species were either not present at the time or would not be present in the future. Here special attention will be focused on significant species that were not detected but known to have occurred previously or possible now.

The Kaau Crater includes the endangered waterbirds (Black-necked Stilt, Hawaiian Duck, American Coot, and possibly the Common Moorhen) (Shallenberger 1977). The fact that none of these were detected during the current survey may reflect deteriorated wetland conditions over the years. There was little standing water during the survey. Earlier in 1993, several ornithology students from the University of Hawaii hiked into the crater and did not see or hear waterbirds. The Kaau Crater is not listed as essential habitat for these endangered species in the recovery plan (USFWS 1985). None of the other sites would be expected to have endangered waterbirds.

The threatened Newell's Shearwater is known only from road kills near the Pali Tunnel. It is not known at this time if these are birds associated with nesting attempts on the Pali or if they are blown up from below by strong winds. Either way, however, makes them possible in the nearby Maunawili Valley site. As a precaution for potential development in this site, all lights should be shaded to prevent birds from being disoriented (Reed et al. 1985).

The threatened White Tern on Oahu is known from a nesting attempt at Koko Head during 1961 (Ord 1961). This makes it possible at the Koko Crater site, although the population now on Oahu is concentrated in Kapiolani Park and portions of urban Honolulu (Harrison 1990).

The Pueo is known from the Maunawili Valley and Koko Crater sites and is possible at the Kaau Crater site. The Pueo inhabits dry forests and rain forests, but is most often seen hunting in grasslands (Scott et al. 1986). This bird might thus be expected in all 3 study sites as an occasional forager if not as a regular breeder, especially if a prey base could be identififed. If this project is to procede further, it might be appropriate to conduct a more comprehensive survey for the bird.

The Oahu Elepaio is possible in several sites. This bird has been declining dramatically during the last 15 years (Williams 1987) and a recent state bird survey revealed small and fragmented populations on this island (Paul Conry, DLNR, pers. comm.). However, it is also the case that the elepaio can exist in forests consisting of mainly introduced trees and understory vegetation. The introduced vegetation in the Kaau Crater and in Maunawili Valley might be suitable habitat for Elepaio. In addition, elepaio have been documented on the nearby Maunawili Trail and on the eastern portion of Oahu on the Koolau Mountains toward Hawaii Kai (Bob Pyle, Bishop Museum, pers. comm.). If this project is to procede further, it might be appropriate to conduct a more comprehensive survey for elepaio.

None of the other significant species are expected in the study sites. The main reason for this is that the study sites do not provide suitable habitat for forest birds that require native forest (Berger 1981, Scott et al. 1986).

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Michael G. Hadfield
2071 10th Avenue
Honolulu, Hawaii 96816
(Office Phone 808-539-7319)

October 26, 1993

Mr. George Krasnick
294 Awakea Road
Kailua, HI 96734

Dear Mr. Krasnick:

The following comprises: (1) a report on the historical occurrence of snail species of the federally endangered genus *Achatinella* ("O'ahu Tree Snails") in the region of Ka'au Crater; and (2) results of a partial survey of the ridge above Ka'au Crater on October 3, 1993.

(1) Historical occurrences of O'ahu tree snails:

Eight species of *Achatinella* occurred in the area of Ka'au Crater, O'ahu, Hawaii. In the following table, I indicate whether these species occurred on the leeward slope of the Ko'olau Mountains, where Ka'au Crater lies, on the Ko'olau summit above Ka'au Crater, or both. I also indicate when the species was last sighted, although the records may not specify that the sighting was at Ka'au Crater. Where last sighting locations are available, they are included below.

Species	Distribution	Last Seen
Achatinella abbreviata	summit & lee slopes	1963
A. buddii	lee slopes only	1900
A. cestus	lee slopes only	1966
A. fulgens	summit and lee slopes	1989 (above Aina Haina)
A. fuscobasis	summit only	1992 (behind Manoa Valley)
A. phaeozona	summit & windward ridge	1974
A. taeniolata	summit & lee slopes	1966
A. viridans	summit & lee slopes	1979 (Wiliwilinui)

Older records cite several of these species as being very abundant in the inner parts of Palolo Valley, including Ka'au Crater, but there are no records of extensive modern surveys of this area. Based on the older records, I would judge that three to four of these federally endangered tree snails may persist in the region of Ka'au Crater. Very extensive surveys are required to determine the current status of O'ahu tree snails in this area.

(2) **Survey of October 3, 1993:**

Approach: Our survey party of two (Dr. Stephen E. Miller and Ms. Lisa Hadway) was lifted to the Ko'olau summit directly above (North of) Ka'au Crater at 12:15 p.m. Approximately forty-five minutes were spent searching native vegetation in this region, between the two power lines that span the summit here, for the presence of native snails (**Area I**). The next one and one-half hours were spent surveying the area from the easternmost power line, along the summit, to the area where a major trail descends toward Ka'au Crater (**AREA II**). Finally, the area along the descending trail was surveyed down approximately the upper two-thirds of its extent for one and one-half hours (**Area III**). These search areas are noted on the accompanying map. The approach used in the survey was to visually locate native vegetation known to serve as habitat for native Hawai'ian tree snails, based on both published records and the surveyors' extensive personal experience.

Results:

Area I: Potential host vegetation included *Pelea spp., Metrosideros polymorpha, Antidesma sp., Wikstroemia sp., Coprosma spp., and Freycinetia arborea* (we assume that the botanical expert, Dr. Winona Char, will identify plant species seen in the survey area). Only a single native snail was seen, a small *Tornatellides sp.* on *Pelea sp.*

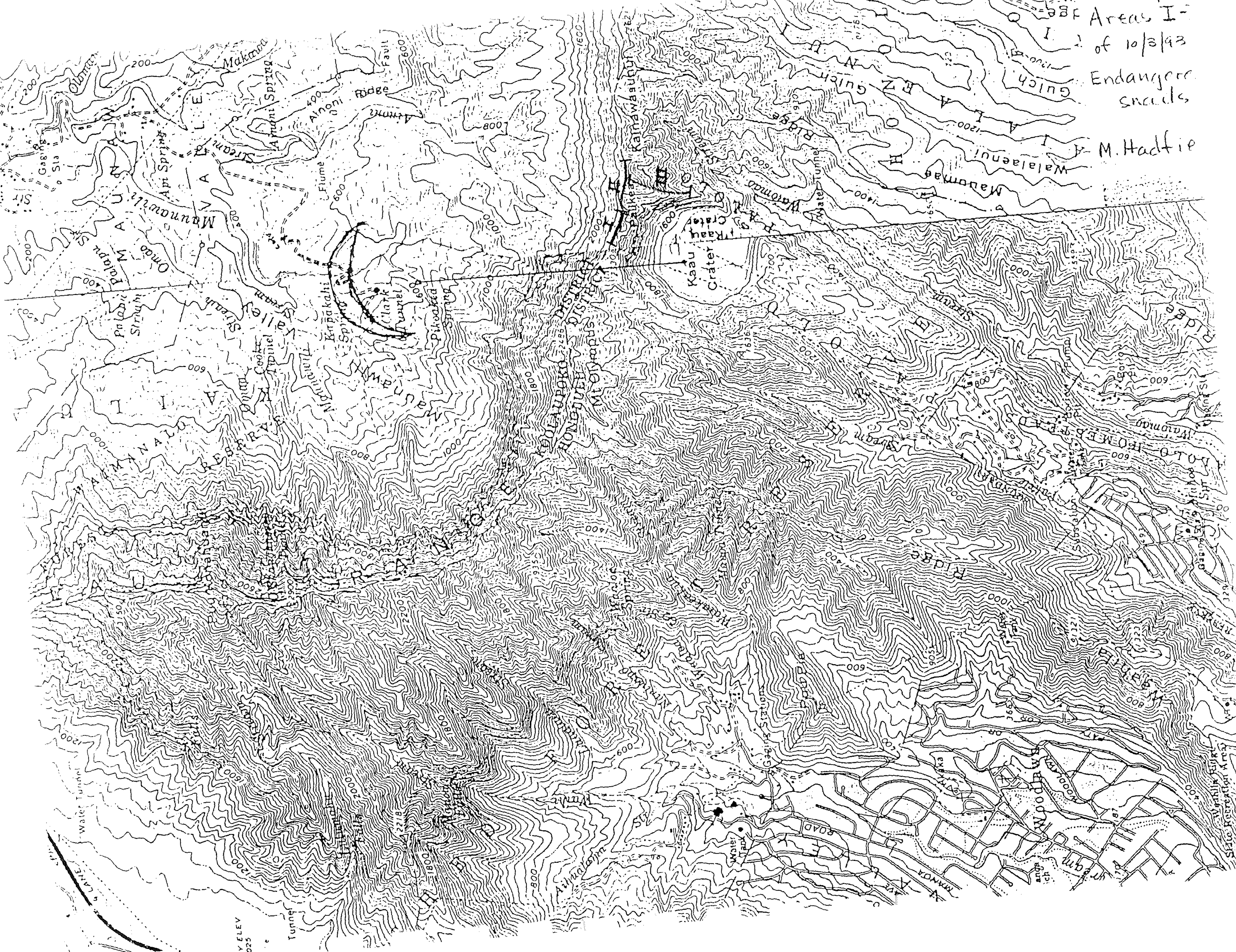
Area II: Vegetation similar to that of Area I. No native snails seen.

Area III: Vegetation includes *Pelea sp., Metrosideros polymorpha, Freycinetia arborea*, and other native species. No native snails seen.

Conclusions: While no *Achatinella spp.* were seen, very little can be concluded from this extremely limited survey. Total time spent on the ground was three hours and forty-five minutes, and the area surveyed was thus limited to a narrow band of vegetation bordering the summit trail and the descending trail to Ka'au Crater through only part of its length. A more complete survey for endangered O'ahu tree snails in this area would require three to four days on the ground, searching both the outer and inner slopes of Ka'au Crater, the patches of ohi'a (*Metrosideros polymorpha*) growing on the crater floor, and the very steep slope between the crater floor and the Ko'olau summit, especially the more western ridge between the crater rim and the summit. In addition, because there were historical populations of tree snails on the windward side of the Ko'olau Mountains in this region, for example *Achatinella phaeozona*, and because the proposed construction would disturb extensive areas on the windward slope, surveys are also necessary on the northern Ko'olau slope.

In summary, no *Achatinella* species were observed, but the survey was too cursory to determine the presence or absence of these federally endangered species in the area of Ka'au Crater. If they do occur there, the extensive construction activities proposed would gravely threaten their survivorship.

Michael G Hadfield 10/26/93
Michael G. Hadfield, Ph. D.



Areas I-
of 10/3/93
Endangere
snails

M. Hadfie

SUMMARY OF FINDINGS
BOTANICAL STUDIES

Following is a short description of the vegetation on the Ka'au Crater and Maunawili Valley sites. The scientific names used in the discussion are in accordance with the most recent taxonomic treatment of the Hawaiian flora by Wagner et al. (1990).

Ka'au Crater

A reconnaissance survey of the Ka'au Crater site was made on 03 October 1993. Transportation to and from the site was provided by helicopter.

The vegetation on the more or less level crater floor is composed of three major vegetation associations. A low, wet meadow composed of the native sawgrass (Cladium jamaicensis), honohono (Commelina diffusa), and great bulrush (Shoenoplectus lacustris) covers most of the crater floor. On the southwestern half of the crater is a low, open scrub composed of 'ohi'a (Metrosideros polymorpha), strawberry guava (Psidium cattleianum), and hame (Antidesma platyphyllum). A tall, dense thicket of strawberry guava is found on the northeastern edge of the crater. The plants form an almost complete cover over the crater floor with only a few, small pockets of open water scattered here and there. The wetlands within the crater have been described in more detail by Elliott and Hall (1977).

On the lower slopes of the crater, where the proposed inlet/outlet structure would be sited, the vegetation consists primarily of guava (Psidium guajava) thickets, dense clumps of ti (Cordyline fruticosa), and scattered patches of banana (Musa X paradisiaca).

The upper slopes and crest of the Ko'olau Mountain range are dominated by a native plant community. Low, windswept 'ohi'a and 'ohi'a ha (*Syzygium sandwicensis*), 3 to 7 ft. tall, are the most abundant trees. Common to occasional are other natives such as *Dubautia*, 'akia (*Wikstroemia oahuensis*), *Hedyotis*, at least three species of *Pelea*, uki sedge (*Machaerina mariscoides*), etc. The introduced, noxious Coster's curse (*Clidemia hirta*) is also common in the area. The proposed project is not expected to directly impact these areas dominated by native plants, some of which may be considered rare and/or vulnerable.

Maunawili Valley

A reconnaissance survey of this site was made on 10 October 1993. Access was by means of the unpaved roads which service the banana farms in the back of the valley.

Vegetation on the proposed reservoir site consists of actively cultivated banana fields on the slopes and a mixed introduced forest within the gulches that cross the project site. The introduced plants include ironwood (*Casuarina equisetifolia*), silk oak (*Grevillea robusta*), rose apple (*Syzygium jambos*), guava, etc.

A native plant community composed primarily of koa (*Acacia koa*) and the matted uluhe fern (*Dicranopteris linearis*) occurs on the steeper slopes behind the proposed reservoir.

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AN ARCHAEOLOGICAL REVIEW OF

MAUNAWILI VALLEY, KAILUA,
KO`OLAUPOKO, O`AHU
TMK; 4-02-10:01

KA`AU CRATER, PALOLO VALLEY,
WAIKIKI, O`AHU
TMK: 3-4-22: 06

KOKO CRATER, MAUNALUA,
KONA, O`AHU
TMK; 3-9-12:01

HECO PROPOSED PUMPED STORAGE HYDROELECTRIC POWER PLANT

by
Carol T. Kawachi, Archaeologist
State Historic Preservation Division
Department of Land and Natural Resources
January 1994

APPENDIX D

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report is for a preliminary study to determine the feasibility of installing a pumped storage hydroelectric power plant on the island of O`ahu. The study is being jointly sponsored by the Hawaiian Electric Company (HECO), the State Department of Business, Economic Development and Tourism (DBEDT) and the Department of Land and Natural Resources (DLNR). The Division of Water and Land Development (DOWALD) contacted the State Historic Preservation Division (SHPD) to do a literature search and archaeological fieldchecks of the proposed sites.

The proposed locations are Ka`au Crater in Palolo Valley with an associated facility in Maunawili Valley (Fig. 1). The two sites are separated by the Ko`olau Mountains and are approximately 1.14 mile (1.83km) apart, centerpoint-to-centerpoint. The other location is Koko Crater with the outlet structure to be moved just south of the Sewage Disposal (Fig. 1).

Ka`au Crater is tax map designation 3-04-22:06; Maunawili Valley, 4-02-10: 01; Koko Crater, 3-09-12:01.

The proposed site location in Maunawili Valley was visited by Carol Kawach, SHPD inter-agency archaeologist, Lou Lopez, project manager of Okahara and Associates, and George Krasnick of GS Associates on 10 November 1993. Ms. Kawachi and Holly McEldowney of SHPD Culture and History Branch, were guided to Ka`au Crater by Ted Strand, a Palolo resident, on 16 December 1993. On 17 December 1993, Ms Kawachi and Mr. Shozo Yuzawa of Electric Power Development Co., Ltd (EPDC International), the engineer subcontracted by the local consulting engineers, Okahara and Associates, did a preliminary survey west of Kalanianaole Highway south of the STP. Due to time constraints, the interior of Koko Crater was not visited.

The literature seach has been limited to archaeological reports available in the State Historic Preservation Division library. Starting from the general to the specific: Kailua *ahupua`a* is presented first, then Maunawili Valley; Waikiki *ahupua`a,* Palolo Valley, then Ka`au Crater; Maunawili *ahupua`a*, lastly Koko Crater.

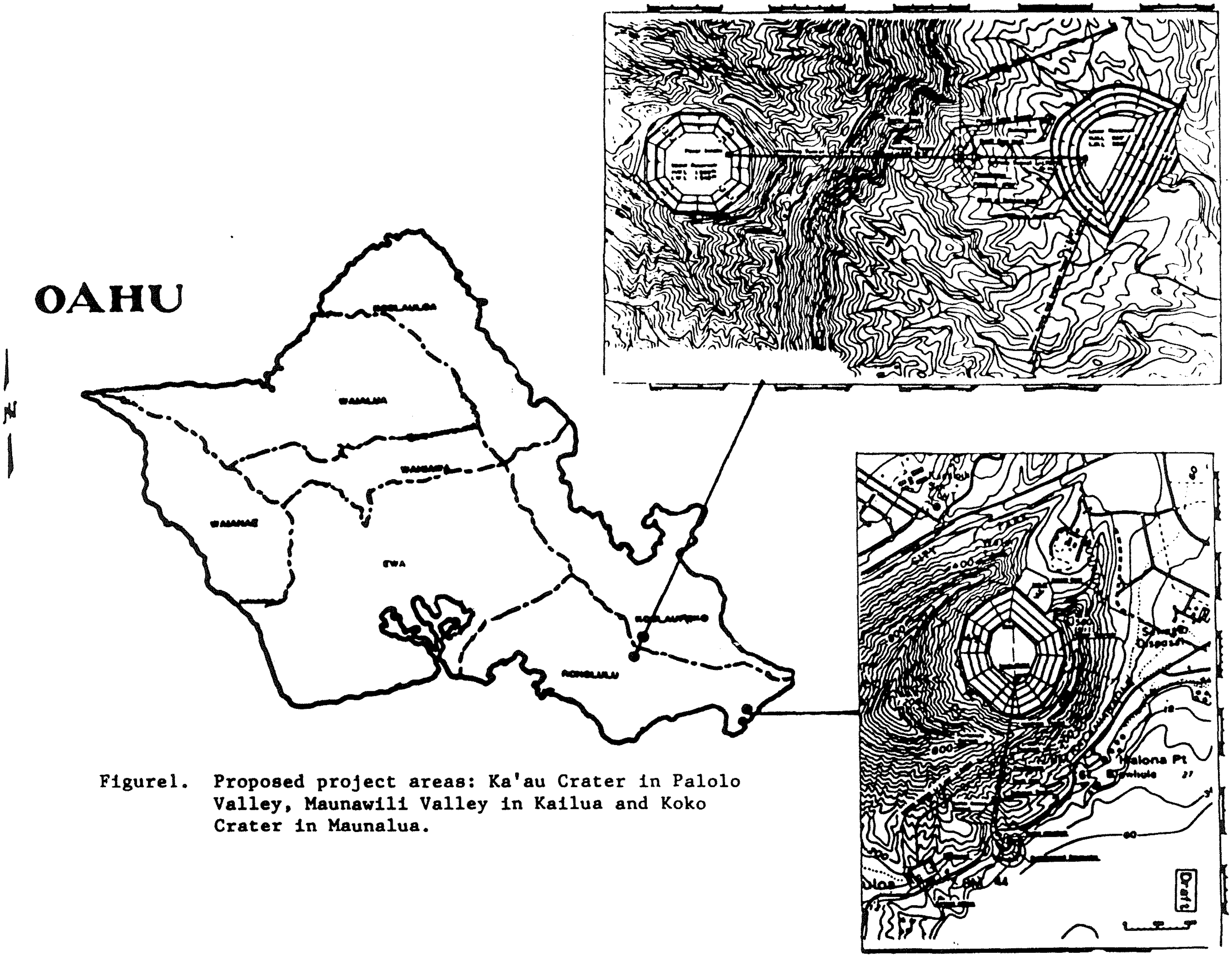

Figure1. Proposed project areas: Ka'au Crater in Palolo Valley, Maunawili Valley in Kailua and Koko Crater in Maunalua.

I. THE MAUNAWILI PROJECT AREA

Introduction

The proposed project will be located in Maunawili Valley, at the base of the Ko`olau Mountain Range, at the southwestern end of Kailua *ahupua`a*.

A. KAILUA *AHUPUA`A*

Located on the windward side of O`ahu, Kailua *ahupua`a* extends from the Ko`olau Mountains to the sea, with Kane`ohe to the north and Waimanalo to the south (Fig.2). The many streams that originate in the mountains flow through Maunawili Valley and Kawai Nui Marsh on its way to the sea. Kailua's coastline extends from Lanikai to Mokapu Boulevard (Fig. 2).

Today, Kailua is most densely populated along the coastline. Modern housing developments cover the midsection excluding Kawainui Marsh. Development is moving back into the valleys in form of housing developments and golf courses. The displaced Luluku banana farmers are farthest back in the valley.

Kailua town sits on a sand berm or accretion barrier which changed a once open bay into a lagoon. The work of Athens and Ward (1991) "suggest that the change from an open marine bay to a terrestrial wetland environment had begun prior to any possible impact from the first human settlers and was the long term result of Holocene sea level change" (Erkelens 1993:22). Occupation on the berm began sometime in the late 13th or 14th centuries (Athens 1983:32).

Referencing geomorphologist John C. Kraft, "Eventually, terrigenous sediments and soils . . . created in the Marsh floor an arable landscape that supported agriculture [taro and rice]" until the early 19th century (Allen 1991:5-6). "The pondfields in Kawainui Marsh now lie buried beneath sediments and soils that continue to fill the marsh basin" (Allen 1988:14)

Settlement on the slopes of Kawai Nui Marsh occurred "by at least A.D. 1300 [and] as early as A.D. 770" (Erkelens 1993:56) at least at Kukanono on the southwestern slope. Erkelen's work substantiates the earlier work by Clark (1980) that Hawaiians had settled around Kawainui Marsh by 1000 BP. Occupation was permanent and continuous with various habitation structures amidst small dryland garden plots.

Prehistoric Land Use

Please refer to Cordy (1977), Drigot and Seto (1982), Kelly and Clark (1980), Kelly and Nakamura (1981), and Creed (1992) for a thorough literature and map study of this

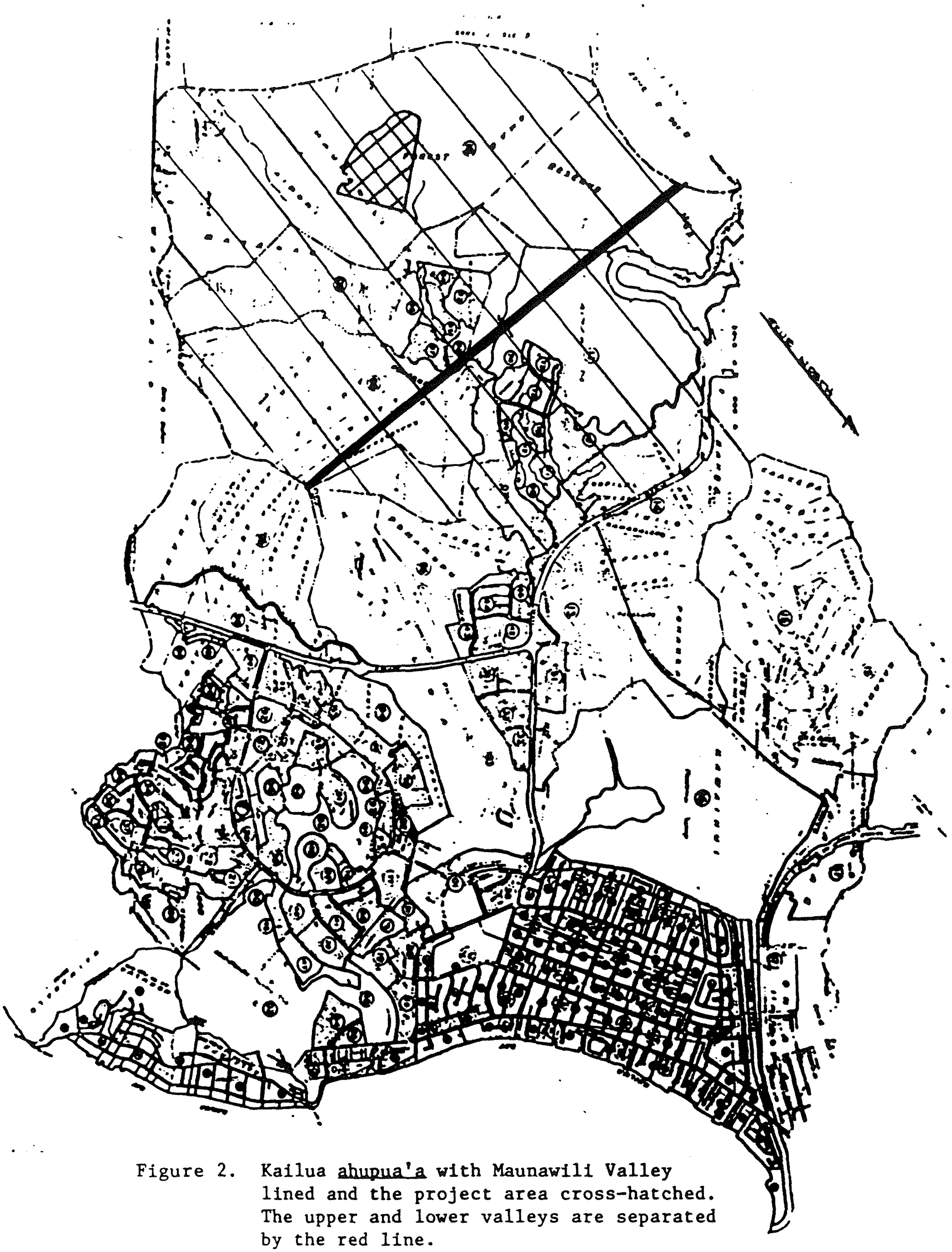

Figure 2. Kailua *ahupua'a* with Maunawili Valley lined and the project area cross-hatched. The upper and lower valleys are separated by the red line.

area. Kawai Nui Marsh and its surrounding areas to the south, east and west have been quite thoroughly investigated archaeologically as well: (Bordner 1977, 1982; Ewart & Tuggle 1977; Clark 1977, 1980; Cordy 1978; Morgenstein 1978; Dye 1979a & b; Allen-Wheeler 1981; Neller 1982a & b; Athens 1983a & b; Barrera 1984b; Watanabe 1988; Kawachi 1988; Kennedy 1990; Hammatt et al 1990; Athens & Ward 1991; Erkelens 1993).

Kailua *ahupua`a* was traditionally divided into 79 land sections called *`ili* (Office of the Commissioner . . .1929:392-397). This is a large number of *`ili* and a pattern often associated with large *ahupua`a* populations and highly productive lands (pers comm Ross Cordy).

High chiefs who have resided in Kailua included Kakuhihewa, Kuali`i (Fornander 1969:274-283), Kahekili (Kamakau 1961:138) and Kamehameha I (Sterling & Summers 1978:232). Kakuhihewa had his famous house in what is now known as Coconut Grove (Sterling & Summers 1978:229). Continued chiefly interest in these lands can be seen from land awards during the Great Mahele of 1848. Queen Hazaleleponi Kapukahaili Kalama, consort of Kamehameha III, received Kailua *ahupua`a* as Land Commission Award (LCA) 4452: *apana* 12, (Royal Patent 9783) (Office of the Commissioner . . .1929:2). She shared it with King Kamehameha III and Princess Victoria Kamamalu (Creed 1992:11). Within the *ahupua`a*, smaller land divisions were awarded to 41 high chiefs (Creed 1992:11).

The lands were highly productive. One hundred and forty-eight (148) awards were made to the *maka`ainana* (commoners) (Office of the Commissioners . . .1929: 3, 392-397). Most of these awards included cultivated lands. Irrigated taro fields were located in the valleys at the back of Kawai Nui marsh (Watanabe 1976; Cordy 1977; Neller 1982; Toenjes & Donham 1985), in the marsh (Cordy 1977), and along the edges of Ka`elepulu pond (McAllister 1933:190). Dryland fields were located along the slopes above the marsh (Cordy 1977; Ewart & Tuggle 1977; Clark 1980; Erkelens 1993; Athens 1983b) and in other drier lands (Allen 1986,1987b & c, 1988; Williams 1988). Additionally, Kawai Nui and Ka`elepulu were large fishponds (Kamakau 1961:457)).

In the 1840s, houses were present along the shore, in the Pohakupu-Kukanono slope near Maunawili (Cordy 1977:24), at the front of Kapaa valley (Creed 1992), and around Kaelepulu pond (Creed 1992). Archaeological research has found scant evidence of permanent habitation in the upper valleys.

Seven heaiu were known in Kailua (McAllister 1933:182-191). Around the perimeters of Kawai Nui Marsh are at least three heiau. Two of them are quite large (Ulu Po, Pahukini). McAllister recorded Holomakani west of Ulumawao Ridge but its exact location is unknown (1933:182).

Other heiau in Kailua were Kukuipilau, Alaala, Kanahau and Kaikipuipui. Kukuipilau, Kanahau and Kaikipuipui were on the southern and southwestern slopes of Olomana Ridge. Alaala, on the coast at Alaala Point, was where "the ceremonies attending the royal birth of Kualii,. . . , were performed" (Thrum 1916:87). Kanahau is where "Hiiaka, stopping on her way to Kauai, was for once satiated with taro tops" (McAllister 1933:190). Kaikipuipui heiau, renovated by Kamehameha I, once "crowned the small hill near the present [1933] road on the dividing line between Kailua and Waimanalo " (McAllister 1933:190).

Allen theorizes that the floodplains, beaches, protected bays, forests and stream valleys of Kailua may have been one of the earliest areas settled (A.D. 400-600) (1991:2). Early dates have come from habitation and agricultural sites along the slopes of Kawai Nui Marsh (Clark 1980; Erkelens 1993), and from Maunawili Valley itself.(Allen 1989).

Even in the post-Contact period, Kailua continued its high-valued status. High chiefs and high-status non-Hawaiians bought or leased land and lived here. There were rich food sources from the land and the sea.

B. MAUNAWILI VALLEY

For this paper, the area of Maunawili inland of Kalanianaole Highway back to the Ko`olau Range, is considered Maunawili Valley (Fig. 3). Maunawili is divided into a lower and upper valley. The lower valley extends inland from Kalanianaole Highway, includes Maunawili Marsh (now an open pasture), and extends up to to where Oma`o Stream meets Maunawili Stream or at the junction of Aloha Oe Drive and Maunawili Road. The lower valley is a relatively flat area dominated by Maunawili Estates housing development. Here the valley floor is ca. 2500 feet (762m) wide.

The upper valley extends inland from the junction of Aloha Oe Drive and Maunawili Road in Maunawili Estates. Beyond this modern housing development, there are very few homes amidst the hills and stream valleys. The proposed project area is in the upper valley just inland of the Hawaiian Sugar Planters Association experiment station (Fig. 3).

Maunawili *`ili* is nestled between Ainoni *`ili* on the east and Oma`o *`ili* on the west (Fig. 4). Their combined boundaries to the top of the Ko`olau Range form Maunawili Valley, "really a series of valleys carved by all the tributaries [Oma`o, Ainoni, Makawao, Olomana] to Maunawili Stream" (Allen 1988:14). Mean annual rainfall in the back of the valley is 118 inches (3,000mm) (Giambelluca et al 1986:138).

The project area is at the base of the Ko`olau Mountain Range at the back of Maunawili Valley, covering approximately 45 acres (18.2ha), and cutting across four tributaries to Maunawili Stream (Fig. 3), approximately 6 miles (10km) from the coast.

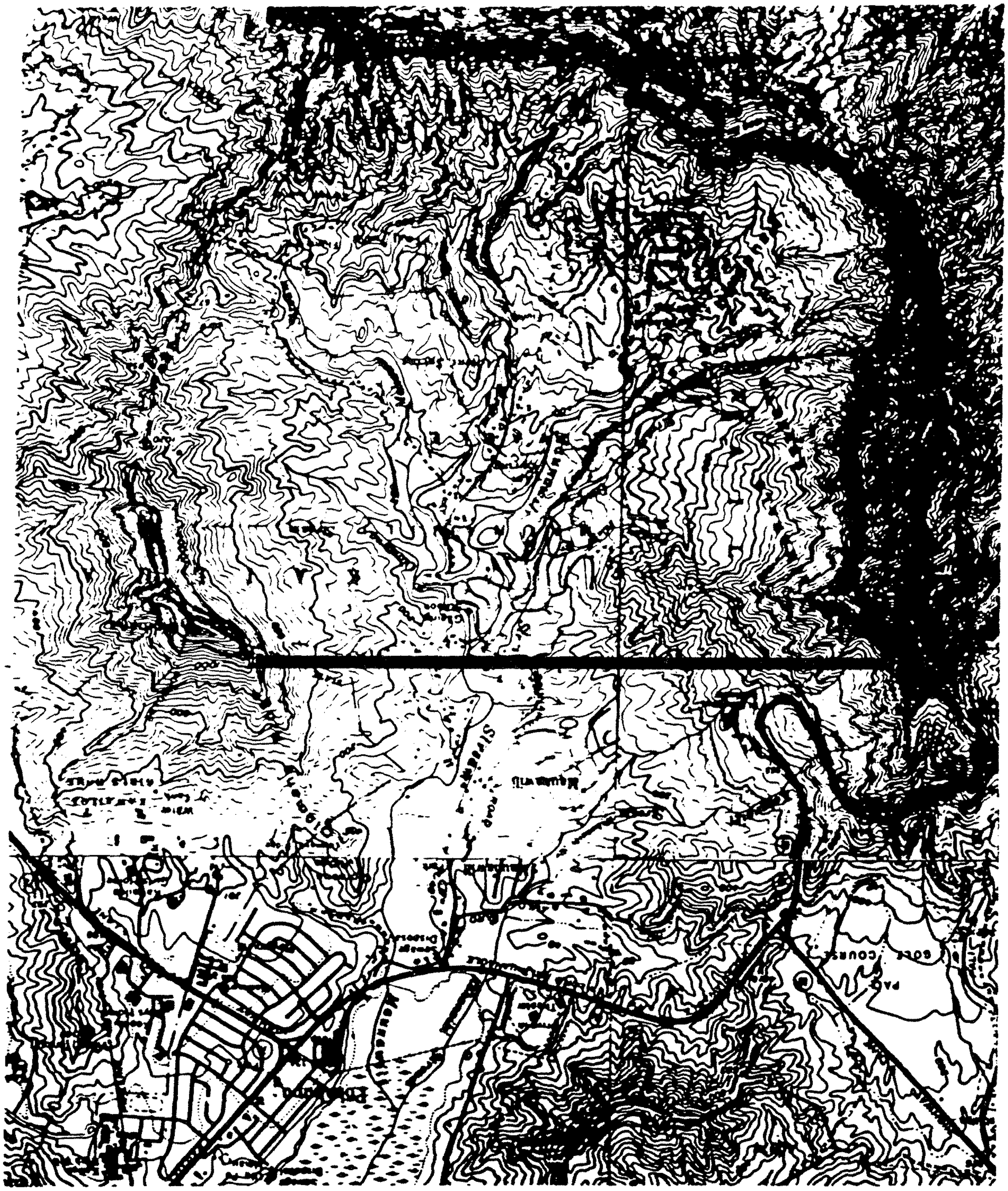

Figure 3. The traditional <u>'ili</u> of Maunawili is outlined in green. The project area is in yellow. The upper and lower valleys are separated by the red line.

This area was formerly Forest Reserve land which was reforested during the 1920s by the Territory of Hawaii (Williams 1988:8). Small truck farms were also here between the late 1920s to the mid 1960s, growing banana, papaya, ginger and sweet potatoes (Williams 1988:12). Vegetation, therefore, varies from areas reforested to those once under cultivation.

A ditch and tunnel system constructed since the 1890s transports water from Maunawili to drier Waimanalo (Stearns and Vaksvik 1935:411-415).

Prehistoric Land Use

Only three small Land Commission Awards were made in Maunawili during the Great Mahele of 1848 (Office of the Commissioner . . . 1929:396): The Foreign Testimony given for Kuheleloa (LCA 4248-B) described two parcels: one consisted of 14 taro patches bounded on two sides by upland and the other two sides by the lands of Kaiole and Waipunalei (14:206). His houselot was bounded on all sides by upland. Pohuli's (LCA 6164) claim in the Native Register (5:251) describe only a *mo`o*, and a *kula*. This information suggests wet and dryland agriculture. Mokulehua's claim (11294) was in neither the Registers or the Testimonies. It is not known exactly where these *kuleana* were located. Wall's 1894 map (Reg Map 2050) does not show any *kuleana* in Maunawili *`ili*.

During the early post-Contact period, the following crops were grown in Maunawili in addition to taro: breadfruit, sweet potatoes, gourds, arrowroot and fruit (Native Register and Testimonies).

Since 1930, approximately twenty archaeological surveys have been reported in Maunawili Valley. Only two were done in the lower valley. The pattern in the lower valley was pondfields on the valley floor with dryland agriculture and habitation sites on the slopes (Allen 1986, 1987a, 1988).

Forty-percent of the proposed project area has already undergone archaeological inventory survey (William 1988; Mills & Williams 1991) in preparation for the relocation of the Luluku banana farmers displaced by the construction of H-3 (Fig. 4). Table 1 describes the sites in the project area. Most of the sites recorded in the narrow upper valleys were associated with agriculture, both irrigated and dryland (Table 2). The pondfields or irrigated systems, near streams or springs, ranged from very small systems across rivulets to a large complex of terraces on both sides of Maunawili Stream. Dryland agricultural fields were in the form of terraces and mounds (Allen 1987b &c, 1988; Williams 1988). In some cases, both irrigated and non-irrigated fields were in the same complex (Allen 1987b, 1988). Kukapoki heiau was the only heiau identified and it overlooked a large complex of terraces along Maunawili stream, suggesting the heiau was probably an agricultural heiau.

Dating indicates "Extensive terracing of hillslope lands became standard practice . . . in Maunawili by A.D. 1300-1400" (Allen 1991:11) and irrigated taro or valley flats dated

BANANA FARMERS' RELOCATION
PROJECT AREA,
UPPER MAUNAWILI, O'AHU

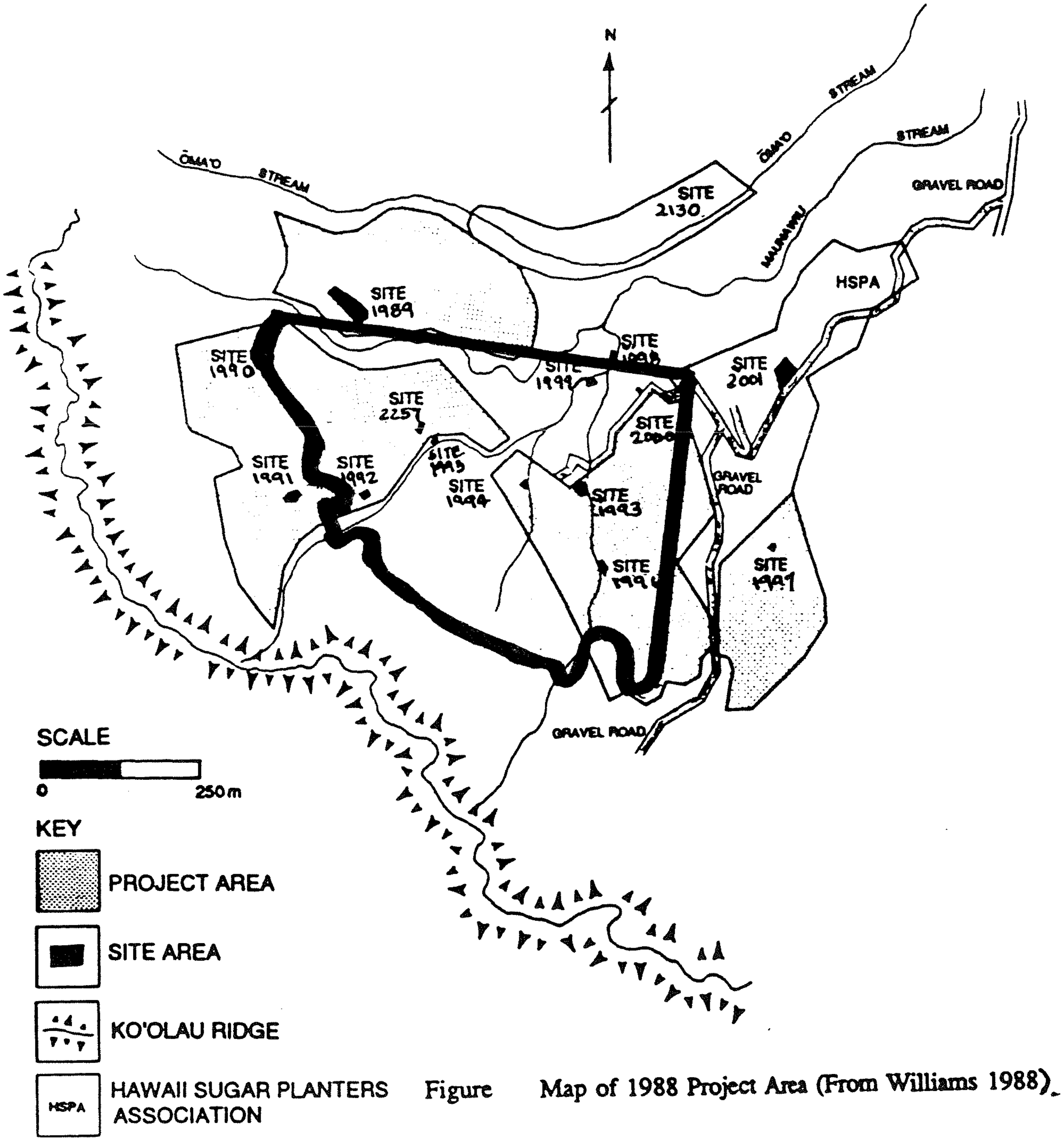

Figure Map of 1988 Project Area (From Williams 1988).

Figure 4. Proposed project area outlined in red. Shaded areas surveyed by Wiliams (1988). Taken from Williams 1988.

Table 1. Archaeological Sites in the Project Area

			Contact		
State #	Description	Location	Pre-	Post-	Reference
1989	60-70 rock mounds	upper valley, N of Maunawili			Wms 1988
1990	split-level terrace, 18 mounds: dryland ag	upper valley, S of Maunawili		x	Wms 1988
1991	30 mounds, 6 terraces, 7 other	upper valley, uppermost			Wms 1988
1992	4 mounds,alignment	upper valley, along stream	AD 1260-1420		Wms 1988
1993	cut banks, stone alignment	road junction' outside		x	Wms 1988
1994	1 terrace facing	marshy flat			Wms 1988
1995	housesite	upper valley		x	Wms 1988
1996	6 irrigated terraces	upper valley	AD 1270-1430	x	Wms 1988
1997	3 terrace remnants	Riley type 1, W of Ainoni			Wms 1988
1998	ag complex: retaining wall terrace remnant rock mound	upper valley, W of Ainoni	x	x	Wms 1988
1999	pecked inscription	Maunawili Falls, outside		x	Wms 1988
2000	irrigated terraces	outside	x		Wms 1988
2001	privy	outside		x	Wms 1988
2257	alignments	HSPA bananas outside		x	Wms 1988

Table 2. Archaeological Sites in the Upper Maunawili Valley

Survey	Survey Level		Land Use	
	I	M	pre-contact	post-contact
McAllister 1930	x		religious	
Allen 1986	x	x	habitation, dryland agricultural complex	habitation
Allen 1987a	x	x	dryland agriculture, lithic wkshp, perm hab (390 ± 100 BP)	temp hab
Allen 1987b	x	x	irrigated & dryland ag, prob perm hab (AD 1400-1500)	perm hab, road, charcoal preparation pit, charcoal kiln
Allen 1988	x	x	religious, irrigated terraces	coffee mill, pig-pen
Williams 1988; Mills & Williams 1992	x		dryland ag (mounds, terraces) complex; pondfield terraces	dryland ag complex; pondfield terraces
Hammatt & Shideler 1991	x		dryland ag terraces; temp hab; irrigated terraces	road, charcoal kiln
Allen 1992	x		lithic manufacture, temp/perm hab	

KEY: I Inventory
M Mitigation

back to A.D. 1200-1400 (Mills & Williams 1992:89-91; Cordy in press) It is suggested, however, that Maunawili may have been "experiencing widespread agriculture earlier than the limited data suggest" (Mills & Williams 1992:98).

Williams cautions against depending solely on surface features for locating pre-Contact sites in Windward areas (Mills & Williams 1992:94). An important subsurface habitation site was uncovered only after the vegetaton had been removed by mechanical means. Based on the evidence of subsurface imu and lithic scatters, Mills and Williams suggest a model of small temporary habitations associated with dryland agriculture in the upper valley (1992:96)

Of the two pre-contact habitation sites found in the lower end of the upper valley, one was permanent, the other was temporary. All other (5) house sites were of the historic period. Allen notes that this paucity of pre-contact habitation sites in the intensively cultivated areas is similar to that of Kane`ohe to the north. The paucity of pre-Contact habitation sites suggests that the well-watered backlands were used almost exclusively for cultivation.

There is no indication of high-status chiefly presence in the upper valley. It is likely that only commoners farmed and worked the fields.

Predictive Site Pattern

Should planning for this project proceed, sixty percent of the project area will need an archaeological inventory survey (non-shaded areas of Figure 4). The types of sites likely to be found include agricultural sites with pondfield terracing in the stream valleys, and dryland terraces and mounds in the drier areas, along with lithic and charcoal manufacturing sites and subsurface habitation sites.

II. The Ka`au Crater Project Area

Introduction

The proposed project element in Ka`au Crater is located in Palolo *a`ili* in the *ahupua`a* of Waikiki in the traditional district of Kona (Fig. 5). Ka`au Crater is located on the south side of the Ko`olau Mountain Range across from Maunawili Valley. Ka`au Crater, only about a mile (1.6km) away from the nearest home, is accessed by a trail on the ridge or from Wai`oma`o Stream. It is approximately five miles (8km) northeast of Diamond Head.

This section of the paper first looks briefly at the *ahupua`a* settlement patterns and then at the patterns of the project area at Ka`au Crater.

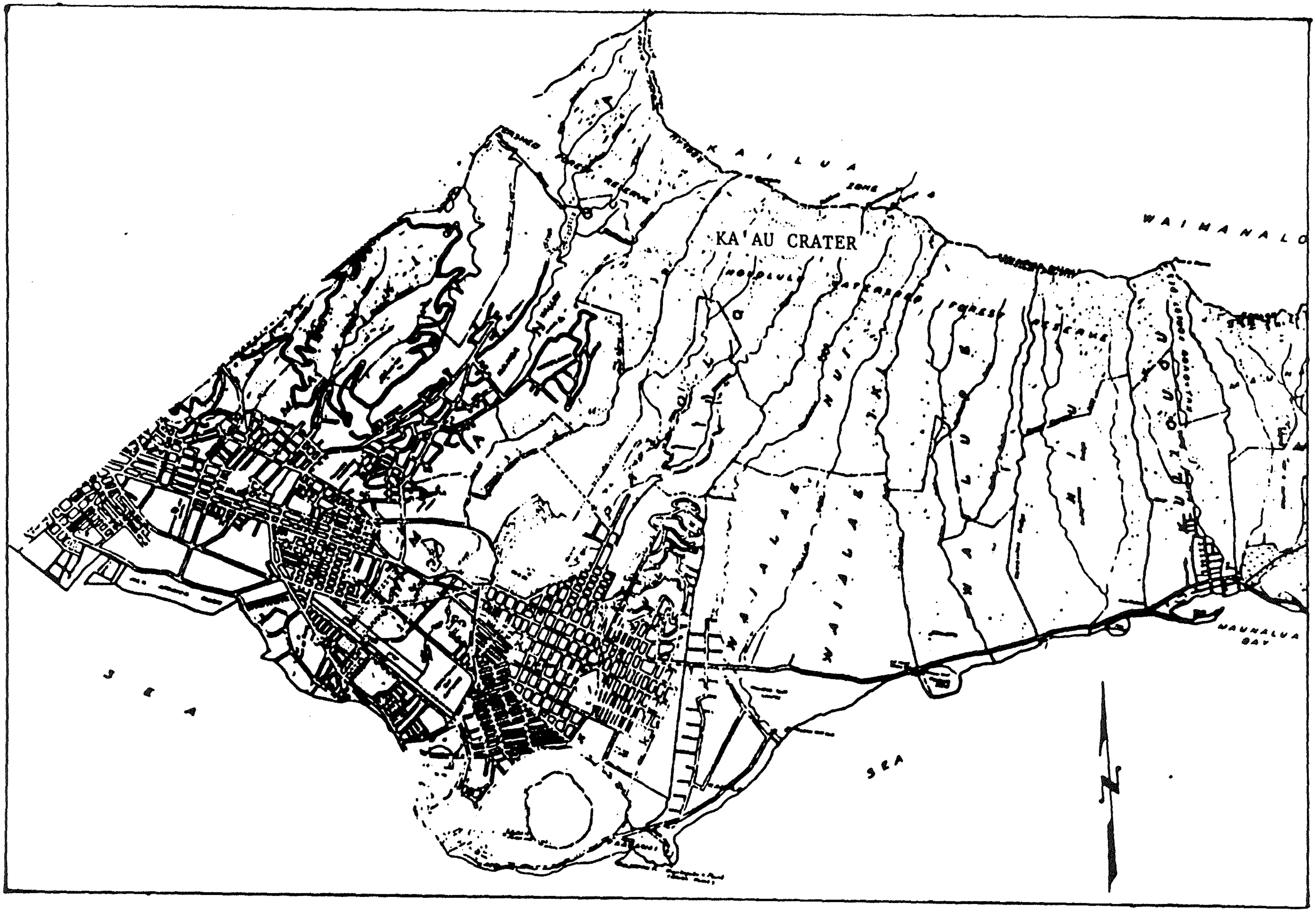

Figure 5. Waikiki <u>ahupua'a</u> from Manoa to Kuli'ou'ou. Ka'au Crater is in back of Palolo <u>'ili</u>.

A. WAIKIKI *AHUPUA`A*

Waikiki *ahupua`a* traditionally extended from Round Top to the ridge east of Kuli`ou`ou Valley (Hawaiian Studies . . . 1987). Within the *ahupua`a* are the valleys of Manoa, Palolo, Wai`alae, Wailupe, Niu and Kuli`oul`ou (Fig. 5). The area today known as Waikiki is actually in Manoa *`ili.*

Environment

Waikiki *ahupua`a* is made up of two major valleys (Manoa, Palolo) and seven minor ones (Pia, Kupaua, Kuli`ou`ou, Wai`alae, Kapakahi, Wailupe, Kulu`i) and seven ridges (Round Top, Wa`ahila, Kalaepohaku, Mau`umae, Wiliwilinui, Hawaii Loa, Kulepeamoa). It includes Ka`au and Diamond Head Crater.

It has rainforests, sandy beaches, coastal plains, high ridges and open valleys. Manoa and Palolo have permanent streams. The smaller valleys have at least one stream, albeit, an intermittent one. East of Wai`alae, the valleys and ridges do not extend inland more than three miles(4.8km) from the coast, and range from 0.3 to 2 miles (0.5 to 4.8km) width at the coast.

Settlement Patterns of the *`Ili*

Waikiki *ahupua`a* encompassed several *`ili* land units: Manoa, Palolo, Wai`alae, Wailupe, Niu and Kuli`ou`ou. Information on the various *`ili* will be uneven due to the limited archaeological and historical information available.

In the following, I will use the term Waikiki in its modern usage, i.e., the coastal area between the Ala Wai Canal on the west extending to Kapahulu Avenue on the east, bounded by Ala Wai Canal on the north and by the sea on the south.

Manoa *`Ili*

Manoa *`ili* is made up of Manoa valley (upper Manoa) and Waikiki with Mo`ili`ili in between. There has basically been no archaeology in Mo`ili`ili or McCully.

In Manoa Valley, `Aihualama, Waihi, Lua`alaea, Naniu`apo, Wa`aloa and Waiakeakua Streams come together at Waakaua Street and become Manoa Stream. Manoa Stream flows down the east side of the valley to meet Palolo Stream just above Wai`alae Avenue before flowing down the Manoa-Palolo Drainage Canal, to Ala Wai Canal and to the sea.

The Mahele land records document taro pondfields, dryland taro, sweet potatoes, house lots, and *kula* in Manoa (Grune 1992:Fig 8). The pondfields covered the valley floor along the streams with sweet potatoes growing on the nearby slopes. In the 1930s there was still about 100 terraces of wetland taro still planted (Handy & Handy 1972:480).

Today, only scant evidence such as agricultural terraces and mounds remain of this once extensive cultivation (Kawachi 1988; Smith 1988). Close to the mouth of the valley, excavation in *Kapapa Lo`i* o *Kanewai*, uncovered buried *`auwai* (irrigation ditches) (Buchard 1992).

Houselots were located on dry areas near the fields (Grune 1992).

Burial remains have been found in hillside caves and in burial pits on the valley floor (Bath 1989; Smith & Kawachi 1989, Bath & Kawachi 1990; Hammatt & Shideler 1991, Kawachi 1991; Dagher 1993).

From Mo`ili`ili to the shore at Waikiki was a huge taro pondfield system watered by canals leading off of Palolo and Manoa streams (cf Vancouver 1801; McAllister 1933; Sterling & Summers 1978; Nakamura 1979; Grune 1992). The seaward part of this system led into fishponds (Handy 1971: 74-76). In 1788-89,." . . some had fish, others turtle" (Meares in McAllister 1933:76). "Most of these fish belong to the chiefs, and are caught as wanted. The ponds are several hundred in number and are the resort of wild ducks and other water fowl" (Bloxam in McAllister 1933:76). In 1901, there still were "14 fishponds in use at Kalia and Waikiki . . . .those at Waikiki were fresh-water ponds" (Cobb in McAllister 1933:76).

On the coastal sand berm many house sites were present (cf Grune 1992) and associated burials (cf Davis 1991). Coastal Waikiki was one of the ruling centers of O`ahu, from the time of Ma`ilikukahi (ca 15th or 16th century) to Kamehameha (ca. 1805) (cf Fornander 1969 II:89; Kamakau 1961, 1992). Thus many features of the court were present - from gaming areas to the large sacrificial heiau of Papaenena and Apuakehau (McAllister 1933:71-76).

The readers are directed to Davis's (1991) work in which he summarizes archaeological investigations in Waikiki over the past 10 years. Suburface excavations have unearthed walls of buried fishponds, prehistoric and early historic habitation deposits, and human and animal burials (Neller 1980, 1981, 1984; Davis 1981, 1984, 1989a & b, 1991; Griffin 1987; Simons 1988; Bath & Kawachi 1989; Riford 1989; Rosendahl 1989a & b; Kennedy 1991; Hurlbett, Carter & Goodfellow 1992; Streck 1992; Pietrusewsky 1992a & b).

On the Waikiki side and at the base of Diamond Head, Papaenaena heiau (site 58), a large *po`okanaka* heiau, used by Kamehameha I in 1804, was in ruins by 1822 and totally demolished in 1856 by Kanaina (McAllister 1933:74). A very small remnant was seen in 1989 by the author. There were also two other *pookanaka* class heiau (Apuakehau Kapua), and two others of unknown class (Kupalaha near Papaenaena and Halekumukaaha), which McAllister was unable to locate (1933:76-78).

Palolo *`Ili*

Palolo *`ili* includes Palolo Valley, Kaimuki, Kapahulu, and Diamond Head. Pukele and Wai`oma`o Streams meet at Palolo Elementary School just above Kiwila Street and become Palolo Stream. Palolo Stream flows through the middle of the valley before it turns west to meet Manoa Stream.

The Indices of Awards . . . (1929) list thirty (30) Mahele awards granted in Palolo. An 1881 monarchy map (Reg Map 906) shows 69 land parcels included in these awards document and indicate an average of 12.2 fields per individual. All of the small awards were inland of Paku`i Street between what is now Palolo Avenue on the west and 10th Avenue on the east. There were some farther inland along Wai`oma`o Stream up to about Halelaau Place. In 1930, some of these taro terraces were still evident (Handy 1971:74).

Only seven awardees claimed houselots (Luahiwa LCA 1646; Keaka LCA 1653; Upepe LCA 1656; Kawaihae LCA 1761; Paele LCA 1842; Lioe LCA 1845; Mahana LCA 1896). Only two houses are shown on the 1881 map (Reg Map 906) and they are mid-valley.

Palolo Valley has had only limited archaeology. A *pookanaka* class heiau, Maumae heiau, was described by Thrum as being in Palolo (McAllister 1933:196). Mauoki heiau (site 62), as described by Thrum, was at the foot of the ridge between Manoa and Palolo (McAllister 1933:78). A heiau was said to be located where the Diamond Head lighthouse now stands (McAllister 1933:74).

Burials in caves along the slopes have been found in Palolo (Kennedy 1987; Kawachi 1989). On the coast by Kapiolani Park and continuing eastward, human remains have been found (Emerson 1902; Neller 1984; Bowen 1963; Cleghorn 1933; Dagher 1993; Dega & Kennedy 1993) all the way to Diamond Head beach park. The sewage project along Diamond Head road just inland of the lighthouse uncovered historical artifacts and charcoal (Mullins et al 1993).

Wai`alae *`Ili*

Wai`alae is named for a spring which "supplied water for the chiefs from olden times" (Pukui et al 1976:220).

The Mahele land records document that Wai`alae iki was was awarded to Abner Paki, father of Bernice Pauahi Bishop (Office of the Commissioners . . . 1929:23).

According to Nagaoka, there were both taro pondfields and dryland taro in Wai`alae *`ili* (1985:11). The broad coastal flats were also planted with hala, coconut, orange, coffee, breadfruit and kou trees, dotted with fishponds and saltponds/bed (Bishop Estate Map, No. 718B, 1920 in Nagaoka 1985).. Of twenty-five awardees, 17 claimed houselots, mainly along the coast (Nagaoka 1985:11-14).

There was a very large heiau, Kaunua Kahekiki, located on top of the ridge which divides Wailupe and Waialae ((McAllister 1933:71).

Burials have been found along the sandy shoreline (Griffin 1987; Bath 1988, 1989; Kawachi 1989).

Wailupe *`Ili*

Wailupe's coastal plain at the mouth of the valley is known today as `Aina Haina (Hind's Land), "named for Robert Hind, who started the Hind-Clarke Dairy there in 1924" (Pukui et al 1981:7).

According to the Mahele land records, there were house lots mostly along the coast, *kula*, a taro pondfield, fishponds, plantings of gourds, orange, coconut, hala trees, sweet potatoes and [pili] grass on the coastal plain (Ogata 1992:Appendix I).

Wailupe peninsula was once a fishpond before it got filled in and turned into a residential neighborhood.

Burial caves and pit burials have been found near the shoreline (Sterling & Summers 1978: 71; Kawachi 1991, Ogata 1992).

A *pookanaka* class heiau, Kawauoha, not located by McAllister (1933:71) was thought to have been on the west ridge of the *`ili* (Ogata 1992:15).

Niu *`Ili*

Niu Valley is actually two valleys formed by the joining of Kupaua and Pia Streams at the front of Kulepeamoa Ridge. There is no listing for Niu in the Mahele records. Following the pattern of similar valleys, the coast was probably where most inhabitants lived.

Handy thought "the marshy land on the flats above the highway" where the streams met might once have had taro terraces (1940:74).

Kamehameha I once had a summer home here in Niu and Kupapa fishpond was once a part of his 2,446 acre estate (Sterling & Summers 1978:273). Kupapa Fishpond was already filled in when seen by McAllister in 1933 and today is simply known as Niu peninsula or beach.

At the front end of the ridge was Kulepeamoa, a large stepped- terrace heiau (McAllister 1933:70).

Burials have been found in caves and on the coastal plain (Erkelens 1992).

Kuli`ou`ou *`Ili*

Kuli`ou`ou, the easternmost *`ili* in Waikiki *ahupua`a*, has its stream flowing on the east side of the valley. There is no listing for Kuli`ou`ou in the Mahele records. As with similar valleys in this *ahupua`a,* it is likely that the main body of habitation was on the coast.

Paiko Lagoon may once have been a fishpond.

Only a corner of a large terrace and old coral pieces were all that McAllister found of what may have been a large heiau on the western side of Kuli`ou`ou *`ili* (1933:70).

Three rock shelters (Makanaiolu, Kawekiu, Kuli`ou`ou) at the front of the valley have been excavated (Emory & Sinoto 1961). The last was believed to have been first occupied about 1000 years ago (Emory & Sinoto 1961).

Kuli`ou`ou was where Kamehameha III "retired with his court for the summer." There was `Elelupe pool which "no one but the king dared touch or pollute that water" (Takemoto et al 1975:23-24).

Summary

The valley floors of both Palolo and Manoa Valleys were once extensively cultivated in taro pondfields. The streams from both valleys met and watered the large pondfield system and fishponds between Mo`ili`ili and Waikki. From Wai`alae to Kuli`ou`ou, there were only intermittent streams. The agricultural pattern was mainly dryland agricultural on the coastal plains with taro pondfields along the flowing streams. Each *`ili* had a fishpond. Some had terraces but what specific crop was being cultivated is unknown. Dryland taro was cultivated where there was sufficient rainfall. Sweet potatoes and other crops were also cultivated on the broad coastal plain.

Palolo and Manoa *`ili* held large populations, with many on the shore and others scattered inland. The numbers of awards and early census data indicate the larger populations of these *`ili.* The small valleys to the east seem to have had much smaller populations based on Mahele data with most living on the shore.

The shore of Waikiki was a royal residential center from the 15th and 16th century to the early 19th century. The *ali`i* lived on the coast with large *pookanaka* class heiau on the slopes of Diamond Head and on the shore. The smaller valleys to the east may have had high-ranking chiefs and overlords as residents for each had a large heiau and a fishpond. In turn, this pattern suggests that these small *`ili* may have once been *ahupua`a* themselves.

Predictive Site Patterns

The settlement pattern for the *ahupua`a* would be habitation, fishpond and saltpond remains along the shore with terraces along the streams and sweet potatoe mounds scattered on the coastal plain. ,

III. The Project Area at Ka`au Crater

Introduction

Ka`au Crater is located in the back of Palolo Valley, in Palolo *`ili*. Palolo Valley extends inland from Wai`alae Avenue back up to the mountain ridge. Mount Olympus and Kainawaauika are the boundary peaks along the mountain range. Ka`au Crater is situated approximately midway between the two peaks and midway between the origin points of Pukele and Wai`oma`o Streams.

Environment

The crater is "almost always in the clouds, and hence derives much of its water from fog drip as well as rainfall" (Shallenberger 1977:230). The annual rainfall amounts to 100 to 450 inches [2540 to 11430mm] (Foote et al 1972:27).

"The flat bog on the crater floor is densely vegetated with grasses, bulrush, hau, ohia, strawberry guava and other shrubs. The crater floor is nearly 1500 feet [457m] across, but less than two percent of the bog was actually open water at the time of the survey [17 August 1977]" (Shallenberger 1977:230). "In these areas the water table is at or near the surface. . . . " (Foote et al 1972:27).

The following was taken from a wetlands and wetlands vegetation study done in 1977:

> "The most extreme form of disturbance occured soon after 1900 when Honolulu hydrologists built an earthern dam at the crater's only outlet, in the hopes of creating a large reservoir for city water supply. This dam, located at the northeastern corner of the crater, caused extensive flooding and destruction of native forest (Andrews 1909). Within a few years, however, the dam had partially broken and most of the reservoir waters had leaked out" (Elliott and Hall 1977:112).

Historic Site Information

The crater itself is clearly a traditional cultural place. The crater was supposedly hollowed out by Maui's fishhook after freeing itself from the boulder Pohaku o Kaua`i (Sterling & Summers 1978:277). Another legend tells of a supernatural rooster, Kaau-helu-moa, who in a fight with Kamapuaa, fell into and died in the spring. The spring is now named Kaau-helu-moa. The water is suppose to appear red from his blood (Sterling and Summers 1978:277). Mr. Strand, our guide, did note that the water flowing out of the crater is red. Informants told him that the crater mud had healing powers. Other accounts state "This was once the site of a natural lake, said by the Hawaiians to be unfathomable" (Nakuina 1905). "Fish were raised [in the lake] for the ancient valley chiefess" (Elliott and Hall 1977:112).

No archaeological survey has been done in the crater although McAllister did record it in 1933 (1933:71). It does not appear, however, that he actually saw it.

The following was told Mr. Strand by a Mr. Horace Akamine, now deceased, who was once a Revenue agent. The crater slopes had once been entirely planted in ti for the making of *okolehao* during Prohibition. Remnants of this activity in form of corrugated iron, bottles, tin cans, and large pits (*imu*) have been observed by Mr. Strand. However, he has never seen rock walls or structures which might be associated with earlier Hawaiian use of the crater.

Ka`au Crater is included in LCA 5931:4, awarded to Iona (Jonah) Pehu,an officer to Kamehameha prior to 1812 (Ii 1959:121) and servant of Liholiho (Probate 1095 1st CC; 1851), who became the land agent for Honolulu under Kuakini (Kamakau 1961:303).

Summary

There is no archaeological information on the crater so an archaeological inventory survey would be needed for planning. It is not likely that habitation or agricultural remains would be found on the floor of Ka`au Crater, which is presently a marsh.

Oral accounts clearly show that the crater and its spring are traditional cultural places. Both would be significant for their traditional cultural significance. This fact might be a constraint for the project.

IV. The Koko Crater Project Area

A. MAUNALUA

Today, Maunalua is the easternmost area in Honolulu District (Fig. 6) but traditionally, it was a part of Ko`olaupoko District, an *`ili* of Waimanalo *ahupua`a*. The modern name of Maunalua is Hawaii Kai, so named by Henry J. Kaiser who developed the area in the 1960s.

Maunalua is roughly triangular shaped with Koko Crater, Makapu`u Point and Pu`u O Kona as apexes. It is approximately 5 miles (8km) on the southeastern shore, 4.5 miles ((7.2km) on its western side and 4.7 miles (7.6km) along the Ko`olau Range.

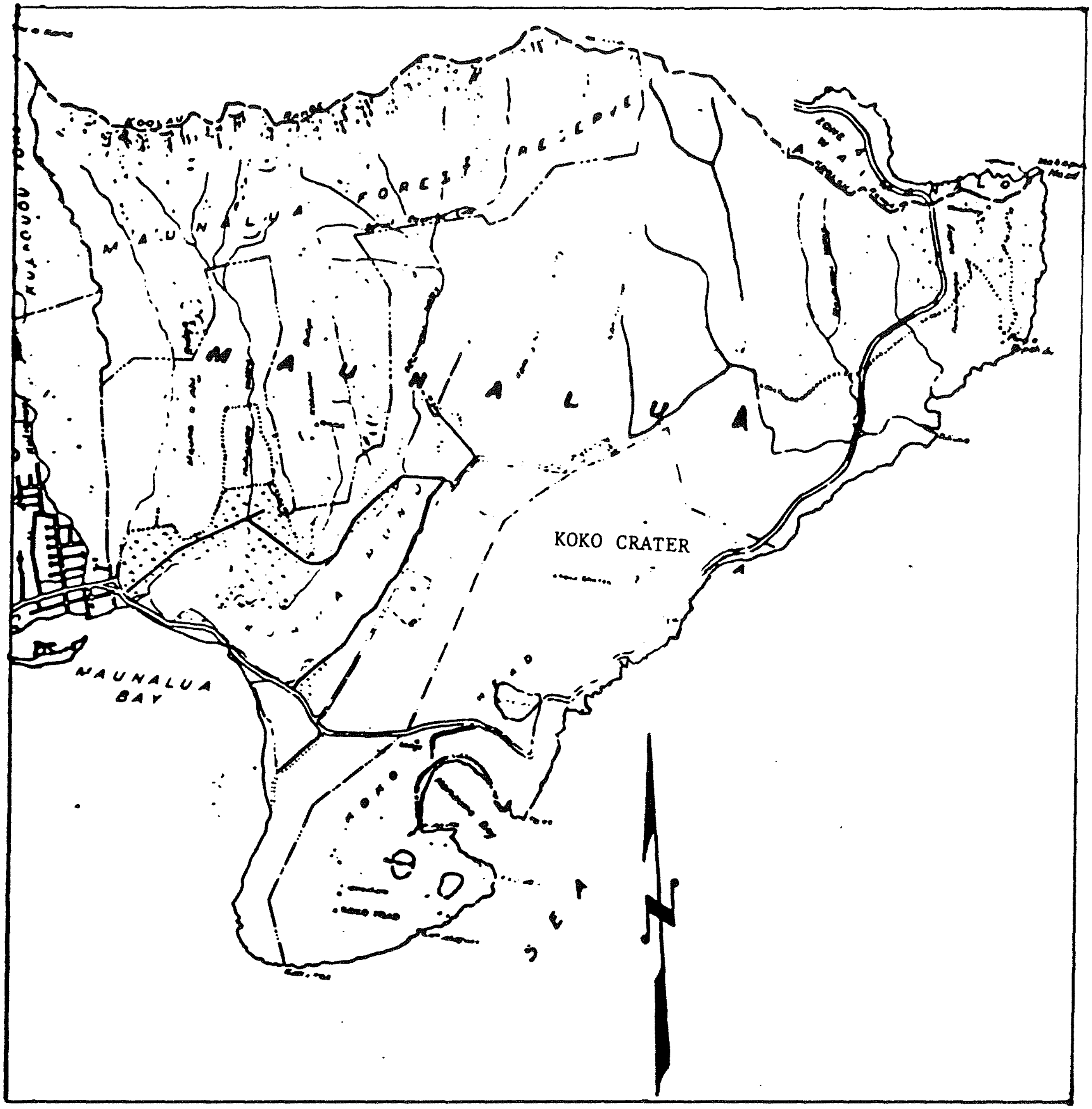

Figure 6. Maunalua <u>ahupua'a</u>. Koko Crater is on the east coast.

Environment

Maunalua includes Kaaiakei, Haha`ione, Kamilonui, Kamiloiki, Kalama Valleys and Mauna o Ahi, Kaluanui, and Kamehame Ridges (Fig. 5). Koko Crater is located at the eastern end of Maunalua with Koko Head or Mookua o Kaneapua and Hanauma Bay to the south. Koko Crater was known to the Hawaiians as Kohelepelepe.

The intermittent streams that flow out of Kaaiakei, Haha`ione, Kamilonui Valleys and Kaluanui Ridge all flow into Kuapa Pond. The intermittent streams from Kalama and the unnamed valley to the east appear to flow into a drainage which once reached the sea at Queen's Beach. Rainfall is about 3 to 4 inches (800 to 1000mm) annually (Giambelluca et al 1986:138).

The soils in the area range from exposed rock, sand and fill land, well drained soils, clay loam, extremely stony clay and coral outcrops (Foote et al 1972: maps 67-68.)

Historic Site Information

No *kuleana* were awarded to commoners in Maunalua during the Great Mahele. But in 1855 and 1880, 38 households were living here (Takemoto et al 1975:25).

In 1933, an archaeological inventory survey by McAllister found permanent house sites in the form of surface stone structures or subsurface layers in the sand northeast of Sandy Beach, Wawamalu Beach, on the eastern side of Kalama Valley mouth; at Hahaione Valley mouth, and at Kahauloa Crater (McAllister 1933:59-68). More recently, house sites have been found on Kaluanui ridge (Price-Beggerly & McNeil 1985)

Burials have been found in caves (McAllister 1933:66; Kam 1985; Price-Beggerly & McNeil 1985), on the slopes of Koko Crater and on the sandy shore (Kawachi & Smith 1990).

McAllister recorded only two small heiau in Maunalua: Pahua, a small, agricultural type heiau and Hawea, a terraced and paved structure (1933:65-66). A probable heiau in the back of Hahaione Valley was bulldozed in 1972 (Tuggle 1972).

Extensive sweet potato patches were found on the eastern side of Kalama Valley mouth (McAllister 1933:63-65). Hahaione Valley once had a "complex set of terraces . . ." (Tuggle 1972) but it is not clear what was cultivated here. In 1868, Brigham reported "a small spring issuing near sea level at the head of Hanauma Bay was used for irrigating several taro patches along the shore" (Stearns & Vaksvik 1935:153).

Temporary habitation sites in caves or rock shelters have been found near Makapu`u Head (Kurashina & Sinoto 1984), near Pahua heiau (McAllister 1933:66), Kaluanui Ridge (Solheim & Gorman 1962; Smart & Bayard 1964-65; Price-Beggerly & McNeil

1985) and in Hanauma Bay (Emory & Sinoto 1961). An open site of "temporary multiple use" was recorded on the tip of Kaluanui Ridge (Folk et al 1993:31).

Perhaps the largest subsistence feature of this land is Kuapa Pond, once known as Keahupua-o-Maunalua (McAllister 1933:69). It was a huge pond with a wall, kuapa, built to cut it off from the sea (Takemoto et al 1975:8) In 1851, it was 523 acres in area (Takemoto 1975:10). In 1921, the water area was 301 acres with a swamp land of 125 acres (McAllister 1933:69; Takemoto et al 1975; Sterling & Summers 1978; Kelly et al 1984). "At one time it was the largest [fishpond on O`ahu] and an important source of mullet (Cobb in Kelly et al:1985:1).

Ko`a* are shrines built to make fish multiply (Pukui & Elbert 1975:145). Three named *ko`a were recorded on the west side of Koko Head or Mookua o Kaneapua: Palialaea and Huanui were for mullet, and Hina was for scad (McAllister 1933:69).

Hanauma Bay, on the east side of Koko Head was "a favorite royal fishing resort" (Sterling & Summers 1978:267), where Queen Kaahumanu and Kamehameha V came, not only to fish but to be entertained by hula dancers and games (Sterling & Summers 1978:267).

Summary

Maunalua is a large land which was extensively developed in the 1960s-1970s into Hawaii Kai, a residential neighborhood. Development has obliterated most of the inland sites but undeveloped coastlines, deep valleys and steep slopes may still yield remnants of past times. Post-Contact land use included sweet potato cultivation and ranching.

Farming in the terraces in the back valleys was probably during the rainy season but the dominant crop appears to have been sweet potatoes planted on the coastal plain and along the slopes. Permanent habitation was probably along the shores of Kuapa Pond and the sea. Fishing and sweet potato cultivation appear to have been the prime activities of the area.

The presence of only three small probable heiau in such a large area and the lack of smaller divisions of lands (*`ili*), suggest that Maunalua was not a place of high-status residents.

B. The Project Area at Koko Crater

Introduction

Koko Crater is within the boundaries of Koko Head Park, a City and County of Honolulu park. The park also includes Koko Head around Hanauma Bay, the Halona Point Blow Hole and the western portion of Sandy Beach.

The project proposes to use Koko Crater as a water storage facility needed for the hydroelectric power plant. A subsurface pipeline will connect the facility to a switch yard and control office to be located near the Sewage Treatment Plant (STP) (Fig. 1).

Environment

Koko Crater is one of several volcanic tuff cones along the southeastern coast of O`ahu (Stearns & Vaksvik 1935:150). The soil within the crater are well-drained soils "developed in alluvium washed from deposits of volcanic ash, cinder and tuff" (Foote et al 1972:72). Its slopes are exposed rock. The area receives about 3 inches (800mm) of rain annually (Giambelluca et al 1986:73).

The crater was not visited. However, at the base of the eastern slope, the vegetation consisted of kiawe, koa haole, finger grass, pili, and other exotics. The section closest to the highway is in tall grass but once past that, the grasses are shorter and not so dense that it is easier to walk through.

Historic Site Information

The crater is a traditional cultural place. Its Hawaiian name as Kohelepelepe. "When Kamapua`a [pig god] attacked Pele near Kalapana, Kapo [Pele's sister] sent her [Pele's] kohe (vagina) as a lure and he left Pele and followed the kohe lele (traveling vagina) as far as Koko Head on Oahu, where it rested upon the hill, leaving an impression to this day. . ." (Beckwith in Sterling & Summers 1978:267).

Community informants told of sites on the interior upper slopes of Koko Crater (pers comm Tom Dye). The project area has not undergone archaeological survey.

McAllister recorded a series of seven aaricultural terraces and a probable house site (site 37) on the low northeastern ridge of Koko Crater (1933:65). No surface sites were noted ont eh southwestern slope by Kennedy in 1987 at the site of the Hawaii Job Corps Center. Human burials havae been found on the eastern upper slopes by hikers in 1989 (Kawachi & McEldowney 1989).

The author and Mr. Yuzawa started just west of the Sandy Beach entrance and checked part of the seaward exit of the project area. This was far from a complete survery. Low retaining walls near gullies and large boulders were observed. These were likely temporary habitation terraces as it is directly inland of the sandy beach.

Summary

Very little has been written about the proposed project area. An archaeological survey is needed within the crater and along the seaward exit to determine whether significant archaeological sites are present. It is not likely that habitation or agricultural sites would be found on the crater floor. It is likely, however, that burials might be found on the interior slopes and the crater floor. However, the crater is a traditional cultural place associated with Pele accounts.

IV. SUMMARY AND DISCUSSION

In Maunawili Valley, sixty percent of the proposed project site still needs to be surveyed. Agricultural and possibly temporary habitation sites are likely to be found. The floor of Ka`au Crater has not been archaeologically surveyed but the crater is a traditional cultural place. Few archaeological sites are anticipated as this crater is beyond the agricultural and housing zones of Palolo *`ili*. Koko Crater also has had no archaeological survey. Limited archival work indicates burials and a low density of habitation and agricultural sites are on its exterior slope, and sites might be found inside. This crater is also a traditional cultural place.

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PRELIMINARY GEOLOGIC RECONNAISSANCE
PUMPED STORAGE PROJECTS
KOKO CRATER AND KAAU CRATER SITES
OAHU, HAWAII

W.O. 3153-00 OCTOBER 22, 1993

FOR

OKAHARA & ASSOCIATES

APPENDIX E

C.W. ASSOCIATES, INC. dba
GEOLABS-HAWAII
Geotechnical Engineering, Geology and Environmental Services

October 22, 1993
W.O. 3153-00

Mr. Louis Lopez
Okahara & Associates
470 N. Nimitz Highway, Suite 212
Honolulu, Hawaii 96817

Dear **Mr. Lopez:**

Submitted herewith is our report entitled "Preliminary Geologic Reconnaissance, Pumped Storage Projects, Koko Crater and Kaau Crater Sites, Oahu, Hawaii."

Our work was performed in general accordance with the scope of services outlined in our fee proposal of July 20th.

Detailed discussion and recommendations are contained in the body of this report. If there is any point that is not clear, please contact our office.

Very truly yours,

C.W. ASSOCIATES, INC.
dba **GEOLABS-HAWAII**

Bob Y.K. Wong

Bob Y.K. Wong, P.E.
President

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2006 Kalihi St. • Honolulu, Hawaii 96819
Facsimile: (808) 847-1749 • Phone: (808) 841-5064

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PRELIMINARY GEOLOGIC RECONNAISSANCE

PUMPED STORAGE PROJECTS

KOKO CRATER AND KAAU CRATER SITES

OAHU, HAWAII

W.O. 3153-00 OCTOBER 22, 1993

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Based on reconnaissance level studies, the Koko Crater and Kaau Crater pumped storage projects appear to be feasible from a geotechnical standpoint provided certain geotechnical concerns can be addressed.

Tuff derived borrow materials at the Koko Crater site are expected to yield earthfill type material. This material may be suitable for earthfill dam construction provided concerns regarding the erodibility of the material on fill embankments can be addressed. Control of groundwater at the Koko Crater powerhouse site is expected to be a difficult and costly problem to overcome.

Construction of a concrete or rockfill dam at the Kaau Crater site appear to be viable alternatives. Basalt derived borrow material at the Maunawili lower reservoir site should provide a source of rockfill material suitable for dam construction at that location. Confined groundwater conditions in the area of the Kaau powerhouse and tunnels will likely present significant construction challenges.

The geologic setting of both sites is described in text followed by discussion of borrow materials, dam sites, reservoir construction, tunnel construction, powerhouse sites and potential geologic hazards.

INTRODUCTION

Preliminary geologic reconnaissance explorations for the proposed Koko Crater and Kaau Crater reservoir and pumped storage hydroelectric plant sites have been completed. Our exploration was performed in general accordance with our proposal, dated July 20th.

PROJECT CONSIDERATIONS

The main components of the proposed pumped storage projects are described in the Integrated Resource Plan prepared by Hawaiian Electric Company. There are two separate sites included in this project. The Koko Crater site is located on the southeast coast of Oahu, just east of Hawaii Kai. The proposed hydroelectric facility would include a reservoir in Koko Crater, a powerhouse located on the coast, a tunnel connecting the reservoir and the powerhouse, and a substation with transmission lines. A dam would be constructed across a gap in Koko Crater to create the reservoir. The dam would be approximately 160 feet high. It is anticipated that the reservoir would be designed with an interior liner. The powerhouse would extend to at least 50 feet below mean sea level. Water conductor tunnels are expected to have an inside diameter of 24 feet, and individual unit penstocks would be approximately 14 feet in diameter. Total tunnel lengths would be on the order of ½ mile.

The Kaau Crater site is located inland at the upper end of Palolo Valley on Oahu. The proposed hydroelectric facility would include an upper reservoir at Kaau Crater Reservoir, a lower reservoir in Maunawili valley, a power house, water conducting tunnels, and a substation with transmission lines. The dam at the crater site would be approximately 100 feet high, and the crater would be lined to conserve water. The lower reservoir would be contained by a dam of approximately 130 feet high, and approximately 2,670 feet long at the crest. The lower reservoir would also be lined to conserve water. The powerhouse would be constructed underground, at an elevation approximately 100 feet below the minimum operating level within the lower reservoir. Water conductor tunnels are expected to have an inside diameter of 18 feet, and individual unit penstocks would be approximately 10 feet in diameter. Total length for access tunnels, low pressure tunnels, vertical shafts and tailrace tunnels would be on the order of about 1½ miles.

PURPOSE AND SCOPE

The purposes of this reconnaissance have been to provide a preliminary assessment of geologic conditions at both sites and to evaluate potential geotechnical constraints for development of the subject project. Our scope of services has included the following:

1) Review of pertinent published and un-published geologic maps and reports available from our own files as well as from the U.S. Geologic Survey, University of Hawaii, etc.

2) Examination of stereopaired aerial photographs (Koko Crater site).

3) Reconnaissance of the sites by an engineering geologist from our office to map geologic conditions exposed at the sites.

4) Preparation of a report (6 copies) presenting our preliminary characterization of geologic conditions at the project sites, and an evaluation of potential geologic concerns. Preliminary geologic maps of both sites have been prepared showing the approximate extent of surficial deposits and mapping of bedrock units.

KOKO CRATER SITE

Site Description

The Koko Crate site is located on the southeast coast of Oahu, just east of Hawaii Kai as shown on the attached Project Location Map, Plate 1. Elevations on the rim of Koko Crater vary from about +500 feet Mean Sea Level (MSL) to about +1200 feet MSL. On the northeast side of the crater is a gap that currently provides a drainage course from the interior of the crater. Elevations in the interior of the crater range from about +240 feet MSL at the gap to about +320 feet MSL at the southwest side of the crater.

A botanical garden is located in the crater where a wide range of native and exotic plants are maintained. Interior and exterior side slopes of the crater are vegetated with scattered grasses and brush. Improvements in the crater appear to be limited to irrigation piping and various unpaved access roads.

The proposed powerhouse would be located south of the crater between Kalanianaole Highway and the coast. Topography in this area slopes very steeply from the highway to the sea level. A wave cut platform of variable width is located at about high tide level. Vegetation on the steep slope consists of sparse grasses with large areas exposing bare rock.

Regional Geology

Koko Crater is a compound tuff cone which is part of the Honolulu Volcanic series (Macdonald, 1970). Potassium-argon dating indicates that Koko Crater is about 32,000 years old. Koko crater is believed to have been formed by violent explosions that occurred when rising lava came in contact with sea water. Fragments of lava as well as fragments of older volcanic rock and coral were ejected and deposited as tuff. The gap at the northeast side of the crater probably resulted from trade winds blowing most of the ash toward the southwest.

Following the period of eruption, the crater has been modified by processes of weathering and erosion to create the current landform. Volcanic fragments in the tuff have been altered to palagonite through weathering processes. Tuff has eroded from the side slopes of the crater creating gullies and steep scarps. The eroded materials have been deposited as talus and alluvium on the interior and exterior of the crater.

Site Geology

A preliminary geologic map of the Koko Crater site is presented on the attached Plate 2. Based on our site reconnaissance and examination of aerial photographs, the approximate extent of surfical soil deposits, bedrock structure, and other geologic features have been depicted on the geologic map. Descriptions of the geologic mapping units are presented below:

Koko Tuff - Areas of the site underlain by Koko tuff are shown on the geologic map using the symbol "Rkt." The Koko tuff contains predominantly silt and sand size fragments of ash and volcanic rock. A darker colored cap of opal-cemented tuff is evident around the rim of the crater. Where the cap has been eroded away, the underlying, lighter colored palagonitized tuff is exposed. Following deposition, this tuff has been altered by weathering to palagonite. The palagonite tuff appears to be more easily eroded than the overlying opal-cemented tuff which tends to form the steep cliffs and scarps in the area.

The light brown palagonite tuff exposed in outcrops appears to be weak to moderately strong, highly fractured and varies from thinly to thickly bedded. The dark brown opal-cemented tuff also appears to be weak to moderately strong but appears to be moderately to occasionally fractured.

Structurally, the Koko Tuff is complex. The dominant structural feature is an antiform with an axis that corresponds roughly with the rim of the crater. In general, beds on the exterior of the crater dip away from the center of the crater whereas beds on the interior of the crater dip toward the center of the crater. A notable exception to this configuration is evident along the interior, northwest slope of the crater where the inward dipping beds appear to have been eroded away to expose outward dipping beds. Horizontally stratified tuff was observed in gullies in the northwest portion of the crater floor. This tuff probably represents some of the youngest tuff associated with Koko Crater.

Koko Basalt - Basaltic "aa" volcanic rock was exposed on both the northwest and southeast sides of the crater gap. These areas are shown on the geologic map using the symbol "Rkb." This volcanic rock appears to have chaotic structure with no evident bedding. The "aa" appears to consist of a dense mass of vesicular basaltic rock fragments.

Alluvium - Alluvium is soil material that has been deposited by flowing water. Portions of the study area that appear to be underlain by alluvium are indicated on the geologic map using the symbol "Ra." Alluvium was exposed in gullies eroded in the crater floor. At the crater gap, an exposure of alluvium over 20 feet thick was observed in the stream course consisting of sandy silt with gravel and cobbles. Elsewhere in the crater, gullies exposed alluvium consisting predominantly of sandy silt with cobbles and boulders. The alluvium generally appeared to be medium dense to dense although some porous gravel beds were observed.

Colluvium - Colluvium is material that is deposited by processes such as slope wash, sheet erosion, rock fall, etc. The transition slope on the interior of the crater between the relatively flat crater floor and the steep side slopes appears to be underlain by colluvium which is designated by the symbol "Rc" on the geologic map. The colluvium appears to contains predominantly of cobbles and boulders with some sandy silt matrix. Abundant boulders up to 10 feet in diameter were observed along the west side of the crater floor.

Colluvium was also mapped in a valley on the north side of Kalanianaole Highway near the proposed powerhouse location. The colluvium is estimated to be about 10 to 15 feet thick in this valley.

The more prominent valley extending west from Halona Blowhole does not appear to be underlain by colluvial deposits. Tuff was observed in the stream bed in this valley.

Landsliding - Evidence of rockfall and rock slides is visible on both the interior and exterior slopes of the crater. The dip slope conditions combined with undermining of the more easily eroded palagonite tuff appears to have resulted in rockfall and rock slides. Scarps resulting from these slope movements are shown on the geologic map using a hatchered line.

Photolineaments - Two linear valleys cross the proposed tunnel alignment near Kalanianaole Highway. Both valleys trend roughly perpendicular to the tunnel alignment. The trend of these valleys is somewhat anomalous when compared to the general drainage pattern in the area. As noted in the discussion regarding alluvial deposits, tuff was observed in the stream bottom of the northern valley. No signs of shearing and no significant difference in the makeup or structural orientation of the tuff were noted on either side valley. Macdonald (1970) interprets these landforms as remnants of the rim of an older tuff cone that has been almost completely eroded away by wave action. Additional investigation of linear valleys would be needed to these understand the origin of these landforms and the possible impact to the project.

Groundwater - Groundwater in the Koko Crater area is probably basal, or near sea level, groundwater. In such close proximity to the ocean, the basal water is likely saline but may have a thin upper zone of brackish water. Localized zones of perched groundwater may exist within the tuff due to variations in permeability; however, these are probably limited in extent.

DISCUSSIONS AND PRELIMINARY RECOMMENDATIONS

General

Based on our reconnaissance level exploration, the Koko Crater pump storage project appears to be feasible from a geotechnical standpoint provided certain geotechnical constraints can be addressed. Our comments regarding various aspects of the project are discussed below followed by comments regarding potential geologic hazards.

Project Construction

Borrow Materials - Considering the weak to moderately strong nature of the Koko Crater tuff, local borrow sites will likely yield earthfill-type material rather than rockfill material. As with any dam construction project, processing of borrow material will be necessary for use of tuff material as embankment fill. Sources of rockfill material exist off-site; however the cost of trucking these materials to the site is probably cost prohibitive.

Because the tuff consists predominantly of silt and sand size particles, tuff derived earthfill material will likely be highly erodible on embankments. Protective vegetation would likely be difficult to establish without irrigation. Tuff derived earthfill would also be susceptible to piping if seepage through the embankment were to occur.

Deposits of low permeability material suitable for dam clay core or reservoir lining were not observed during our site reconnaissance. Clayey silt soils, while having sufficiently low permeabilities for lining, appear to be scattered in occurrence and of limited thickness.

Alluvium in the crater appears to be a potential source of granular filter material. Processing of the alluvium would be needed to achieve an appropriate gradation for use as filter material.

Dam Site - To reduce the amount of settlement the dam will experience, over-excavation of the alluvial materials at the crater gap will likely be required. Alluvium at the crater gap was observed to be at least 20 feet thick where exposed in the stream course draining the crater. Tuff observed at the left and right dam abutments should provide adequate foundation support for dam construction. Where basalt is exposed at the dam abutments, probing should be performed to detect any voids or cavities. Depending on the location and size of voids, grouting or filling of voids with engineered fill may be needed.

Reservoir Construction - The tuff and alluvium within the crater, in general, appear to be highly permeable. Lining of the reservoir will be needed to reduce the potential for large losses of water through infiltration. Tuff and alluvium within the crater do not appear to be highly compressible and will likely provided adequate support for liner construction.

Tunnel Construction - Tunnel excavation in the weak to moderately strong tuff appears to be feasible using road headers, tunnel boring machines, or drill and blast methods. Considering the highly fractured, thinly bedded nature of the tuff, the need for temporary tunnel crown support should be anticipated. Near vertical road cuts up to 30 feet high along Kalanianaole Highway appear to have performed reasonably well for many years. Based on the performance of the existing road cuts along Kalanianaole Highway, vertical rock faces should have very good standup time. However, this should be further evaluated during detail design.

Where tunneling extends below sea level, basal groundwater will be encountered. Due to the high permeability of the tuff, very high rates of flow would enter underground openings below sea level. Any excavations below sea level will require carefully designed and constructed groundwater control measures such as grout curtains and dewatering.

Powerhouse Site - Construction concerns for the proposed powerhouse site will be similar to those described for tunneling. Control of groundwater infiltration will likely be the most difficult and costly problem to overcome. For larger underground openings, adverse bedding may be of concern. Well developed bedding planes in the tuff dip at an inclination of about 10 degrees toward the southeast at the powerhouse location. Large southeast facing excavation faces may be subject to bedding plane block failure unless appropriate support measures are used.

Geologic Hazards

Slope Stability - As presently planned, it does not appear that the proposed project would adversely affect stability of the slopes in the area. Areas of rockfall and rock sliding are located well above the anticipated reservoir level. The possibility of rockfall and rock sliding will continue to exist on the steep slopes above the reservoir, primarily on the west and northwest sides of the reservoir. Future studies should be conducted to evaluate the potential for a large rockfall or rock slide to impact the reservoir and consider the resulting consequences from wave action or temporarily elevated reservoir levels.

Seismicity - Except for the island of Hawaii, the Hawaiian Islands are not considered a highly active seismic area. Under the Uniform Building Code, the island of Oahu has been designated as Seismic Zone 2A which indicates that for design purposes a horizontal peak ground acceleration of 0.15g should be used. The Uniform Building Code establishes minimum seismic design criteria for any structures constructed in such a zone for resistance to deformation and damage resulting from such strong ground motion. Therefore, any structures that will be built as part of the project should be designed with consideration of the hazards of seismic activity.

Volcanic Activity - As noted in the text of the report, Koko Crater is believed to be approximately 32,000 years old. Most geologists generally consider volcanoes active if they have erupted within the last 11,000 years and volcanoes that have erupted within the last 2 million years are considered potentially active. By this definition, Koko Crater can be considered a potential active volcano.

In general, the northwestern Hawaiian Islands are the oldest while the southeastern islands are the youngest. Although Koko Crater can be considered potentially active, the trend of activity in the Hawaiian Islands would suggest that the likelihood of renewed volcanic activity on Oahu during the life span of the project is relatively low.

Inundation - Inundation, or flooding, can originate from landward water courses or from tsunami. The Koko Crater reservoir site is located sufficiently inland and at a high enough elevation that the possibility of inundation by tsunami is remote. Intense rain storms can cause localized flash flood conditions in the drainage courses on the flanks of Koko Crater that may transport mud and rock debris.

Depending on the actual location of the powerhouse and substation, these facilities could be subject to inundation by tsunami. The zone between Kalanianaole Highway and the coast is within the potential inundation area shown on tsunami evacuation maps.

Ground Subsidence - Ground subsidence is generally the result of either consolidation of soft or loose subsoils or of the collapse of voids in the subsurface. The project site does not appear to be underlain by soft or loose soils; therefore, ground subsidence resulting from the consolidation of soft or loose subsoils does not appear to be a consideration for the subject project. Tuff rock formations generally do not contain voids or cavities that may be subjected to collapse. Basalt foundation materials should be probed and treated as noted in the dam site section of this report.

KAAU CRATER SITE

Site Description

Kaau Crater, the upper reservoir site, is located at the head of Palolo Valley on the southwest side of the Koolau mountain range. The lower reservoir site is located in Maunawili Valley on the northeast side of the Koolau range. Both the upper and lower reservoir sites are shown on the attached Project Location Map, Plate 3.

Elevations on the rim of Kaau Crater vary from about +1700 to +1800 feet MSL. On the southeast side of the crater is a gap that currently provides a drainage course from the interior of the crater. The elevation at the gap is about +1460 feet MSL.

The floor of Kaau Crater is a swampy area vegetated with grasses, brush and trees. Interior and exterior side slopes of the crater are vegetated with dense brush and trees. Improvements in the area of Kaau Crater appear to be limited to high voltage transmission towers located on the southwest rim.

The Maunawili reservoir site is located in Maunawili Valley about 1 mile north of Kaau Crater. Conceptual plans suggest that the dam would be located at about elevation +600 feet MSL.

The Maunawili reservoir site is densely vegetated with trees and brush. Improvements in this area include an unpaved access road located downstream of the tentative dam site, high voltage transmission towers on the ridge to the south of the dam site, and Pikoakea Spring and Clark Tunnels are located near the tentative left abutment.

Regional Geology

Kaau Crater is associated with the Honolulu Volcanic series (Macdonald, 1970) and is believed to have been blasted out of Koolau basalt by explosive eruptions. While the Koolau basalts that form the rim of the crater are estimated to be over 2 million years old, the eruptions that formed the crater have been dated as recent as about 32,000 years old.

Following the period of eruption, the crater has been modified by processes of weathering and erosion to create the current landform. Basalt rock has eroded from the side slopes of the crater creating gullies. The eroded materials have been deposited as talus and alluvium on the interior of the crater.

The Maunawili reservoir site is located in an area mapped as Koolau dike complex rock (Stearns, 1966). The Koolau dike complex is basaltic volcanic rock having nearly vertical structure resulting from repeated intrusions of lava. A contact between the near-horizontally structured Koolau basalt to the south and the vertically structured Koolau basalt has been mapped near the base of the Pali or steep cliff on the north side of the Koolau range.

Site Geology

A preliminary geologic map of the Kaau Crater and Maunawili sites is presented on the attached Plate 4. Based on our site reconnaissance and examination of aerial photographs, the approximate extent of surfical soil deposits, bedrock structure, and other geologic features have been depicted on the geologic map. Descriptions of the geologic mapping units are presented below.

Koolau Dike Complex - Portions of the study area underlain by the Koolau dike complex are shown on the geologic map using the symbol "Tkdc." Rock of the Koolau dike complex generally consists of gray to black near vertical basalt dikes ranging from several inches to several feet thick. Only limited exposures of rock were visible at the Maunawili site. In stream bottoms and at Pikoakea Spring, the basalt exposed appeared to be strong to very strong, with few vesicals, and range from highly to occasionally fractured.

Koolau Basalt - The crest of the Koolau range and the area around Kaau Crater are underlain by Koolau basalt as indicated on the geologic map using the symbol "Tkb." Koolau basalt varies from dense to very vesicular and typically has nearly horizontal structure. Basalt exposures at the gap in Kaau Crater were moderately weathered, highly fractured with massive structure. "Stair stepping" patterns on the cliff faces of the Koolau range suggest alternating layers of dense, massive basalt and layers of less dense, highly fractured or more erodible basalt.

Alluvium - Alluvium is soil material that has been deposited by flowing water. Portions of the study area that appear to be underlain by alluvium are indicated on the geologic map using the symbol "Ra." Alluvium was exposed in gullies eroded in the crater floor and in stream courses in the Maunawili valley.

Alluvium within Kaau Crater probably consists of silt and clay with some interlayered organic material or peat. The alluvium in the crater was observed to be saturated and soft. Men walking across the crater floor sink into the soft silt and clay 3 to 6 inches. Beneath the soft silts and clays, coarser grained alluvium may exist in the crater.

Stream courses in the Maunawili reservoir area have been numbered Nos. 1 through 3 on the geologic map for discussion purposes. Where the access road crosses Stream No. 1, in-situ basalt appears to be exposed in the stream bottom. Small pockets of alluvium may be present upstream of the access road; however, the stream generally appears to be in an erosive mode. Where the access road crosses Stream No. 2, alluvial in-filling of the valley was approximately 150 feet wide and could be on the order of 30 feet or more in thickness. The alluvium exposed in the stream bank consisted of dense clayey sand and gravel. Several hundred feet upstream of the access road, near Pikoakea Spring, the alluvial deposit narrowed to only about 20 feet wide with an estimated thickness of about 10 feet. In-situ basalt was exposed in Stream No. 3 where the access road crosses the stream.

Colluvium - Colluvium is material that is deposited by processes such as slope wash, sheet erosion, rock fall, etc. The transition slope on the interior of the crater between the relatively flat crater floor and the steep side slopes appears to be underlain by colluvium which is designated by the symbol "Rc" on the geologic map. The colluvium probably contains predominantly cobbles and boulders with sand, silt and clay matrix.

Landsliding - Evidence of debris flows or debris avalanches is visible on steep slopes in the area of the Kaau Crater and on the Pali upslope of the Maunawili site. In general, these landslides appear to have occurred where a thin layer of soil and weathered rock in very steep swales or gullies becomes saturated and moves down slope as an incoherent mass of soil and rock debris.

Groundwater - Groundwater in the Kaau Crater area was observed to be very near the ground surface. Low permeable silts and clays in the crater appear to have formed a perched ground water condition in the crater. The vertical and lateral extent of this layer is not known at this time and should be further evaluated. At the time of our site visit, runoff from the crater through the crater gap was visually estimated at about 60 gallons per minute.

Groundwater in the Koolau basalt surrounding Kaau Crater probably occurs in two forms: 1) groundwater perched in more permeable horizontal layers in the basalt; and 2) basal groundwater at great depth below the crater. In the area of the Maunawili reservoir, significant quantities of dike impounded groundwater may exist within the basaltic rock. Groundwater flowing from Pikpakea Spring is probably dike impounded groundwater.

CONCLUSIONS AND RECOMMENDATIONS

General

Based on our reconnaissance level exploration, the Kaau Crater pumped storage project appears to be feasible from a geotechnical standpoint provided certain geotechnical constraints can be addressed. Our comments regarding various aspects of the project are discussed below followed by comments regarding potential geologic hazards.

Project Construction

Borrow Materials - Spur ridges in the proposed Maunawili reservoir area appear to be potential sources of basalt rockfill material. Depending on the configuration of the reservoir, removal of spur ridges could enhance reservoir capacity. Basalt rock on the rim of Kaau Crater should also have characteristics appropriate for use as rock fill; however, the high visibility of the crater rim may be of concern.

Deposits of low permeability material suitable for dam clay core or reservoir lining were not observed in our reconnaissance of the Maunawili reservoir area. Clayey silt residual soils, while having sufficiently low permeabilities for lining, appear to be of limited thickness and do not appear to occur in sufficient quantities for practical use.

Silts and clays within Kaau Crater may be suitable for use as liner material for the Kaau reservoir. These materials currently function to some extent as a natural liner in the crater. It is possible that these materials could be processed and reworked to form a more uniform and reliable liner. Soft soil and shallow groundwater conditions would present difficulties that would need to be overcome to process the silts and clays.

Alluvium in the Maunawili reservoir area may be a potential source of granular filter material although the quantities available appear to be limited upstream of the access road. Basalt rock, if crushed and screened, may be a potential source of filter material.

Dam Site - To reduce the amount of settlement the Maunawili dam will experience, overexcavation of the alluvial materials will likely be required. Alluvial deposits upstream of the access road appear to be limited in extent and, therefore, do not appear to present a significant constraint to dam construction. Once basalt rock foundation conditions are exposed, probing to detect possible voids in the rock may be required. Depending on the size and location of voids or cavities, grouting or filling with compacted fill may be appropriate to improve foundation support. With appropriate keying benching, and probing as noted above, basaltic rock at the left and right dam abutments should provide adequate foundation support for dam construction.

Moderately weathered basalt rock is exposed across the bottom and sides of the gap in Kaau Crater. With appropriate keying, benching and probing, the basaltic rock should provide adequate support for a rock fill or concrete dam. It should be noted that the existing exterior slopes at the gap of the crater is relatively steep. The steep slope may present a constraint for the downstream slope of the dam.

Reservoir Construction - Although the silt and clay in the bottom of Kaau Crater appears to have low permeability characteristics, basalt rock and colluvial transition slopes around the perimeter of the crater floor may have high permeability. Lining of the reservoir will be needed to reduce potential large losses of water through infiltration. Alluvium within the crater appears to be highly compressible and may experience significant settlement under reservoir loading. Depending on the thickness of the compressible silts and clays, reworking of the compressible materials may reduce the potential settlements to acceptable levels. A combination of reworking the compressible materials, with the use of a lining system that can accommodate some settlement, may be needed.

Alluvium and basalt rock at the Maunawili site appears to have high permeability characteristics, therefore, lining of this reservoir should be anticipated.

Tunnel Construction - Tunnel excavation in the basaltic rock appears to be feasible using conventional drill and blast methods. Considering the variable nature of the basalt, the need for temporary tunnel crown support on portions of the tunnel should be anticipated. Zones of dense, moderately fractured rock should have adequate standup time on near vertical faces without temporary support.

Abrupt changes in groundwater levels may be encountered during tunneling through basalt of the dike complex. Vertical discontinuities in the dike complex often contain zones of shearing and clay gouge that can act as groundwater barriers. Appropriate exploration and tunneling methods will need to be used to reduce potential construction and safety problems associated with sudden, large volume flows of groundwater and zones of sheared rock.

Powerhouse Site - Siting of the powerhouse within the dike complex will likely place the powerhouse below the confined groundwater level. Control of groundwater infiltration by grouting and dewatering will most likely be needed to permit construction.

Geologic Hazards

Slope Stability - Areas of debris flows and debris avalanches are located above both reservoir sites. The volumes of material involved in these types of slope movements are likely to be small; therefore, a significant impact on reservoir levels is not anticipated. Project facilities should be sited outside potential debris flow paths. For example, the inlet/outlet structure at the Kaau Crater should be sited toward the center of the crater, beyond the toe of colluvial transition slope on the north side of the crater.

Seismicity - Seismic conditions for the Kaau site are as described in the Koko Crater "Seismicity" section.

Volcanic Activity - Conditions with respect to volcanic activity at the Kaau site are similar to those describe in the Koko Crater volcanic activity section.

Inundation - Inundation, or flooding, can originate from landward water courses or from tsunami. The Kaau Crater and Maunawili reservoir sites are sufficiently inland and at high enough elevations that the possibility of inundation by tsunami is non-existent. Intense rain storms can cause localized flash flood conditions in the drainage courses on the flanks of Kaau Crater and upslope of the Maunawili site that may transport mud and rock debris.

Ground Subsidence - Ground subsidence is generally the result of either consolidation of soft or loose subsoils or of the collapse of voids in the subsurface. As noted in previous sections of this report, appropriate investigation and treatment of compressible materials and potential cavity areas will be required to reduce the potential for problems of this type to acceptable levels.

ADDITIONAL SERVICES

This preliminary assessment of geologic conditions and geotechnical constraints has been based on a reconnaissance level exploration. Site specific geotechnical investigations should be performed to characterize actual site conditions and develop recommendations for the projects.

LIMITATIONS

The preliminary findings and recommendations submitted in this report are based in part upon information obtained from points of observation in the field. Variations of conditions between the field data points may occur; and the nature and extent of these variations may not become evident until additional exploration or construction is performed. If variations then appear evident, it will be necessary to re-evaluate the recommendations provided in this report.

Elevations discussed in this report were determined by interpolation from elevation points on U.S.G.S. Topographic Maps. The physical location and elevation of the field data points should be considered accurate only to the degree implied by the method used.

The geologic contacts shown on the attached geologic maps are based on reconnaissance level mapping and as such are very approximate and subject to interpretation.

This report has been prepared for the exclusive use of Okahara & Associates and their consultants for specific application to the preliminary design of the project in accordance with generally accepted geotechnical engineering principles and practices. No warranty is expressed or implied.

PLATES

The following plates are attached and completes this report:

Plate 1 - Project Location Map, Koko Crater Site

Plate 2 - Preliminary Geologic Map, Koko Crater Site

Plate 3 - Project Location Map, Kaau Crater Site

Plate 4 - Preliminary Geologic Map, Kaau Crater Site

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Respectfully submitted

C.W. ASSOCIATES INC.
dba **GEOLABS-HAWAII**

By

Raymond P. Skinner
Principal Geologist

BOB Y. K. WONG
No. 3862

By Bob Y.K. Wong

Bob Y.K. Wong, P.E.
President

BYKW:RPS:crc

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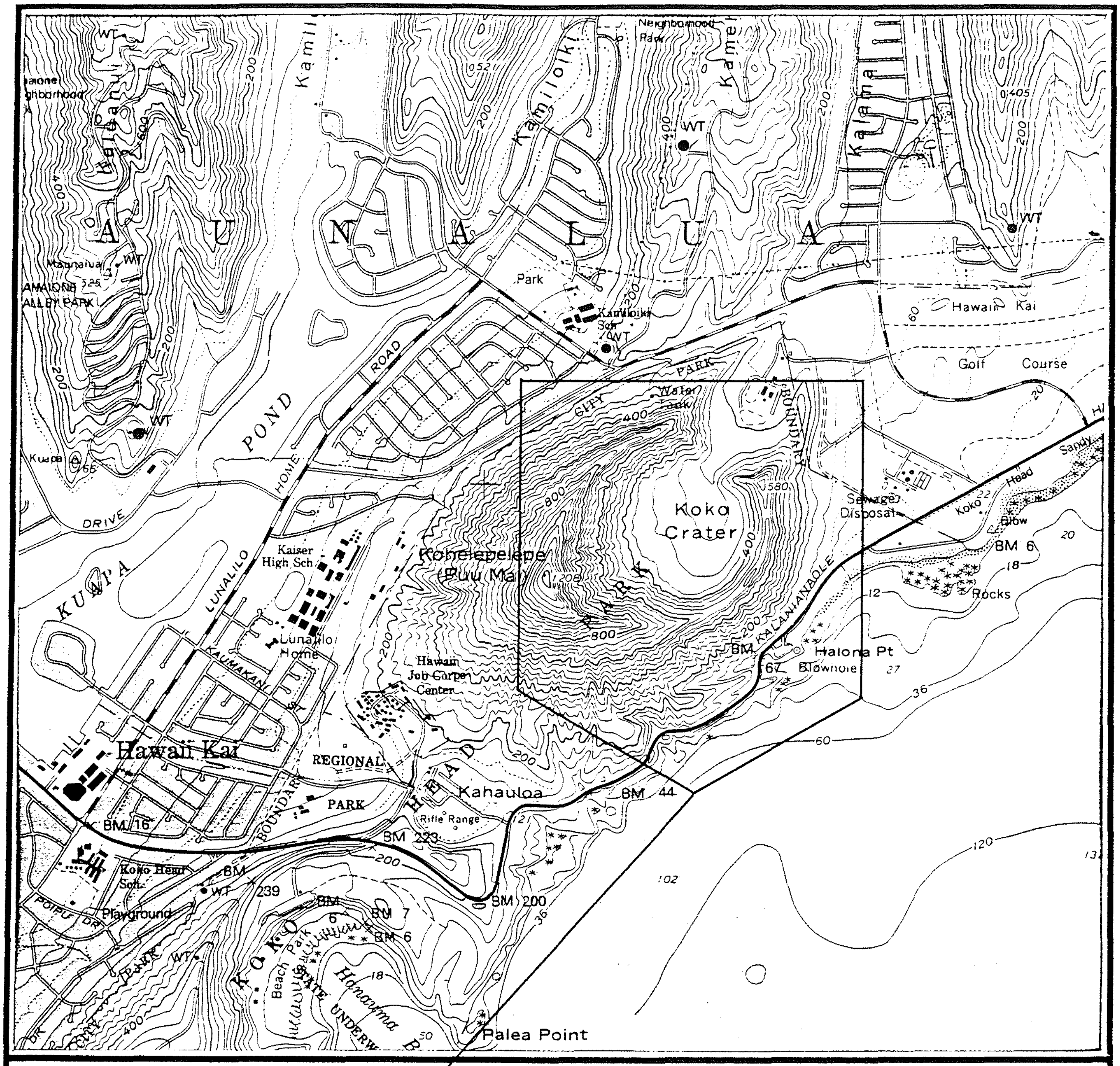

GENERAL PROJECT LOCATION

N

PROJECT LOCATION MAP

KOKO CRATER PUMPED STORAGE PROJECT
HAWAII KAI, OAHU, HAWAII

PLATE 1

REFERENCE: U.S.G.S. QUADRANGLE MAP;
KOKO HEAD, OAHU, HAWAII (1983)

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Foundation & Soil Engineering · Geology

DATE	DRAWN BY
OCTOBER 1993	K H N
SCALE	W.O.
1" = 2,000'	3153-00

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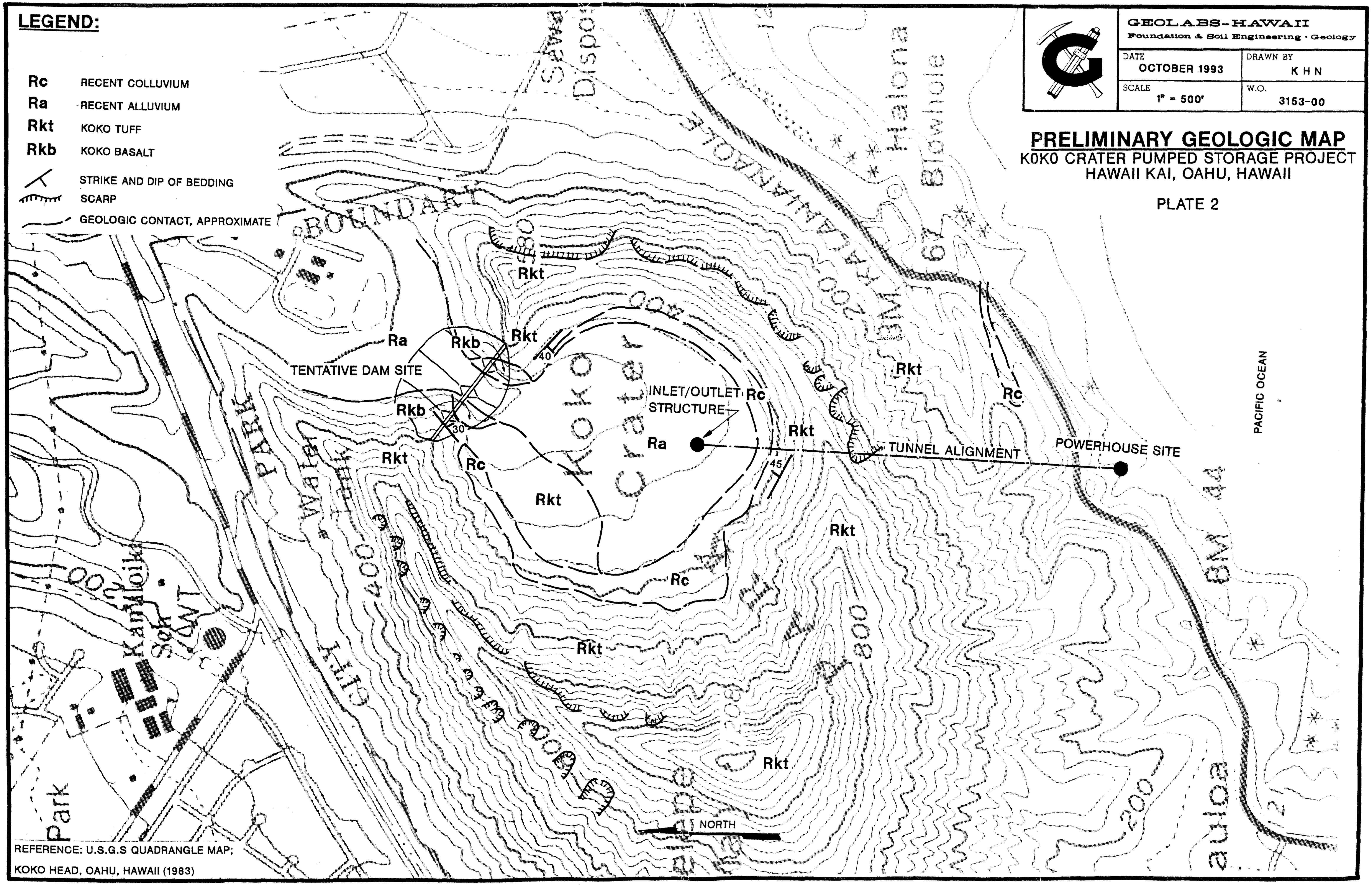
SCALE 1" = 500'	W.O. 3153-00

PRELIMINARY GEOLOGIC MAP
KOKO CRATER PUMPED STORAGE PROJECT
HAWAII KAI, OAHU, HAWAII

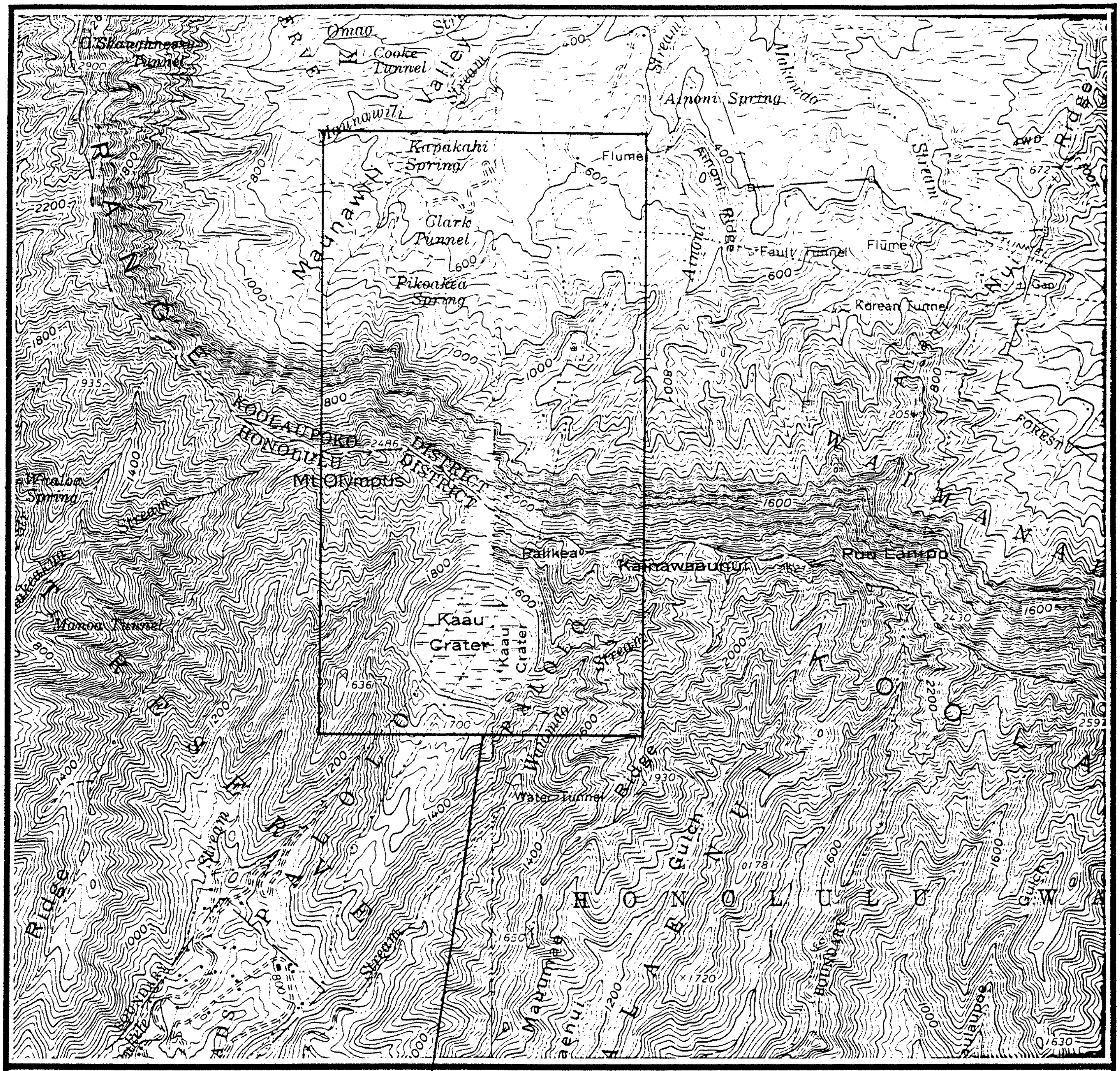
PLATE 2



LEGEND:

Rc	RECENT COLLUVIUM
Ra	RECENT ALLUVIUM
Rkt	KOKO TUFF
Rkb	KOKO BASALT
⟋	STRIKE AND DIP OF BEDDING
⌒	SCARP
— —	GEOLOGIC CONTACT, APPROXIMATE

REFERENCE: U.S.G.S QUADRANGLE MAP;
KOKO HEAD, OAHU, HAWAII (1983)



GENERAL PROJECT LOCATION

N

PROJECT LOCATION MAP

KAAU CRATER PUMPED STORAGE PROJECT
HONULULU, OAHU, HAWAII

PLATE 3

REFERENCE: U.S.G.S. QUADRANGLE MAPS;
HONOLULU & KOKO HEAD, OAHU, HAWAII
(1983)

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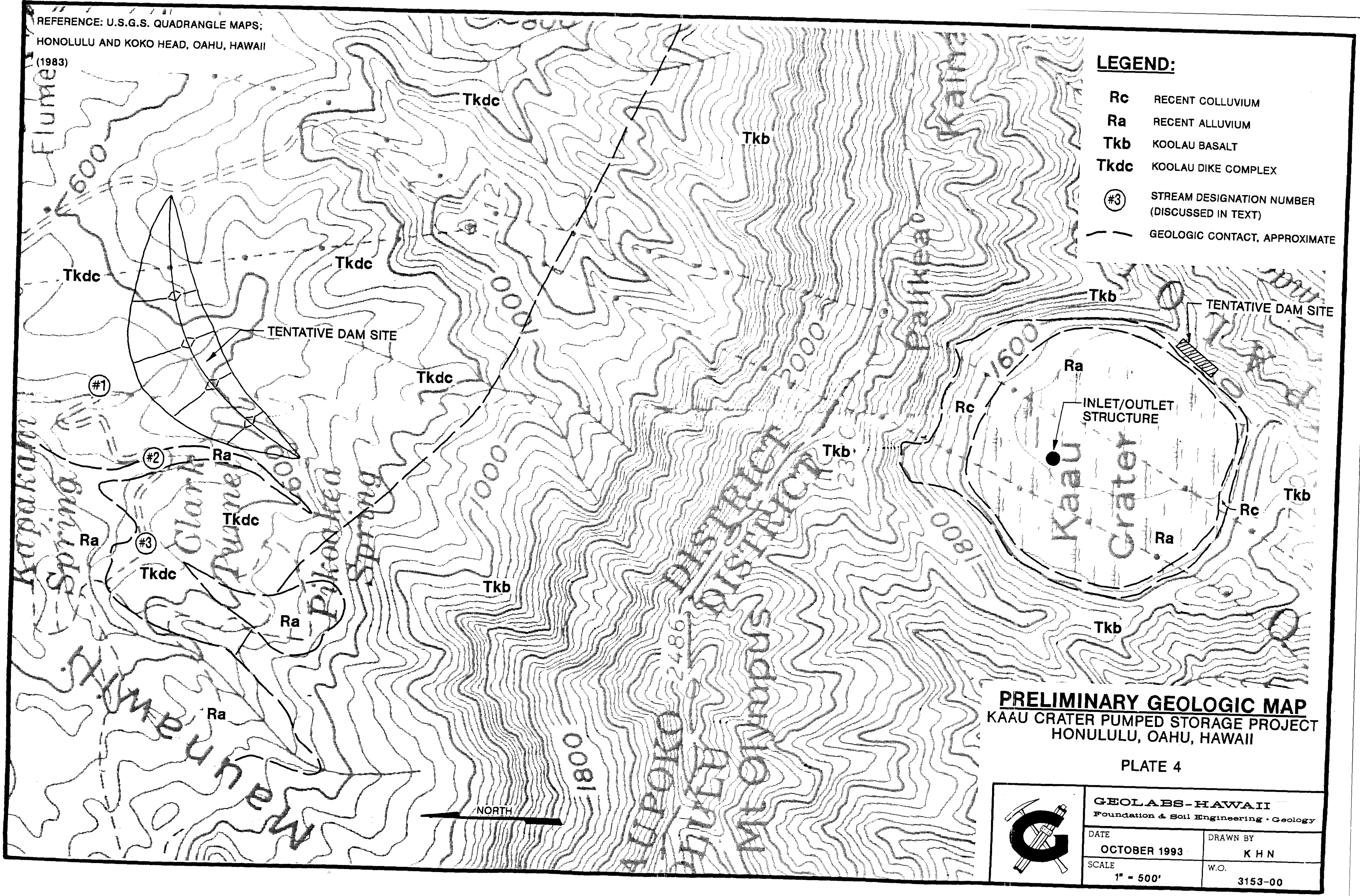

PRELIMINARY GEOLOGIC MAP

KAAU CRATER PUMPED STORAGE PROJECT
HONULULU, OAHU, HAWAII

PLATE 4

GEOLABS-HAWAII
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DATE OCTOBER 1993	DRAWN BY K H N
SCALE 1" = 500'	W.O. 3153-00

PUMPED STORAGE HYDROELECTRIC POWER PLANT STUDY, OAHU, HAWAII

OCEAN ENGINEERING CONSIDERATIONS FOR THE INLET/OUTLET STRUCTURE AT THE KOKO CRATER SITE

Prepared for:

Okahara & Associates, Inc.
470 North Nimitz Highway, Suite 212
Honolulu, Hawaii 96817

Prepared by:

Edward K. Noda and Associates, Inc.
615 Piikoi Street, Suite 1000
Honolulu, Hawaii 96814

December 1993

APPENDIX F

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(Note: all figures follow page 12)

1.0 INTRODUCTION

Hawaiian Electric Company has performed a reconnaissance level study identifying the potential feasibility of a pumped storage hydroelectric power plant at two sites on Oahu: Koko Head Crater (which uses sea water) and Ka'au Crater (which uses fresh water). As a result of this work and the desire of the State of Hawaii to further explore the feasibility of these projects and to select the more feasible project for subsequent consideration, the Department of Land and Natural Resources (DLNR) has contracted with Okahara & Associates, Inc. to undertake a prefeasibility study to provide more accurate estimates of developing each site and its potential. The study would give more specific indication of the technical feasibility of the sites and potential environmental impacts.

Edward K. Noda and Associates, Inc. was retained to provide conceptual ocean engineering criteria and considerations related to the ocean inlet/outlet structure for the Koko Crater facility site. This report generally describes the physical oceanographic environment at the proposed inlet/outlet structure location, design considerations affecting alternative inlet/outlet structure concepts, and potential oceanographic impacts related to construction and operation.

2.0 PHYSICAL OCEANOGRAPHIC ENVIRONMENT

Based on available information, this section summarizes the physical oceanographic environment at the proposed site for the inlet/outlet structure associated with the pumped storage hydroelectric plant at the Koko Crater site. The primary factors include bathymetry, the littoral processes (typical waves and currents), and potential storm wave impacts.

The Koko Crater site is located on the southeast end of Oahu between Koko Head and Makapuu Point. Figure 1 shows the location and the sectors of wave exposure for the site. Figure 2 shows a vicinity map and topographic features at the site. Two specific locations are being considered for the inlet/outlet (Site A and Site B), depending on the construction options as described in Section 3.0.

The island mass shelters the site from winter North Pacific swell. These waves undergo considerable diffraction and refraction effects prior to reaching the site as much reduced wave heights. The site is directly exposed to the predominant northeast tradewind waves and to summer southern swell. Normally a high wave energy environment during the summer months when the tradewinds are persistent and strong, the site is calmest during the winter months when the trades weaken and winds can be light and variable. However, infrequent Kona storm waves from the southwestern quadrant can impact the site during winter months. Infrequent hurricanes passing south of the islands (traveling from the southeast to southwest direction) also generate sizeable waves that can impact the site.

Wave data from a Waverider buoy situated offshore Makapuu Point[1] is the most representative long-term data to describe the typical offshore wave climate at the site. The Waverider buoy is moored in about 400-foot water depth offshore Makapuu Point, and is more exposed to the winter North Pacific swell than the project site location. Therefore, while the wave data during winter months over-estimates the wave conditions at the project site, the data for the summer months can be considered applicable to the project site. Table 1 summarizes the wave data obtained over an eight year period. Percent frequency of occurrence of significant wave height versus wave period is provided for the summer season (May-Oct) and winter season (Nov-Apr). An annual summary is also provided for 1988 (representing a typical year and one in which there were no data gaps in the record). During a typical year, the data indicates that waves are less than 8 feet the majority of the time, with periods generally less than 8 seconds.

From the existing data, the water depth at the proposed shoreline site for the inlet/outlet structure is relatively deep near the base of the shoreline cliff, estimated to be approximately 30-40 feet below MLLW. From the NOAA hydrographic chart of the vicinity (Figure 3), the nearshore bottom slope is approximately 1V:13H from the base of the shoreline cliff to 60-foot water depth about 400 feet from shore. Because of the relatively deep nearshore depths, the predominant tradewind waves undergo little refraction effects and can approach at oblique angles to the shoreline.

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[1] Coastal Data Information Program, sponsored by the U.S. Army Corps of Engineers, data reports by the Scripps Institution of Oceanography.

TABLE 1
MEASURED WAVE DATA OFFSHORE MAKAPUU POINT

% Frequency Occurrence of Significant Wave Height vs. Period

	Hs/Ts	4-6	6-8	8-10	10-12	12-14	14-16	16-18	TOT%
Summer 1981-1988	<2′								0.0
	2-4′	2.9	6.1	0.5	0.2				9.7
	4-6′	25.5	27.0	1.8	0.7	0.4	0.1		55.7
	6-8′	4.1	21.9	1.5	0.8	0.1			28.5
	8-10′	0.1	4.1	0.5	0.5	0.1			5.4
	10-12′	0.1	0.3	0.3					0.8
	TOT%	32.6	59.5	4.5	2.4	0.8	0.2		100
Winter 1981-1988	<2′								0.0
	2-4′	0.4	3.2	0.5	0.2				4.5
	4-6′	7.4	15.7	4.6	3.5	0.9	0.2		32.2
	6-8′	5.1	21.6	5.0	3.6	1.3	0.2		36.9
	8-10′	0.5	11.7	2.3	1.8	1.1	0.3		17.8
	10-12′		3.2	0.8	0.8	0.3			5.2
	12-14′		1.2	0.6	0.2	0.1	0.1		2.4
	14-16′		0.2	0.3	0.2				0.8
	16-18′								0.2
	TOT%	13.5	57.0	14.2	10.5	3.7	0.9	0.1	100
Annual 1988	<2′								0.0
	2-4′	1.2	3.9	0.2	0.1				5.5
	4-6′	19.5	22.3	2.2	1.6	0.1			45.7
	6-8′	6.1	24.0	3.2	2.4	0.5	0.1	0.1	36.5
	8-10′	0.5	6.1	0.9	1.1	0.8	0.2		9.7
	10-12′		0.8	0.3	0.5	0.2			1.7
	12-14′		0.2	0.2			0.2		0.6
	14-16′		0.1	0.1	0.1				0.3
	16-18′					0.1	0.1		0.2
	TOT%	27.3	57.5	7.1	5.9	1.6	0.6	0.1	100

Hs = significant wave height
Ts = significant wave period

The nearshore currents are relatively strong and persistent. Figure 4 shows the circulation patterns and currents in the vicinity of the site.[2] Flood tide currents set alongshore in the southwestward direction (towards Koko Head). Ebb tide currents set offshore in the east-northeastward direction. Current data obtained approximately 1.3 miles offshore the site indicate that there is a consistent overall net drift in the southwestward direction (flood tide currents are more persistent and stronger than ebb tide currents). Maximum measured flood tide current was about 1.2 knots, while maximum measured ebb tide current was about 1 knot.

The coastal reach at the proposed site of the inlet/outlet is a rocky, wave swept shoreline. There is little sediment along this coastal cliff site. Sandy Beach Park is situated approximately 1 mile northeast of the project site, and Hanauma Bay is situated approximately 1 mile southwest of the project site. Halona Blowhole (a visitor attraction) is located approximately 1,500 feet northeast of the site, around a rocky point and on the opposite side of Halona Cove. Figure 5 is a reference map showing points of interest along this coastal reach.[3] The rocky point just northeast of the project site is shown to be the site of the Honolulu Japanese Casting Club Monument. This rocky point is apparently a popular fishing spot.

Because of the wave exposure and relatively deep water depths near the shore, the site is vulnerable to large storm wave

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[2] From "Circulation Atlas for Oahu, Hawaii", by Karl H. Bathen, published by the University of Hawaii Sea Grant College Program, Sea Grant Miscellaneous Report UNIHI-SEAGRANT-MR-78-05, April 1978.

[3] From "Reference Maps of the Islands of Hawai'i, Fourth Edition, Full Color Topographic Map of O'ahu", published by University of Hawaii Press.

activity. Deepwater hurricane-generated waves and Kona Storm waves can impact the site with large breaking wave heights at the shoreline. Assuming a water depth of 30 feet near the base of the shoreline cliff, deepwater design wave height of 30 feet[4] with 12 second period, and a bottom slope of 1V:13H, the design breaking wave height is about 38 feet and the depth at which the design wave initiates breaking is also about 38 feet.[5]

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[4] From "Hurricane Vulnerability Study for Honolulu, Hawaii, and Vicinity, Volume 2, Determination of Coastal Inundation Limits for Southern Oahu from Barbers Point to Koko Head", prepared for the U.S. Army Engineer Division, Pacific Ocean, prepared by Charles L. Bretschneider and Edward K. Noda and Associates, Final Report dated May 1985. Estimated deepwater design wave based on SE Model Scenario Hurricane, wave approach direction from approximately 175 degrees true.

[5] Breaking wave height and breaking depth as determined from the "Shore Protection Manual", U.S. Army Corps of Engineers, Coastal Engineering Research Center, Waterways Experiment Station, 1984.

3.0 DESIGN CONSIDERATIONS AFFECTING THE INLET/OUTLET

Figure 6 depicts the conceptual plan for conveying water to and from the ocean and Koko Crater. The required tunnel size between the powerhouse and the inlet/outlet structure is 25 feet. Two basic alternatives are available for the inlet/outlet structure. These are: (1) continuous tunneling offshore to the inlet/outlet structure location; (2) tunneling to the shoreline, with a conduit extending to the base of the cliff and an offshore breakwater to protect the inlet/outlet. Figure 7 shows these two options.

Site A is the preferred location for the first option (Option A, Figure 7-a), because tunneling distance between Koko Crater and the inlet/outlet location is minimized. The inlet/outlet structure would be extended sufficiently far offshore such that it would not be subject to large breaking waves. For an estimated deepwater design wave of 30 feet with 12-second period, the breaking depth is about 38 feet. Therefore, based on the estimated bathymetry along the tunnel alignment, it is recommended that the inlet/outlet structure be located at least about 300+ feet from shore in water depth of about 50 feet or greater. While the inlet/outlet structure would not be subjected to breaking wave forces, the structure would still need to be designed for stability under the wave velocities and accelerations imposed by the design wave conditions. As depicted in Figure 7-a, the inlet/outlet is extended about 500 feet offshore to water depth of about 65 feet, at which point the conduit is fully exposed on the ocean bottom with a clearance depth above the conduit of about 30 feet.

Site B is the preferred location for the second option (Option B, Figure 7-b). This option requires the initial construction of a cofferdam so that the conduit could be constructed in the "dry".

An offshore breakwater is also necessary to provide wave protection. The shoreline configuration at Site B is ideal because the small cove can be enclosed more easily by the breakwater. Because of the relatively deep water depths near the shoreline, the conduit need not be extended a great distance offshore to reach sufficient depth of water for the inlet/outlet. It is estimated that a conduit length of less than 100 feet may be required, dictated primarily by the requirement to place the breakwater at least about 150 feet from shore to provide sufficient work area. As depicted in Figure 7-b, the inlet/outlet daylights at the base of the shoreline cliff, with excavation of the ocean bottom to the invert depth of about 50 feet. The breakwater provides a wave-protected environment for the inlet/outlet during construction and operation. Because large breaking waves could be expected at the shoreline, the breakwater structure would protect the inlet/outlet from storm wave impact and prevent large fluctuations in the water surface elevation.

The breakwater structure would preferably be a rubblemound structure. The rubblemound breakwater would not only dissipate wave energy more effectively than an impervious structure, but would also serve to "filter" large objects from the intake waters. For a rubblemound breakwater structure, the armor size would necessarily have to be very large for stability under the design wave conditions. Assuming the use of dolos concrete armor units, the individual dolos units would be on the order of 40 tons. Figure 8 shows a conceptual typical section for a rubblemound breakwater. The conceptual design was developed using the Automated Coastal Engineering System (ACES)[6] computer

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[6] Automated Coastal Engineering System (ACES) Version 1.07a, April 1993, developed by the Automated Coastal Engineering Group, Research Division, Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station.

program. The application for breakwater design provides estimates for armor weight, minimum crest width, armor thickness, and the number of armor units per unit area of a breakwater using Hudson and related equations.

The breakwater crest elevation need not be high enough to prevent wave overtopping during design wave conditions. The primary consideration is to reduce wave heights sufficiently to permit construction and efficient operation of the inlet/outlet. For the conceptual breakwater design, the transmitted wave heights were estimated using the ACES computer program. The ACES application for determining wave transmission through a permeable structure uses a method developed for predicting wave transmission by overtopping coefficients using the ratio of breakwater freeboard to wave runup (suggested by Cross and Sollitt, 1971), combined with the model of wave reflection and wave transmission through permeable structures of Madsen and White (1976). Table 2 provides the results for a range of wave conditions.

A breakwater crest elevation of +12 feet MLLW would result in minimal or no wave overtopping during typical high wave conditions (say up to 18-foot waves that could be expected on an annual basis). However, because of the permeability of the structure, transmitted wave heights would be about 3 feet (or less). The transmitted wave height for the design wave condition would be about 7 feet due to both overtopping and transmission through the structure. The breakwater crest width and crest elevation are considered the minimum necessary. A higher or wider crest would result in reduced wave transmission, but with greater cost and visual impacts.

TABLE 2
TRANSMITTED WAVE HEIGHTS FOR BREAKWATER UNDER VARIOUS WAVE CONDITIONS

Wave Conditions	K_R	K_{Tt}	K_{To}	K_T	H_T (ft)
10 ft, 14 sec south swell	0.57	0.19	0.0	0.19	1.9
14 ft, 14 sec extreme south swell	0.57	0.16	0.04	0.17	2.3
14 ft, 9 sec storm-generated waves	0.18	0.15	0.0	0.15	2.1
18 ft, 10 sec storm-generated waves	0.23	0.14	0.07	0.16	2.8
22 ft, 11 sec storm-generated waves	0.33	0.13	0.14	0.19	4.2
26 ft, 11 sec storm-generated waves	0.32	0.12	0.18	0.22	5.6
30 ft, 12 sec design wave	0.42	0.11	0.22	0.24	7.2

K_R = wave reflection coefficient
K_{Tt} = wave transmission coefficient through structure
K_{To} = wave transmission coefficient by overtopping
K_T = total wave transmission coefficient = $(K_{Tt}^2 + K_{To}^2)^{1/2}$
H_T = transmitted wave height = K_T x incident wave height

Other design alternatives are available for the breakwater structure, such as using concrete caissons or other concrete wave-absorbing structures. These structures would be prefabricated and installed in modules to form the continuous breakwater. Generally, such concrete structures are more costly to construct than a rubblemound structure. If designed to permit throughflow, they are also more difficult to design with respect to wave energy absorption and wave transmission characteristics. However, depending on the availability of materials for the rubblemound structure and the constructability aspects (wave exposure and accessibility), modular concrete breakwater alternatives may be cost-competitive.

4.0 POTENTIAL OCEANOGRAPHIC IMPACTS

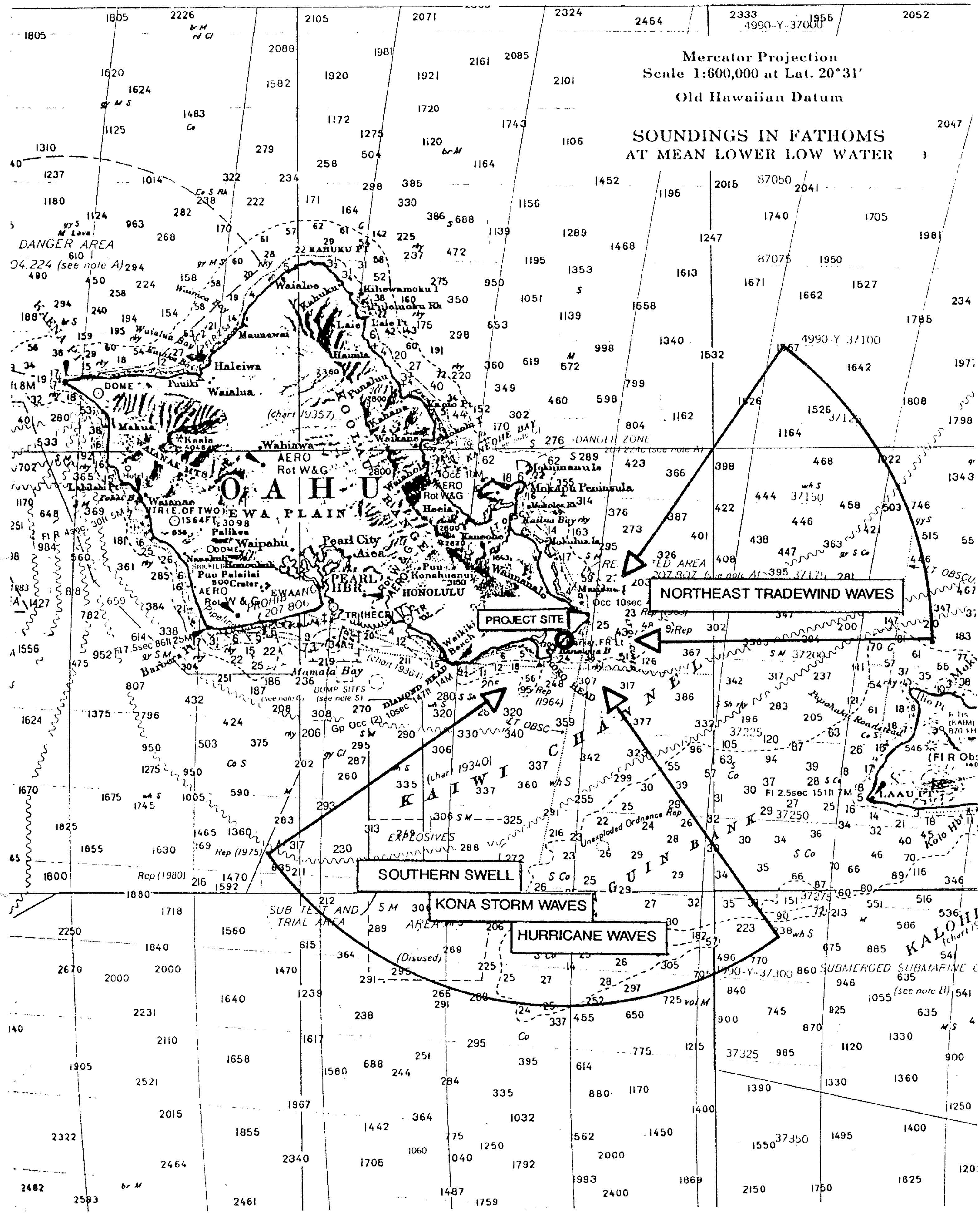
The potential significant oceanographic impacts during construction are primarily related to turbidity generated by the in-water activities and the area of ocean bottom impacted by the construction. The continuous tunneling option would result in the least impacts since the in-water activities would be limited in scope and duration. Disturbance to the ocean bottom would occur only along the tunnel alignment after it daylights at the ocean bottom. Because of the deep depths, wave exposure, and strong currents, silt-containing devices (such as silt screens) would not be effective. However, the turbidity impacts would be expected to be minimal since the high energy ocean environment would quickly disperse the silts that may be generated by the excavation.

The second option, where the conduit daylights at the shoreline cliff and is protected by an offshore breakwater, would not generate significant turbidity if the construction is performed in the dry. However, construction of the rubblemound breakwater could result in turbidity generated over a more extended time frame, but with lower turbidity levels than associated with breaking through the ocean bottom (which may require the use of explosives). The cofferdam construction, to enable the installation of the conduit in the dry, would impact the shoreline area because the water areas landward of the cofferdam would be filled after installation of the conduit. The rubblemound breakwater, while permanently covering the ocean bottom under its footprint, would be expected to enhance the marine biota in the vicinity by providing a more diverse habitat. In addition to the new tidal and subtidal habitat created by the breakwater slopes, the protected waters within the confines of the breakwater would also provide sheltered habitat where none currently exists along this wave-exposed shoreline.

Neither options would significantly impact existing littoral processes. Because of the paucity of sand in the offshore area, potential impacts to littoral transport is not an issue. There would be no impacts to the sandy beach areas located about 1 mile northeast of the site nor to Hanauma Bay located approximately 1 mile southwest of the site.

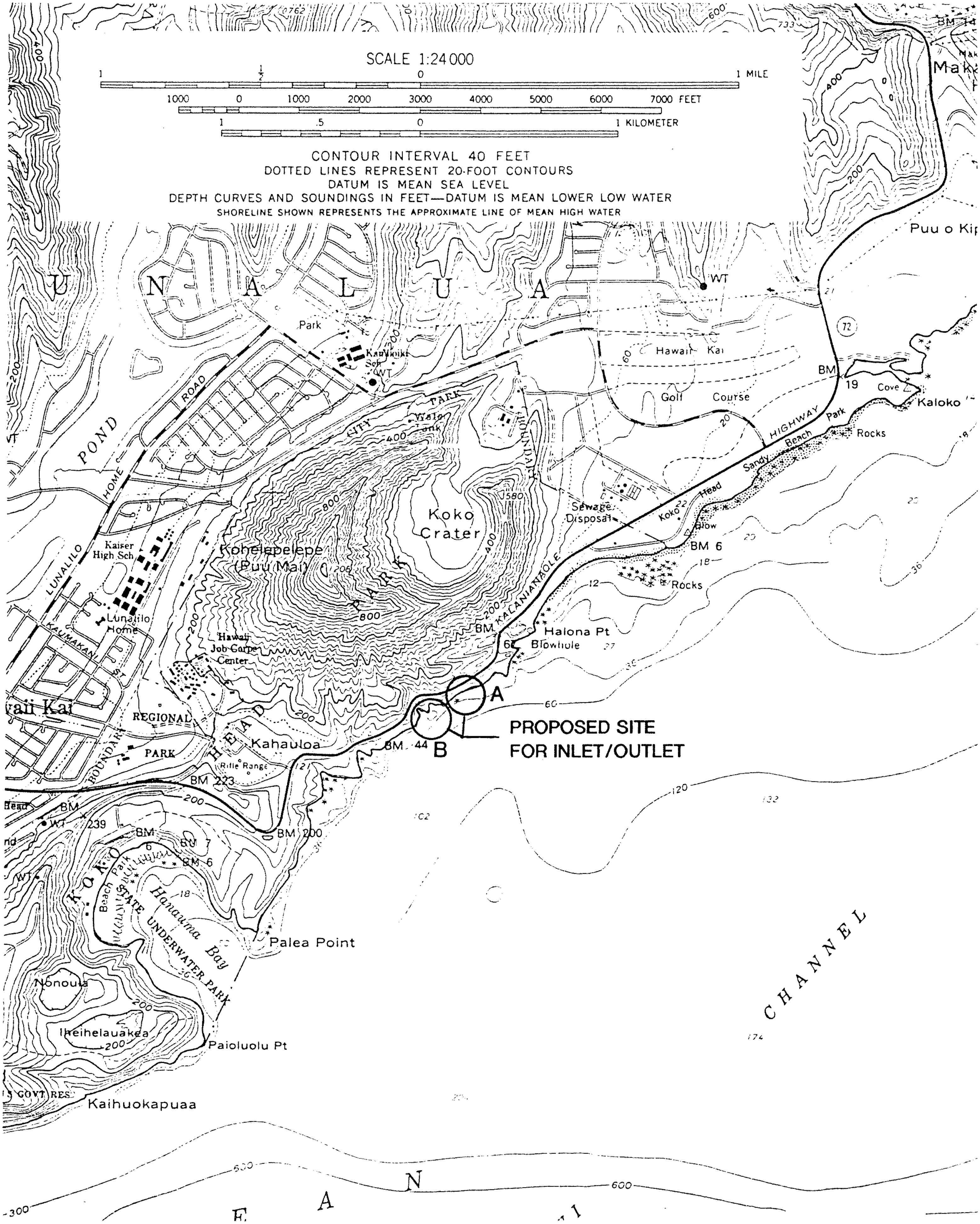
The project site is also sufficiently isolated from Halona Blowhole, such that there will be no significant impacts in the short-term or long-term due to the in-water construction.

There are potential public safety concerns due to the nearshore or offshore structures. For the offshore inlet/outlet structure, there is a concern with respect to the safety of divers who may be "caught" by the high flows. The inlet/outlet should be designed to prevent divers (or other large marine animals) from either approaching too close to the inlet/outlet (i.e. provide a cage structure around the inlet/outlet), or from being entrained by the flows (i.e. by design of the inlet/outlet structure). For the breakwater-enclosed inlet/outlet option, the shoreline should be adequately secured to prevent access to the breakwater-enclosed water area. Because there is always the possibility that persons may trespass into the secured shoreline area, the inlet/outlet should also have measures to prevent entrainment by intake flows.



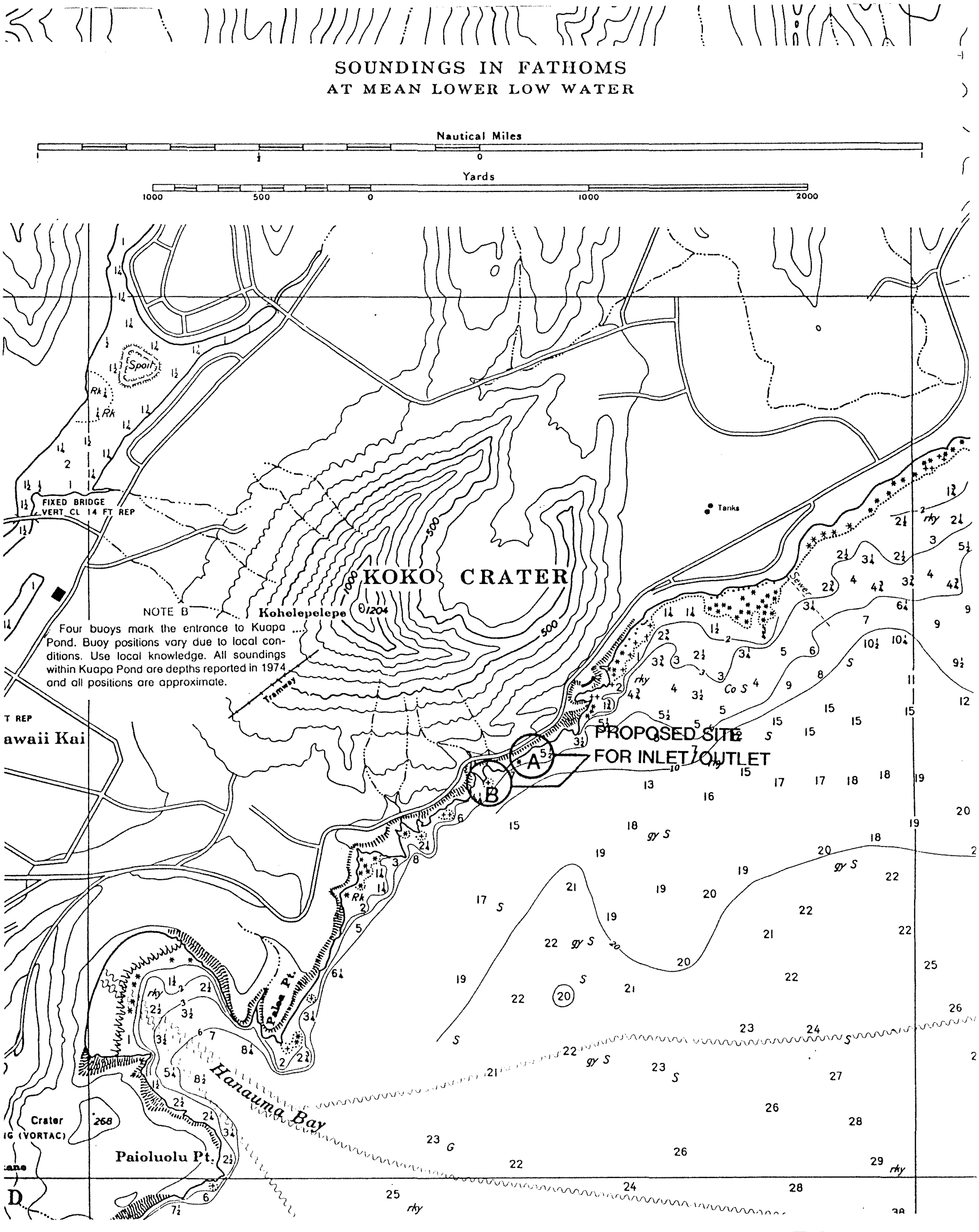
Location Map Showing Sectors of Wave Exposure

FIGURE 1



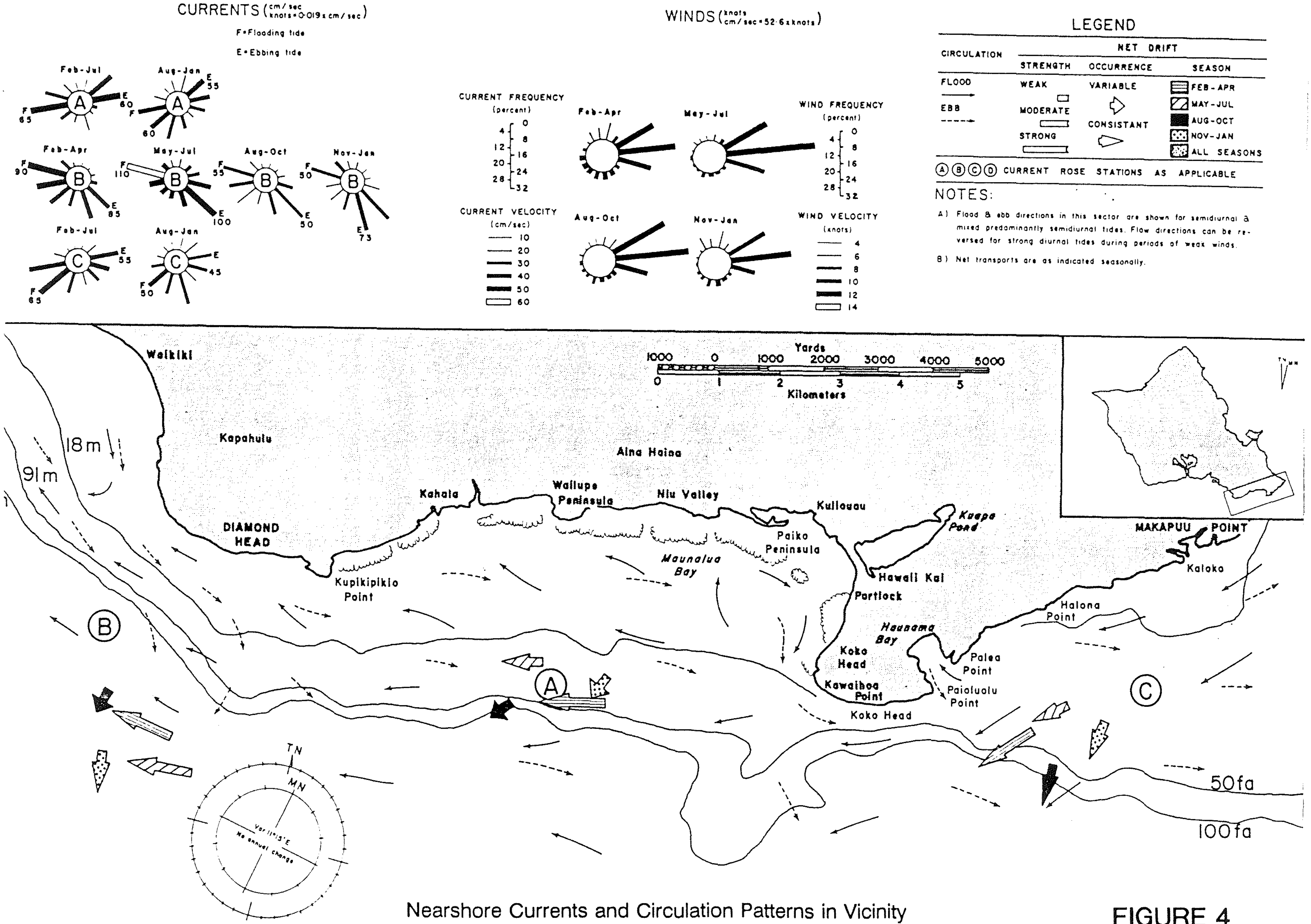
USGS Topographic Map of Vicinity (Scale 1:24,000)

FIGURE 2



NOAA Hydrographic Chart of Vicinity (Scale 1:20,000)

FIGURE 3



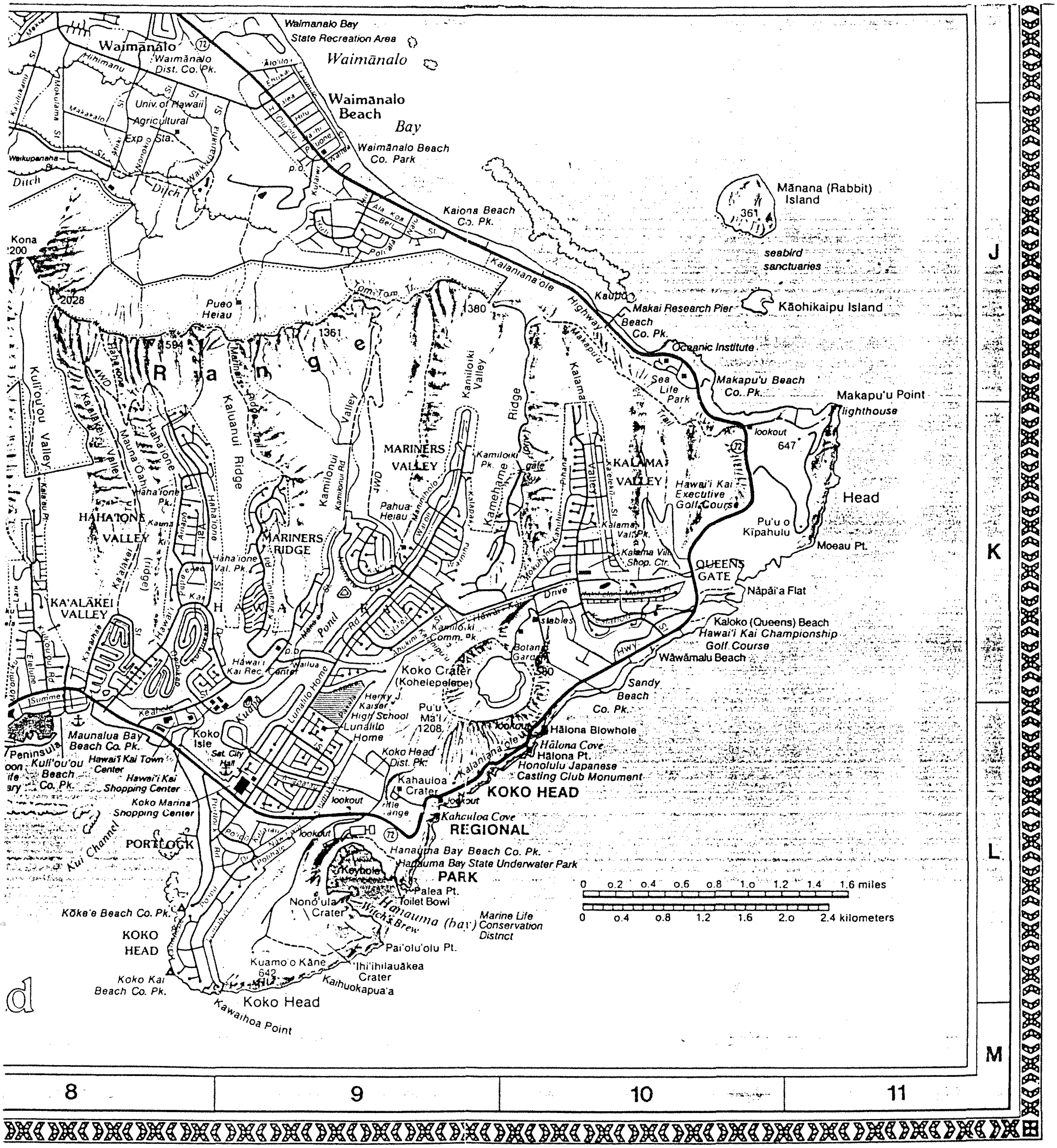
NOTES:

A) Flood & ebb directions in this sector are shown for semidiurnal & mixed predominantly semidiurnal tides. Flow directions can be reversed for strong diurnal tides during periods of weak winds.

B) Net transports are as indicated seasonally.

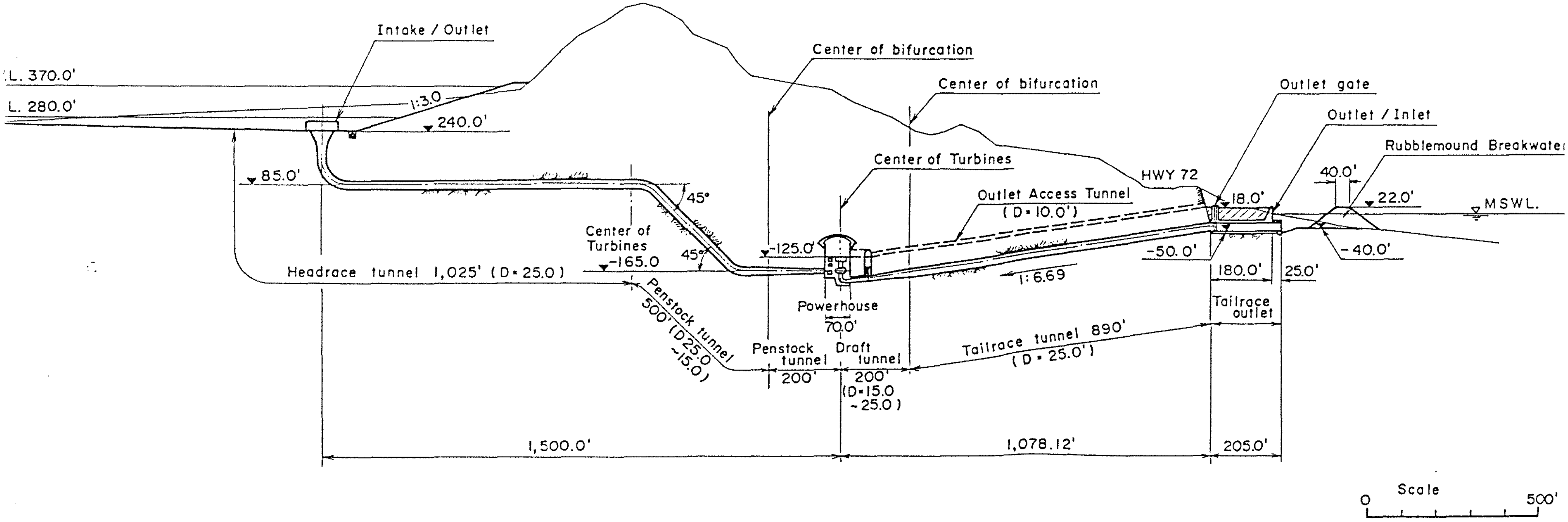
Nearshore Currents and Circulation Patterns in Vicinity
(from Circulation Atlas for Oahu, Hawaii by Karl H. Bathen, 1978)

FIGURE 4



Reference Map Showing Points of Interest
(published by University of Hawaii Press)

FIGURE 5



Conceptual Profile for Koko Crater Pumped Storage Hydroelectric System
(from EPDC International Ltd.)

FIGURE 6

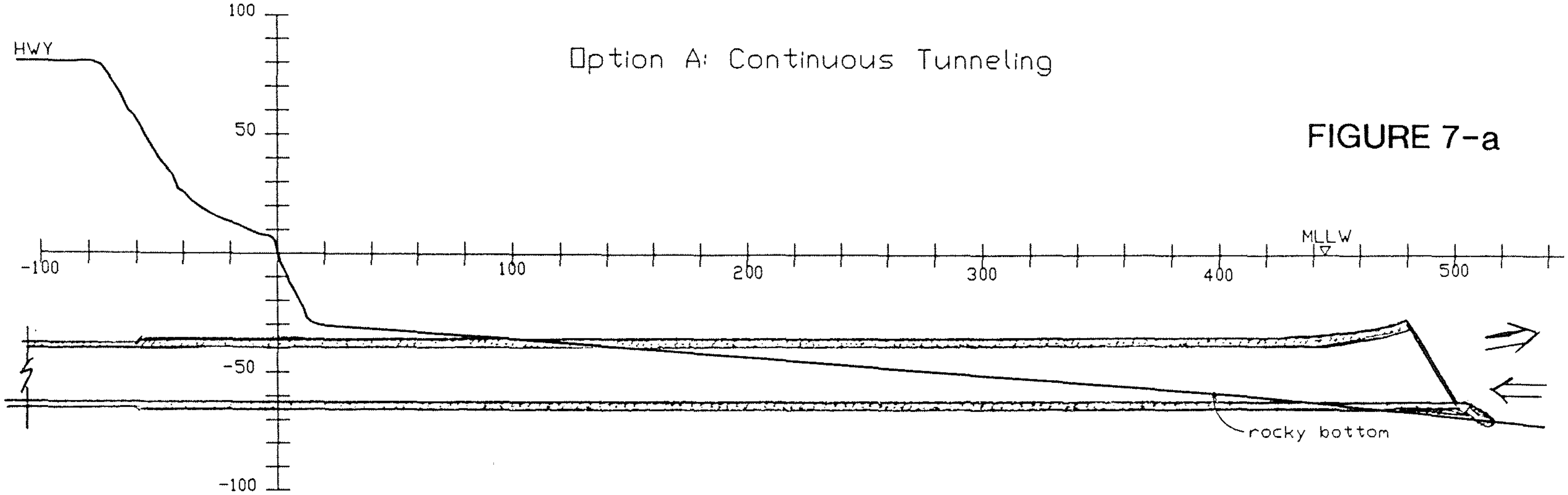


FIGURE 7-a

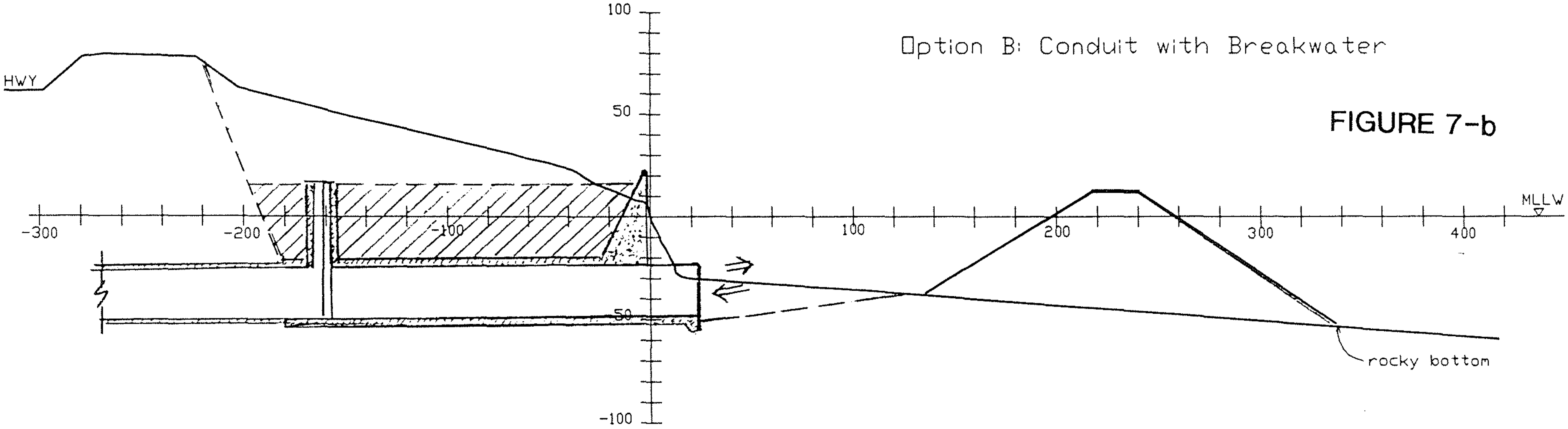
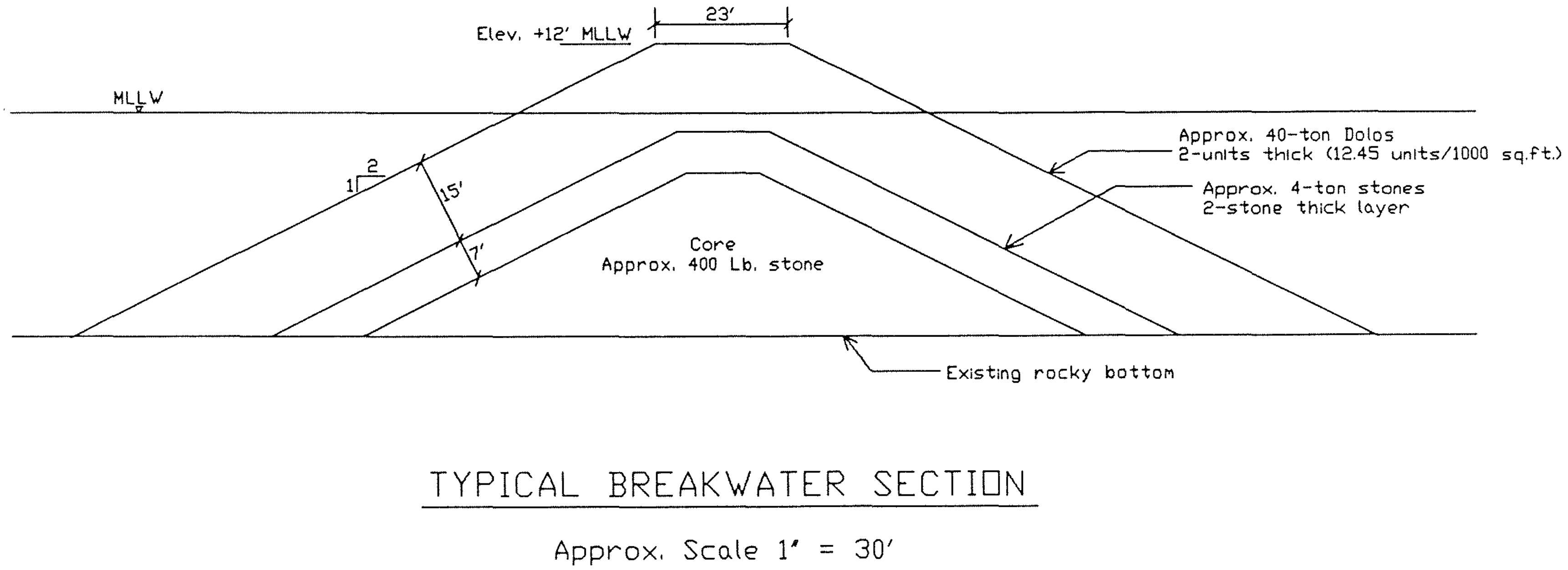


FIGURE 7-b

Conceptual Profile for Inlet/Outlet Options
(after EPDC International Ltd.)

FIGURE 7



Conceptual Typical Section for Rubblemound Breakwater

FIGURE 8

GENPP 19-8
TA/R

INTEROFFICE CORRESPONDENCE

Hawaiian Electric Co., Inc. An HEI Company

November 1, 1993

To: Thomas C. Simmons
From: Debbie Fujikami
Subject: Pumped Storage Hydro Feasibility Study

The following is our rough analysis to provide to Okahara & Associates, Inc. (Lou Lopez) for their pumped storage hydro feasibility study.

Objective

The objective of this analysis is to determine, as a first step in the pumped storage hydro feasibility study, how a pumped storage hydro unit fits into the HECO system in the year 2005, in terms of daily versus weekly cycling, pumping and generating hours, and size (MW) limits.

Conclusions

Pumped storage hydro (PSH) units have the potential to save fuel for the HECO system. Daily cycling of a PSH unit intuitively makes sense because of the daily pattern of load. Daily cycling is supported by the analysis which shows more fuel savings with daily cycling than weekly cycling.

The number of pumping hours is about 8 (around 10 p.m. to 6 a.m.) and the number of generating hours is up to about 14 (around 7 a.m. to 9 p.m.). Based on the preliminary results, a 100 to 180 MW (generating) PSH unit could be utilized in 2005 on the HECO system. 180 MW is the upper limit so as not to increase spinning reserve requirements (spinning reserve is equal to the largest unit on the system which is presently 180 MW).

Analysis

GEPPS

GEPPS was run first to determine an addition schedule (see Exhibit 1). This run is with the new load forecast (8/27/93, revised in an 10/8/93 IOC) and follows the resource sequence from the IRP plan (REP-1). A combustion turbine (CT) is added in 1998 based on the current contingency plan. PROSCREEN and HEPROSIM runs were then made.

APPENDIX G

PROSCREEN
Five PROSCREEN runs were made based on the GEPPS plan.

1. No PSH unit.
2. 100 MW PSH unit in 2000. No second CT (2012). PSH has 1 cycle/week.
3. 200 MW PSH unit in 2000. No second CT (2012). PSH has 1 cycle/week.
4. 100 MW PSH unit in 2000. No second CT (2012). PSH has 5 cycles/week.
5. 200 MW PSH unit in 2000. No second CT (2012). PSH has 5 cycles/week.

These runs consistently show fuel savings with the PSH unit from the time the unit is installed. Also, the runs consistently show more fuel savings with 5 cycles/week (daily cycling) than 1 cycle/week (weekly cycling) from the time the unit is installed. Further, the runs consistently show more fuel savings with the 200 MW PSH unit than the 100 MW unit (the pumping and generating capacities were assumed to be the same). These results show that there is a potential for fuel savings by adding a PSH unit, and that in terms of fuel savings, daily cycling is preferable to weekly cycling, and a 200 MW PSH unit is preferable to a 100 MW unit.

A comparison of the annual generation for the four cases with a PSH unit shows that the PSH generates more with daily cycling than weekly cycling, especially when the coal-fired fluidized bed combustion (FBC) units are on the system. In the runs, FBC units are added in 2005 and 2009. The 200 MW PSH unit generates more than the 100 MW unit, especially when the FBC units are on the system. These results show that there is a potential to utilize a PSH unit more with daily than weekly cycling and that there is a potential to use more energy than that provided by a 100 MW PSH unit. Also, the FBC units appear to contribute greatly towards the energy stored in the PSH units.

HEPROSIM
HEPROSIM was run for the year 2005 based on the GEPPS plan, with no PSH unit. This run shows the hourly dispatch of units assuming the load profile in Exhibit 2. The run (see Exhibit 3) was supplemented with a tabulation of numbers at the bottom of the exhibit. These numbers show the capacity available (from HPOWER, AES, Kalaeloa, and a FBC unit) to store energy into a PSH unit, and the load on other units (Kahe 1-6, Waiau 3-8, G1-2 which represent Waiau 9-10, and G3 which is a CT) that may be displaced by a PSH unit. As shown in this exhibit, the PSH unit may be pumped during the late night and early morning hours (around 10 p.m. to 6 a.m.) and may generate during the day (around 7 a.m. to 9 p.m.). Note that the HEPROSIM run assumes that the FBC unit is base loaded, and this affects the Kalaeloa energy purchase amount.

According to these results, a PSH unit with a 215 MW pumping capacity is needed (see SUM (Off-Peak) in hour 3). Assuming the PSH unit will not displace the Kahe units, these results show a need for a PSH unit with a 135 MW generating capacity (see SUM w/o KAHE in hour 12). Note that since the unit loadings are for an hour, they represent energy (megawatthours) as well as load (megawatts). The pumping energy is in the ballpark of the generating energy (1331 MWH pumping versus 1496 MWH generating). Exhibit 4 graphs the hourly unit loading of Exhibit 3.

Attachments
cc: L. Ebisui/S. Higa
D. West

IRP GENPP 22, Studies/Statistics

GPD-cf

GEPPS Addition Schedule

HE-GEPPS MK 3 CAPACITY MODEL SUMMARY FOR 1993 THRU 2013 RUN PL191 /PU1877 /PB344 10/15/93

		MINIMUM SPECIFIED		ACTUAL	INSTALLED CAPACITY		NORM YEAR END MARGIN							UNIT RATINGS	
YEAR	PEAK	MARG	RISK	RISK	EMER	NORM	MW	PCT	UNIT	CHANGE	CAUSE	WEEK	MONTH	EMER	NORM
START					1730	1669									
1993	1162	0	4.50	118.05	1730	1669	507	43.6							
1994	1167	0	4.50	81.47	1730	1669	502	43.0							
1995	1169	0	4.50	81.08	1730	1669	500	42.8							
1996	1179	0	4.50	55.64	1730	1669	490	41.6							
1997	1187	0	4.50	42.68	1730	1669	482	40.6							
1998	1205	0	4.50	229.35	1818	1751	546	45.3	G1	ADDED	DATE	1	JAN	88	82
1999	1225	0	4.50	146.29	1818	1751	526	42.9							
2000	1246	0	4.50	60.94	1818	1751	505	40.5							
2001	1267	0	4.50	51.35	1818	1751	484	38.2							
2002	1290	0	4.50	20.47	1818	1751	461	35.7							
2003	1313	0	4.50	18.87	1818	1751	438	33.4							
2004	1336	0	4.50	10.40	1762	1695	359	26.9	H8	RETIRED		52	DEC	56	56
					1705	1638	302	22.6	H9	RETIRED		52	DEC	57	57
05	1360	0	4.50	4.89	1909	1832	472	34.7	F1	ADDED	RISK	22	JUN	204	194
06	1384	0	4.50	7.08	1909	1832	448	32.4							
2007	1410	0	4.50	4.76	1909	1832	422	29.9							
2008	1438	0	4.50	4.69	1860	1783	345	24.0	W3	RETIRED		39	SEP	49	49
					2010	1933	495	34.4	WA	ADDED	DATE	40	OCT	150	150
					1955	1881	443	30.8	W9	RETIRED		52	DEC	55	52
					1902	1831	393	27.3	W0	RETIRED		52	DEC	53	50
2009	1467	0	4.50	5.08	1853	1782	315	21.5	W4	RETIRED		30	JUL	49	49
					2003	1932	465	31.7	WB	ADDED	DATE	31	AUG	150	150
					2207	2126	659	44.9	F2	ADDED	RISK	44	NOV	204	194
2010	1497	0	4.50	24.20	2207	2126	629	42.0							
2011	1529	0	4.50	23.20	2150	2069	540	35.3	W5	RETIRED		52	DEC	57	57
					2092	2011	482	31.5	W6	RETIRED		52	DEC	58	58
2012	1561	0	4.50	4.94	2180	2093	532	34.1	G2	ADDED	RISK	14	APR	88	82
2013	1595	0	4.50	5.04	2268	2175	580	36.4	G3	ADDED	RISK	48	DEC	88	82

Trial 3

G1-G3:	Simple cycle combustion turbine
F1-F2:	Atmospheric fluidized bed combustion
WA-WB:	Waiau repower
H8-H9:	Honolulu 8, Honolulu 9
W3-W6, W9-W0:	Waiau 3-6, Waiau 9-10

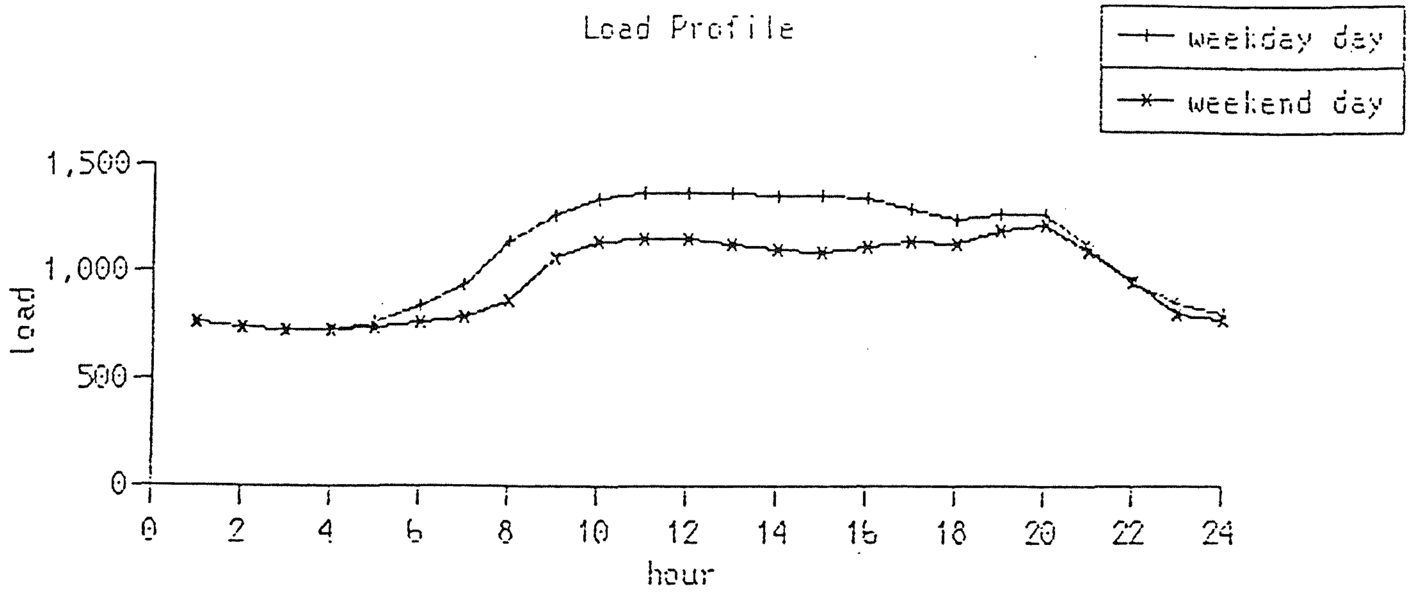
Exhibit 1

```
---------------------------  LOADPLOT - ENTRY PANEL  ---------------------------
COMMAND  ===>

   This program will display your load profile for a given week and year.

      Filename  ===> PL191        Week  ===> 31     Year  ===> 2005
```

August



```
Enter PF3 to cancel operation.
```

Exhibit 2

Projected Hourly Unit Loading (MW)
2005

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Unit	Min *	Max
System Load	758	736	725	728	763	831	941	1134	1263	1334	1357	1360	1358	1354	1348	1332	1288	1244	1260	1260	1119	950	847	801	H1	25	46
A1 (AES)	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	A1	63	180
F1 (FBC)	148	126	115	118	153	194	194	194	194	194	194	194	194	194	194	194	194	194	194	194	194	194	194	191	B2	65	180
B2 (Kalaeloa)	65	65	65	65	65	92	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	108	65	F1	53	194
H1 (H Power)	25	25	25	25	25	25	45	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	25	25	K1	35	
K5 (Kahe 5)	70	70	70	70	70	70	70	102	111	116	119	119	119	118	118	116	113	109	111	111	100	73	70	70	K2	35	
K4 (Kahe 4)	35	35	35	35	35	35	35	55	64	69	72	72	72	71	71	69	66	62	64	64	54	35	35	35	K3	35	
K3 (Kahe 3)	35	35	35	35	35	35	35	68	84	92	92	92	92	92	92	92	88	80	83	83	65	35	35	35	K4	35	
K2 (Kahe 2)	35	35	35	35	35	35	37	61	67	70	72	72	72	72	71	70	68	65	67	67	60	41	35	35	K5	70	
K1 (Kahe 1)	35	35	35	35	35	35	35	54	66	73	76	77	76	76	75	72	69	64	66	66	52	35	35	35	K6	60	
W8 (Waiau 8)	35	35	35	35	35	35	35	57	64	67	69	70	69	69	69	67	66	62	64	64	56	37	35	35	W3	0	
W7 (Waiau 7)	35	35	35	35	35	35	35	57	64	68	70	71	71	70	70	68	66	62	64	64	55	35	35	35	W4	0	
K6 (Kahe 6)	60	60	60	60	60	60	60	80	103	116	123	124	124	123	120	116	110	98	102	103	76	60	60	60	W5	0	
W6 (Waiau 6)									20	22	23	23	23	23	22	22	21	20	20	20					W6	0	
W5 (Waiau 5)									20	20	20	20	20	20	20	20	20	20	20	20					W7	35	
W4 (Waiau 4)										20	21	21	21	21	20	20									W8	35	
W3																									G1	0	
G3																									G2	0	
G1																									G3	0	
G2																											
Off-Peak																									Sum		
H1	21	21	21	21	21	21																0	21	21	168		
A1	0	0	0	0	0	0																0	0	0	0		
B2	115	115	115	115	115	88																0	72	115	850		
F1	46	68	79	76	41	0																0	0	3	313		
SUM (Off peak)	182	204	215	212	177	109																0	93	139	1331		
On-Peak																											
K1							0	19	31	38	41	42	41	41	40	37	34	29	31	31	17				472		
K2							2	26	32	35	37	37	37	37	36	35	33	30	32	32	25				466		
K3							0	33	49	57	57	57	57	57	57	57	53	45	48	48	30				705		
K4							0	20	29	34	37	37	37	36	36	34	31	27	29	29	19				435		
K5							0	32	41	46	49	49	49	48	48	46	43	39	41	41	30				602		
K6							0	20	43	56	63	64	64	63	60	56	50	38	42	43	16				678		
W3							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0		
W4							0	0	0	20	21	21	21	21	20	20	0	0	0	0	0				144		
W5							0	0	20	20	20	20	20	20	20	20	20	20	20	20	0				240		
W6							0	0	20	22	23	23	23	23	22	22	21	20	20	20	0				259		
W7							0	22	29	33	35	36	36	35	35	33	31	27	29	29	20				430		
W8							0	22	29	32	34	35	34	34	34	32	31	27	29	29	21				423		
G1 (Waiau 9)							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0		
G2 (Waiau 10)							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0		
G3 (CT)							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Sum		0		
SUM w/KAHE							2	194	323	393	417	421	419	415	408	392	347	302	321	322	178	►	4854		4854		
SUM w/o KAHE							0	44	98	127	133	135	134	133	131	127	103	94	98	98	41	►	1496				

* Minimum is zero for cycling and peaking units for the purpose of calculating the load that can be displaced by a pumped storage hydro unit.

HYDRO2A.XLS

E. it 3

Projected Hourly Unit Loading
2005

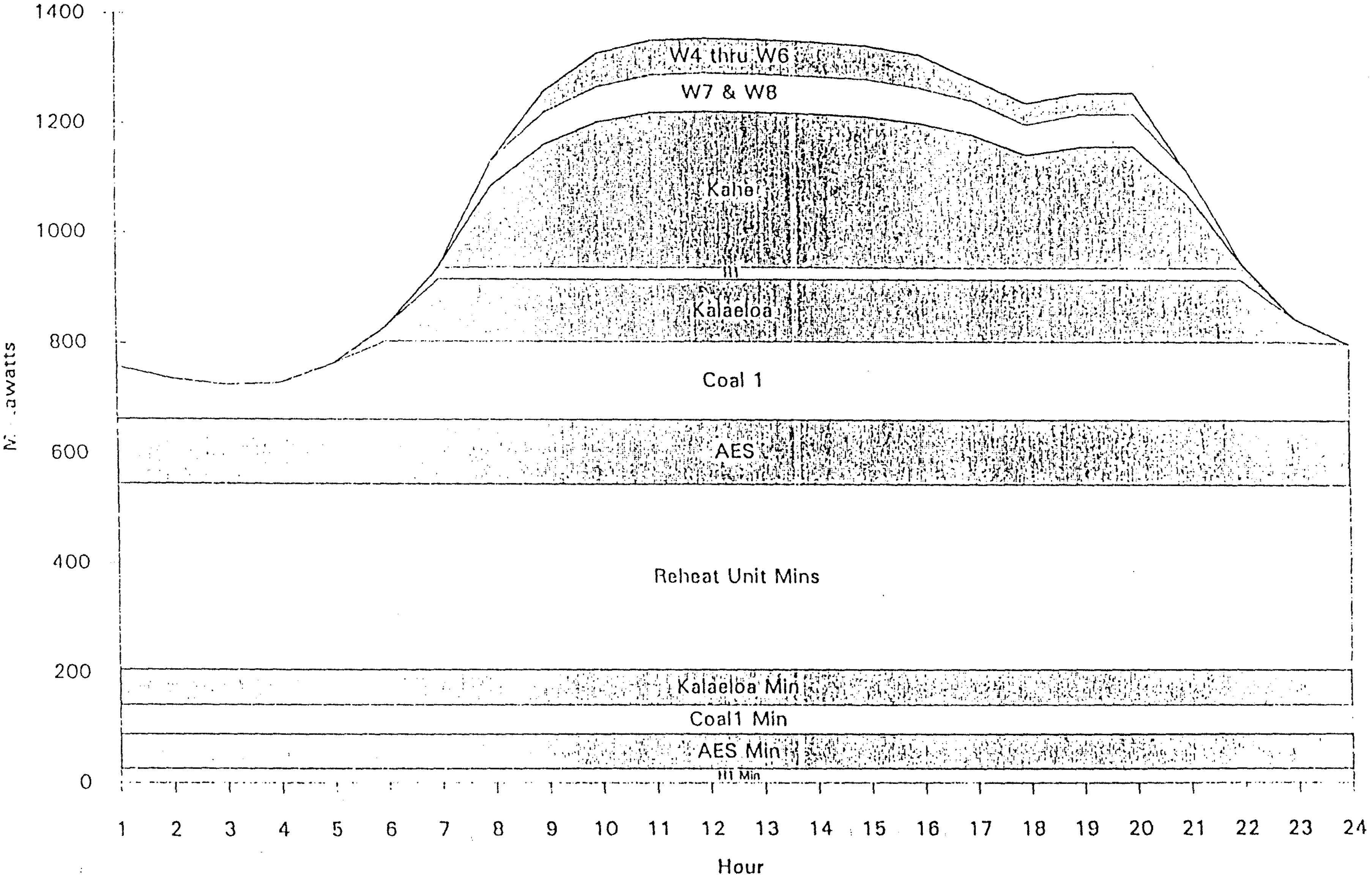


Exhibit 4

Hawaiian Electric Company, Inc. • PO Box 2750 • Honolulu, HI 96840-0001

CONST 112674
YA/G

February 11, 1994

Mr. Lou Lopez
270 Opihi Kau Way
Honolulu, Hawaii 96825

Dear Mr. Lopez:

Subject: Pumped Storage Hydroelectric Project
Transmission/Substation Cost Estimates

As requested at the December 1993 meetings with Mr. Yuzawa, the following transmission and substation information are attached:

1. Single line electrical diagrams for Kaau and Koko Crater locations;
2. Cost estimates for 138 kV transmission liens for Kaau and Koko Craters ($700,000 for one mile and $8.1 million for 9 miles, respectively); and
3. Cost estimates for 138 kV substation for Kaau and Koko Craters (7.3 to 12.5 million and $19.8 million, respectively.)

The costs are rough estimates. Please call me at 543-7987 if you have any questions.

Sincerely,

Arthur Seki
Energy Specialist

AS:kef
Enclosures

cc: M. Kaya (DBED)
D. Okahara (Okahara & Associates)
M. Tagomori (DLNR)
Route:RBM/JY/GKY (w/enclosures)

An HEI Company

APPENDIX H

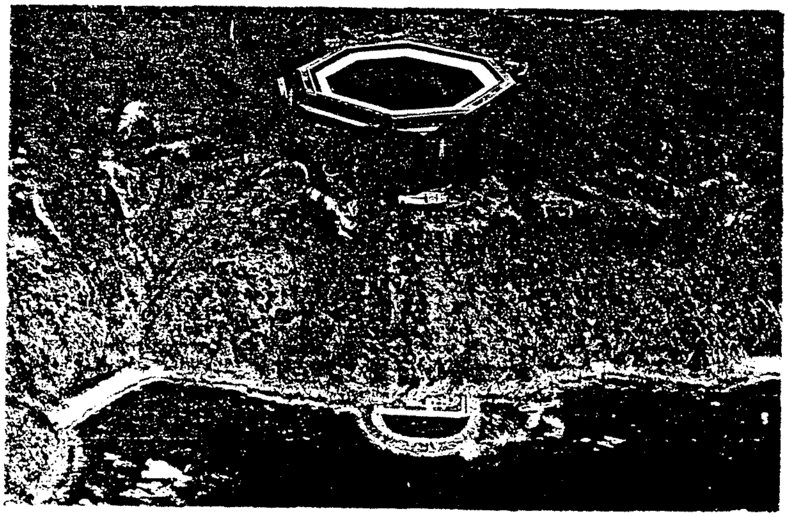
Demonstration Test of Seawater Pumped-Storage Power Plant

INTRODUCTION

The concept of seawater pumped-storage power generation, using the sea as the lower reservoir, is considered to be effective for Japan, as the country is surrounded by the sea and has steeply sloped coastlines. The Ministry of International Trade and Industry (MITI) has been conducting surveys of suitable sites for such a project since around 1960. However this type of power generation has not been developed as yet, since various technological and environmental problems arising from the use of seawater have not been resolved.

Electric Power Development Co., Ltd. (EPDC), under commission from MITI, had, since 1981, been conducting preliminary studies and feasibility, surveys concerning seawater pumped-storage power generation in Okinawa Prefecture as the object of investigation till 1989. As a result, EPDC had been able to identify most of individual technical problems involved. In 1990, EPDC began construction of this plant in Okinawa.

The plant is being constructed at Churasaku in the Kunigami village, on the Pacific coast of northern Okinawa Island, at the southern, end of the Japan archipelago. (See picture 1 & Figure 1)



Picture 1 Image Picture of the plant

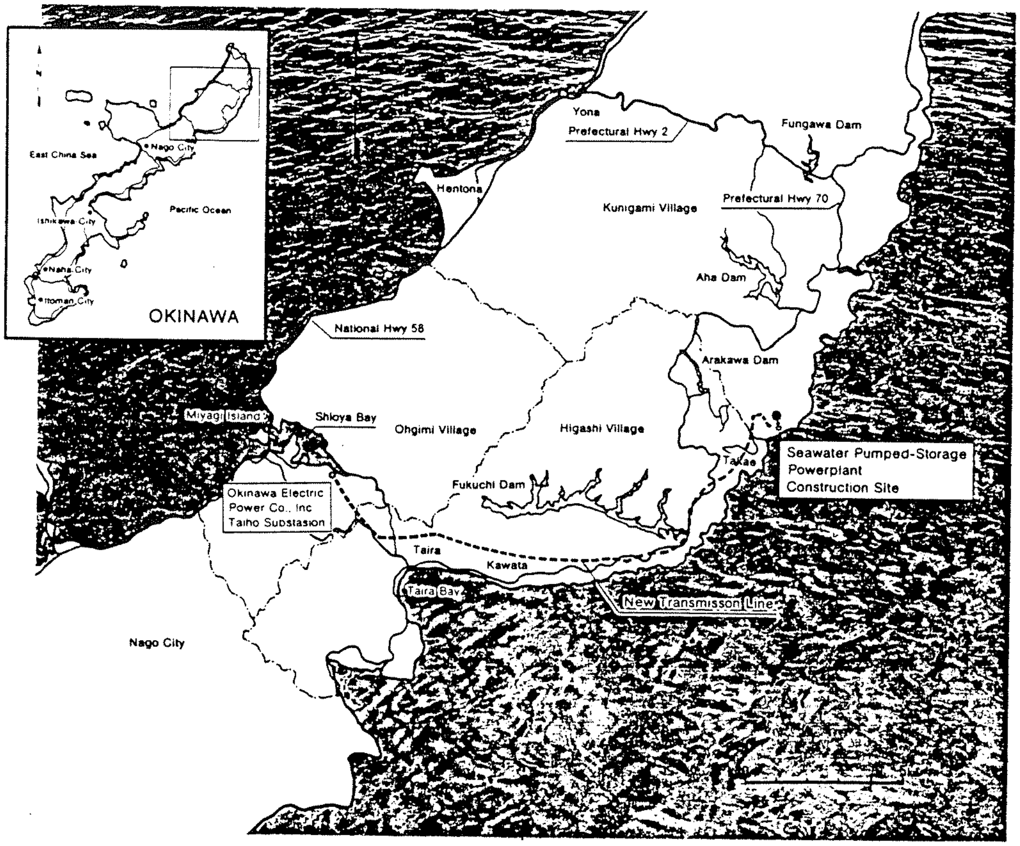


Figure 1 Location of the Plant

PURPOSE OF TEST

Pumped-storage electrical power generation is an efficient way in achieving optimal use from existing thermal and nuclear power generating plants.

Since Japan is surrounded by water, favorable geographical conditions exist for seawater pumped-storage power plants. Investigation and research of the phenomenon has been ongoing for a long time.

Before such power plants can be put to practical use, the concepts must be proven through extensive testing. MITI conducted six years of technical and environmental investigations in seawater pumped-storage power generation beginning in 1981. In 1987, MITI decided to start construction on a demonstration model plant. The plant has an output capacity of

30 megawatts and is unique as the worlds first seawater pumped-storage power generation facility.

This demonstration test is a government initiative undertaken by EPDC.

WHAT IS A SEAWATER PUMPED-STORAGE POWER PLANT?

Seawater pumped-storage power plants have several advantages over fresh-water pumped-storage power plants in current use. Costs for dam construction are lower since the sea is used as the lower reservoir. Furthermore, power transmission can be more efficient since the power plants can be built near electric power consumption areas. However, several technical and environmental concerns caused by using seawater will have to be solved.

Metal corrosion and marine organism growth is accelerated in seawater as compared to freshwater requiring the development of new technology.

Since seawater will be pumped to the upper reservoir, the environment will have to be protected from seawater seepage and spray caused by strong winds.

OUTLINE OF THE PROJECT

EPDC, under commission from MITI, has been making basic studies for resolving the problems peculiar to a seawater pumped-storage power project and of the measure to be taken.

As a result, an approximate outlook regarding the measures to be taken against the individual problems anticipated was obtained. As the next stage, it was decided that a comprehensive and long-term verification should be made by constructing a plant of real scale and carrying out trial operation. (See Figure 2.3, Table 1)

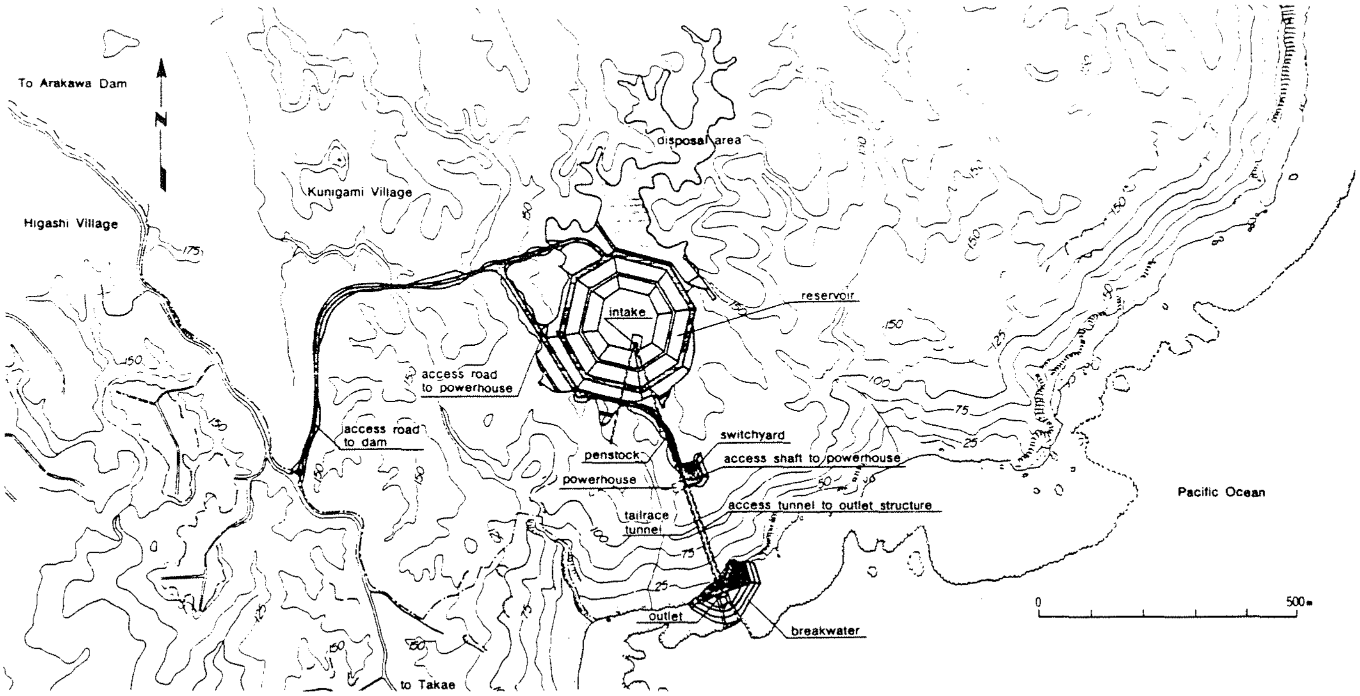


Figure 2 Plan of the Plant

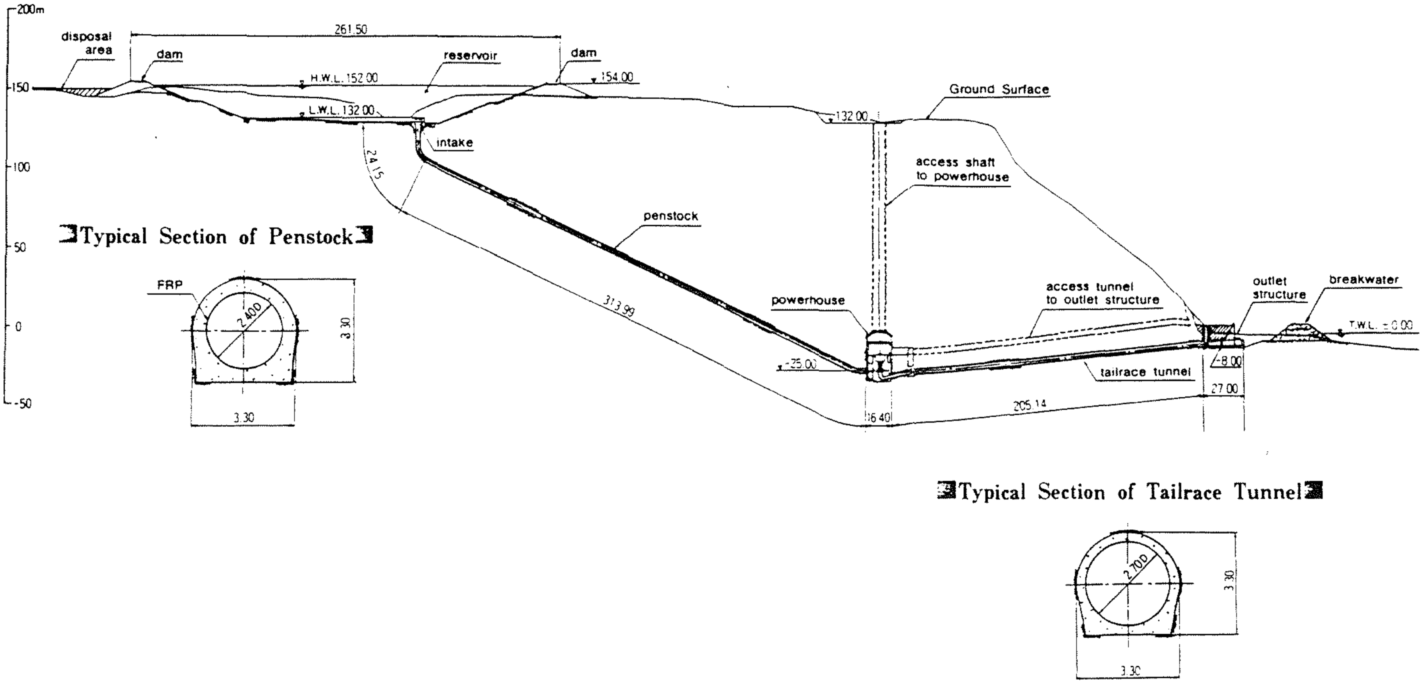


Figure 3 Profile of the Plant

Table 1 Specifications of the Plant

ITEM	UNIT	DATA
Regulating Reservoir		
High Water Level	m	152
Low Water Level	m	132
Available Drawdown	m	20
Water Surface Area	km^2	0.05
Gross Storage capacity	$10^6 m^3$	0.59
Effective Storage Capacity	$10^6 m^3$	0.56
Type		excavated type (Rubber Sheet Lining)
Dam		
Type	-	Filldam with Facing (Rubber Sheet Lining)
Height	m	25
Crest Length	m	848
Volume	$10^3 m^3$	360
Waterway		
Penstock (Inside Dia. x Length)	m x m	2.4 x 314
Tailrace Tunnel (Inside Dia. x Length)	m x m	2.7 x 205
Power Generating Scheme		
Normal Headwater Level	m	149
Normal Tailwater Level	m	0
Normal Effective Head	m	136
Maximum Discharge	m^3/s	26
Maximum Output	MW	30
Transmission Line (Churasaku-Taiho)	-	66 kV, 1 cct Total Length 18 km (Approx.)

The plant includes construction of an excavated type reservoir (approximately 250 x 250 m) on a table and of the elevation around 150 m approximately 600 m from the sea shore.

Maximum discharge of 26 m^3/s is drawn by an intake at the bottom of the reservoir, and conducted through a penstock of length approximately 340 m to a powerhouse provided approximately 150 m underground. After generation of a maximum output of 30 MW with the effective head of 136 m, the water goes through a tailrace tunnel of a length approximately 200 m and discharges into the sea from an outlet. During pump-up, seawater is pumped up in reverse from the sea to the upper regulating reservoir.

For transmitting the power generated and receiving the power for pump-up, a transmission line of 66 kV will be newly constructed over a distance of approximately 18 km for connection with Taiho Substation of Okinawa Electric Power Co., Inc.

After construction on the plant is completed, it will be operated for five years, during which time the plant will be checked for metal corrosion (to the turbine and other components), marine life growth (shellfish etc.), and environmental monitoring data will be collected. Total verification will be obtained for the use of seawater pumped-storage technology for electric power generation.

DESIGN OF FACILITIES

Upper Reservoir

Rubber sheet lining is to be provided as the sealing medium for the regulating reservoir, to prevent seawater from seeping into the surrounding ground. However, in case any leakage does occur, leakage detection and water collection systems are to be provided in a gallery beneath the reservoir.

The crest of the reservoir is to have a free-board of 2 m above, the high water level in view of the wave caused by strong winds (maximum wind speed 50 m/s during typhoons).

Furthermore, a 1 m high parapet is to be provided as a measure to prevent seawater spray.

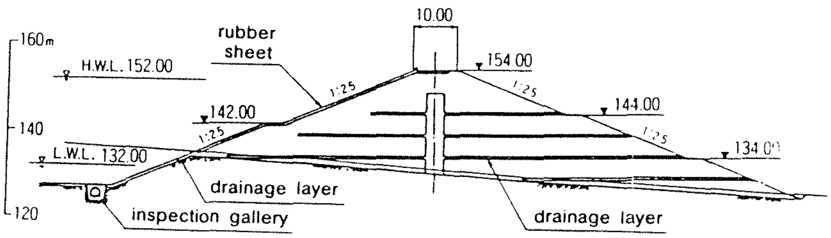


Figure 4 Typical Section of Dam

Waterway

To prevent seepage of seawater into the groundwater, the penstock is to have an inner lining mainly of fiberglass reinforced plastic pipe; steel pipe will also be used in place (at bends).

To minimize growth of marine organisms in the waterway, a special coating around the parts consisting of steel pipes will be provided. This coating will also serve to improve corrosion protection.

The tailrace is to be concrete-lined, but a special coating will be provided at the inner surface of the concrete to minimize adhesion of marine organisms.

Powerhouse

The powerhouse is to be an underground type provided approximately 150 m below the ground surface. The underground powerhouse cavern is to be 17 m in width, 32 m in height, and 41 m in length. The volume of excavation for the cavern is approximately 18,000 m^2.

For construction of the powerhouse, delivery of equipment such as the generator-motor, and for installation of an elevator and stairway, a vertical shaft of height 153 m and inside cross section 7 m x 7.6 m is to be provided adjacent to the powerhouse.

Intake and Outlet

Precast concrete breakwaters are to be set in the surroundings of the outlet, to minimize changes in flow conditions of the sea area and to reduce deep water wave reflection.

To minimize the effect on coral as much as possible, the approach flow velocity of the outlet screen is to be less than 1 m/s.

It was feared there could be adverse effects on the surrounding sea area as a result of changes in water temperature and water quality, depending on the length of time that seawater is retained in the upper reservoir. However a study showed it was considered that the changes would be very small.

Electrical Facilities

For the parts of the pump turbine requiring high strength such as runners and guide vanes, it is planned to adopt a modified variety of austenite type stainless steel judged to be optimum among stainless steels from the standpoints of strength, corrosion resistance, and forgoing technology. Regarding other members, the designs are to be for preventing rises in equipment cost by means such as the combined use of durable paint and electric corrosion protection.

IMPACT ON VEGETATION AROUND THE UPPER RESERVOIR

Plants with strong resistance to salt were found to grow thickly in the vicinity of the upper reservoir.

As a result of studies carried out concerning the salt spray from the upper reservoir, it was predicted that there would be no effect on vegetation in view of the small surface area of the plant reservoir. During investigations concerning salt damage to sugar cane (which is the main agricultural crop of Okinawa), it was found that wind damage during typhoons is a considerably more serious problem in Okinawa Island than salt damage.

To confirm these predictions and assessments, some observations and measurements of groundwater levels, salt concentrations in soil, and salt spray quantities, are to be carried out in the monitoring process before and after construction.

ENVIRONMENTAL PROTECTION

As a result of environmental assessment, it is believed that the environmental impact of the plant will be minimal by taking following measures.

1. The total surface area within the upper reservoir will be covered with a rubber sheet to protect the reservoir from seawater seepage.

2. The waterway will be lined with FRP (Fiber glass Rainforced Plastic) to prevent corrosion and to protect from seawater seepage.

3. Special emphasis will be made on water velocity and the outlet structure to protect coral and marine life from the inflow and outflow.

4. The tunnel and powerhouse will be located underground to ensure the existing pleasant natural scenery is retained.

Maximum emphasis and care will be taken to ensure minimal disturbance of the natural habitat and wildlife. Emphasis will also be place on minimizing the effect of noise, vibration, and water discoloration.

WHAT IS A VARIABLE SPEED PUMPED-STORAGE SYSTEM?

This system can control pumping input and generating output by changing the rotational speed of motor/generator. Characteristics of a variable speed system are:

1. An AFC (Automatic Frequency Control) pumping operation becomes possible because of variable pumping input.

2. A variable speed system can be operated at the optimum speed of a pump-turbine. Therefore the system efficiency is much improved. and operating range can be expanded.

3. A variable speed system can control effective power rapidly to improve power system stability.

TEST DEMONSTRATION

The following items will be tested:

1. Tolerance of materials against corrosion, salinity, etc.

2. Observation of marine growth adhering to materials and a determination of measures to protect the materials.

3. Effects of seawater spray on the surrounding environment.

4. Evaluation of the variable speed pumped-storage system.

5. Evaluation of the seawater pumped-storage power plant operation interconnected with the power system.

OPERATION OF A PUMPED STORAGE POWER PLANT

Electrical consumption varies greatly through the day. Consumption during late night and early morning is approximately 50% less than during daylight hours. However nuclear and thermal power plants are more efficient and economical if operated at a constant rate.

A pumped-storage power generation system can increase system efficiency since during times of low electrical usage, power from existing nuclear and thermal power plants can be used to drive turbines to pump water into the upper reservoir.

During daylight hours when high usage occurs, peak power can be generated by releasing water from the upper reservoir, through the pumped-storage power plant, on out to the lower reservoir. Significant savings can be realized using this technology.

Pumped-storage power generation is a very efficient method of saving electrical power during off peak times when an excess can be produced. Furthermore it is essential to develop these efficient power plants that rely on using water resources as renewable energy.

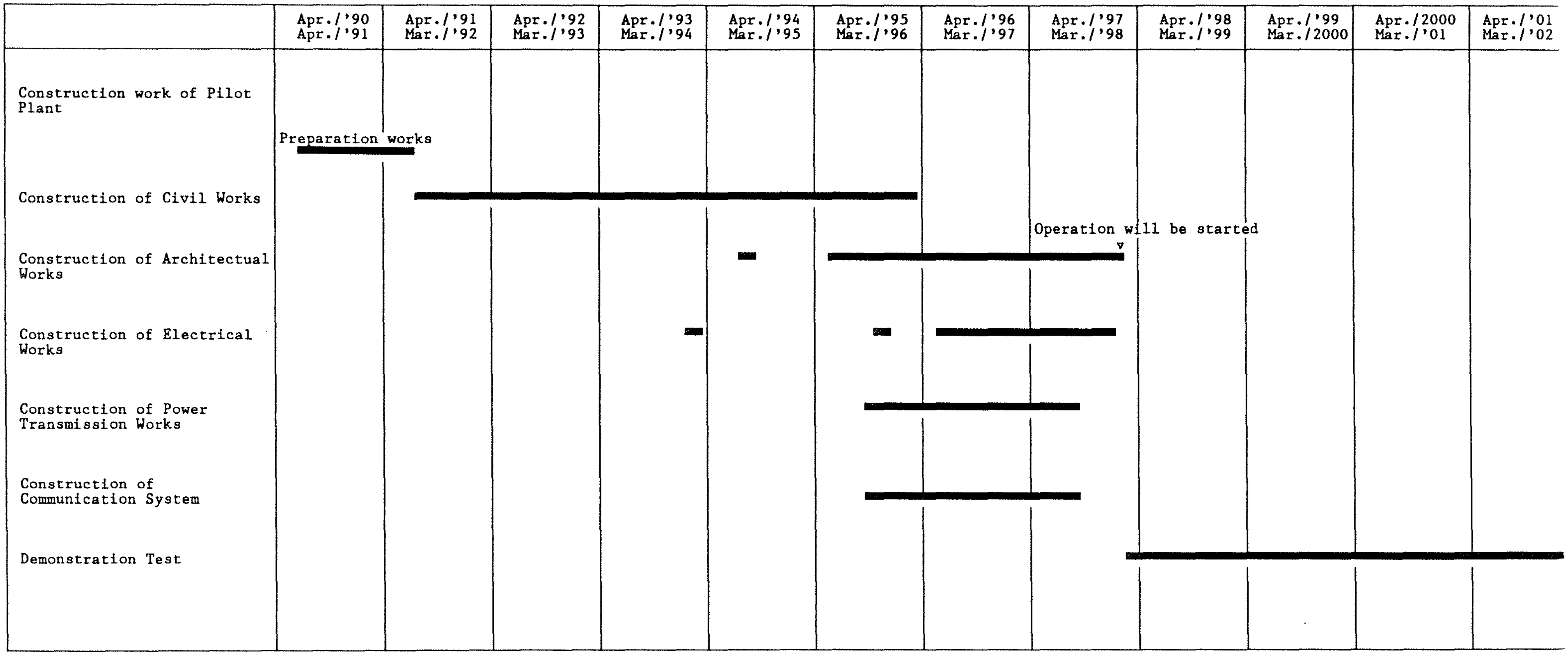
This project is a demonstration test of a seawater pumped-storage power plant sponsored by the MITI, and is undertaken by EPDC.

WORK SCHEDULE

The construction started in July, 1991 has progressed 60% of the total civil work as of April, 1993.

After construction on the plant is completed, test operation is to be carried out for a five-year period, during that period investigations will be made on corrosion protection effects (concerning metallic materials for the waterway and turbine), and the adhesion of marine organism. Also, environmental monitoring data will be collected for establishment of a comprehensive seawater pumped-storage power generation system.

Work Schedule



Progress of the Construction Works of the Seawater Pilot Power Plant on Okinawa

(progress of civil works up to end of the year 1993)

Item	Works	Progress
Reservoir	Excavation Embankment	83% 71%
Intake structure	Excavation Concrete	19% 0%
Penstock L = 314 m (ϕ 2.4 m)	Excavation Concrete	100% 100%
Drainage tunnel L = 187 m	Excavation Concrete	91% 65%
Disposal area	Excavation	-
Access road to dam L = 140 m	Excavation	-
Access road to powerhouse L = 380 m	Excavation	100%
Access shaft to powerhouse L = 148 m	Excavation Concrete	100% 11%
Powerhouse	Excavation Concrete	100% 18%
Draft gate hall	Excavation Concrete	99% 0%
Access tunnel to outlet structure L = 180 m	Excavation Concrete	100% 98%
Switchyard	Excavation Concrete	- -
Tailrace L = 205 m (ϕ 2.7 m)	Excavation Concrete	100% 0%
Outlet structure	Excavation Concrete Rubblemound Breakwater	78% 99% 60%

Total progress of civil works : approximately 65%

Total progress : approximately 35.4%

FILE : 1194BA **PROJECT :** KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : PROJECT SUMMARY SHEET 1 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
SUMMARY DIRECT COST CONSTRUCTION								
A. MOBILIZATION				1,180,000		350,000		1,530,000
B. SPECIAL PLANT				320,000		10,000		330,000
1. UPPER RESERVOIR				18,541,000		11,630,000		30,171,000
2. INTAKE STRUCTURE				1,787,000		1,068,000		2,855,000
3. i) PENSTOCK TUNNEL				7,144,000		5,673,000		12,817,000
ii) DRAFT TUBE TUNNEL				887,000		1,034,000		1,921,000
iii) TAILRACE TUNNEL				2,625,000		2,965,000		5,590,000
4. POWERHOUSE				5,677,000		7,040,000		12,717,000
5. DRAFT GATE HALL				2,253,000		740,000		2,993,000
6. OUTLET STRUCTURE				12,596,000		6,231,000		18,827,000
7. POWERHOUSE ACCESS				5,591,000		6,209,000		11,800,000
8. OUTLET ACCESS TUNNEL				949,000		2,263,000		3,212,000
9. POWERHOUSE EQUIPMENT				40,290,000				40,290,000
10. SWITCHYARD				14,348,000				14,348,000
11. TRANSMISSION LINE				5,861,000				5,861,000
TOTAL DIRECT COST				120,049,000		45,213,000		165,262,000
CONTRACTORS OH	15.00%							24,789,000
SUBTOTAL								190,051,000
CONTRACTORS CONTINGENCY & FEE	15.00%							28,508,000
SUBTOTAL								218,559,000
BOND & HAWAII G.I. TAX	4.50%							9,835,000
DESIGN / CM	6%							13,704,000
TOTAL PROJECT 1994 DOLLARS								242,098,000
OWNERS CONTINGENCY	5%							12,105,000
MITIGATING MEASURES	1%							2,421,000
TOTAL CONSTRUCTION 1994 DOLLARS								256,624,000
LAND AQUISITION								TO BE DETERMINED

FILE : 1194BA PROJECT : KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 2 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
A. MOBILIZATION								
OCEAN FRT	1,000	TNS	500	500,000				500,000
TOW	LS			500,000				500,000
LOCAL FRT	1,500	TNS	20	30,000				30,000
RIG UP	LS			75,000		250,000		325,000
RIG DOWN	LS			75,000		100,000		175,000
TOTAL				1,180,000		350,000		1,530,000
B. SPECIAL PLANT								
ELECTRIAL (SUBSTAION & MCC)	LS			100,000				100,000
VENT. FANS	LS			100,000				100,000
SPECIAL VENT FACILITY	900	LF	100	90,000				90,000
RAIL SWITCHES ETC	6	EA	20,000	120,000				120,000
DUMP PIT	LS			10,000		10,000		20,000
TOTAL				320,000		10,000		330,000

FILE : 1194BA **PROJECT :** KOKO CRATER - PUMPED STORAGE REV. NO. 0 29–Mar–94

ITEM : DIRECT COST SHEET 3 OF 10 PAGES

		QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
	<u>1. UPPER RESERVOIR</u>								
1A.	EXCAVATION CLEAR & GRUB	70	ACRES	600.00	42,000	2400.00	168,000	3000.00	210,000
	EXCAVATION	1,703,704	CY			2.00	3,407,407	2.00	3,407,407
	RIP MATERIAL	25,000	CY			1.00	25,000	1.00	25,000
	ROCK EXC. ALLOW	15,000	CY	5.00	75,000	10.00	150,000	15.00	225,000
	TOTAL	1,703,704	CY		117,000		3,750,407	2.27	3,867,407
1B.	EMBANKMENT SPREAD & ROLL	1,500,000	CY			1.50	2,250,000	1.50	2,250,000
	FINE GRADE	305,556	SY			0.40	122,222	0.40	122,222
	INSPECTION ROAD	12,700	SY	19.00	241,300			19.00	241,300
	TOTAL	1,500,000	CY		241,300		2,372,222	1.74	2,613,522
1C.	RUBBER MAT	305,556	SF	16.00	4,888,889	0.20	61,111	16.20	4,950,000
1D.	PROTECTIVE MAT (TUNNEL & POWERHOUSE EXC.)			MAT =	1.7 FT THICK				
	SPERAD, ROLL & COMPACT	170,000	CY			12.00	2,040,000	12.00	2,040,000
	TOTAL	2,750,000	SF				2,040,000	0.74	2,040,000
1E.	TRANSITION ROCK	376,852	TNS	20.00	7,537,037		0	20.00	7,537,037
	PLACE	203,704	CY			13.50	2,750,000	13.50	2,750,000
	TOTAL	203,704	CY		7,537,037		2,750,000	50.50	10,287,037
1F.	CONCRETE INSPECTION GALLERY	2,750	LF						
	EXC.	14,400	CY			6.60	95,040	6.60	95,040
	BACKFILL							N I C EXCAVATE NEAT	
	CONCRETE	14,333	CY	105.00	1,505,000	15.00	215,000	120.00	1,720,000
	FORM	57,750	SF	0.65	37,538	6.00	346,500	6.65	384,038
	RESTEEL	121,275	#	0.65	78,829			0.65	78,829
	TOTAL	14,333	CY		1,621,367		656,540	158.92	2,277,907
1G.	MEASURING INST.	LS			200,000				200,000
1H.	OTHERS 15.00% OF ABOVE	LS			3,935,381				3,935,381
	<u>TOTAL ITEM 1</u>				18,540,974		11,630,280		30,171,254
	<u>2. INTAKE STRUCTURE</u>								
	EXCAVATION MASS	2,963	CY			8.25	24,444	8.25	24,444
	EXCAVATION SHAFT	4,815	CY	28.00	134,815	87.00	418,889	115.00	553,704
	CONCRETE	7,407	CY	105.00	777,778	25.00	185,185	130.00	962,963
	FORMS	40,000	SF	4.00	160,000	7.50	300,000	11.50	460,000
	RESTEEL 100 #/CY	740,741	#	0.65	481,481			0.65	481,481
	OTHERS 15.00%	1	LS		233,111		139,278		372,389
	<u>TOTAL ITEM 2</u>	7,407	CY		1,787,185		1,067,796	385.42	2,854,981

FILE : 1194BA PROJECT : KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 4 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
3. i) PENSTOCK TUNNEL								
EXCAVATION - INCLINED PART								
UTILITIES & SUPPLY	9,333	CY	5.50	51,332			5.50	51,332
EXCAVATION	9,333	CY	7.00	65,331	110.00	1,026,630	117.00	1,091,961
GROUT	68,040	CF	4.50	306,180	7.50	510,300	12.00	816,480
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	500	LF	24.00	12,000	27.00	13,500	51.00	25,500
HAUL SPOIL	9,333	CY	1.25	11,666			1.25	11,666
TOTAL ITEM	9,333	CY		446,509		1,550,430	213.97	1,996,939
EXCAVATION - OTHER								
UTILITIES & SUPPLY	32,407	CY	5.50	178,239			5.50	178,239
EXCAVATION	32,407	CY	7.00	226,849	69.00	2,236,083	76.00	2,462,932
GROUT	120,000	CF	4.50	540,000	3.60	432,000	8.10	972,000
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	1,425	LF	24.00	34,200	27.00	38,475	51.00	72,675
HAUL SPOIL	32,407	CY	1.25	40,509			1.25	40,509
TOTAL ITEM	32,407	CY		1,019,797		2,706,558	114.99	3,726,355
CONCRETE -INCLINED PART								
FORM	39,270	SF	2.06	81,080	1.65	64,796	3.71	145,876
CONCRETE	2,814	CY	110.00	309,540	23.75	66,833	133.75	376,373
RESTEEL 85 #/CY	239,190	#	0.35	83,717	0.30	71,757	0.65	155,474
TOTAL ITEM	2,814	CY		474,337		203,386	240.84	677,723
CONCRETE - OTHER								
FORM	105,640	SF	5.25	554,160	1.90	200,716	7.15	754,876
CONCRETE	9,333	CY	110.00	1,026,630	23.75	221,659	133.75	1,248,289
RESTEEL	793,305	#	0.35	277,657	0.30	237,992	0.65	515,649
TOTAL ITEM	9,333	CY		1,858,447		660,367	269.88	2,518,814
MEASURING INSTRUMENT	LS			150,000				150,000
TOTAL ITEM				150,000				150,000
OTHERS	10%			394,909		512,074		906,983
TOTAL ITEM	OF ABOVE			394,909		512,074		906,983
FRPM (25 DIAM, L= 400)	400	LF	7000.00	2,800,000	100.00	40,000	7100.00	2,840,000
TOTAL ITEM				2,800,000		40,000		2,840,000
TOTAL PENSTOCK TUNNEL				7,143,999		5,672,815		12,816,814

FILE : 1194BA PROJECT : KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 5 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
3. ii) DRAFT TUBE TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	5,185	CY	6.50	33,703			6.50	33,703
EXCAVATION	5,185	CY	7.00	36,295	105.00	544,425	112.00	580,720
GROUT	42,000	CF	4.50	189,000	6.50	273,000	11.00	462,000
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	400	LF	24.00	9,600	27.00	10,800	51.00	20,400
HAUL SPOIL	5,185	CY	1.25	6,481			1.25	6,481
TOTAL ITEM	5,185	CY		275,079		828,225	212.79	1,103,304
CONCRETE								
FORM	25,140	SF	12.50	314,160	1.40	35,196	13.90	349,356
CONCRETE	1,556	CY	110.00	171,160	23.75	36,955	133.75	208,115
RESTEEL 85 LBS/CY	132,260	#	0.35	46,291	0.30	39,678	0.65	85,969
TOTAL ITEM	1,556	CY		531,611		111,829	413.52	643,440
OTHERS	10%			80,669		94,005		174,674
TOTAL ITEM	OF ABOVE			80,669		94,005		174,674
TOTAL DRAFT TUBE TUNNEL				887,359		1,034,059		1,921,418
3. iii) TAILRACE TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	23,074	CY	6.50	149,981			6.50	149,981
EXCAVATION	23,074	CY	7.00	161,518	63.16	1,457,354	70.16	1,618,872
GROUT	189,000	CF	4.50	850,500	3.80	718,200	8.30	1,568,700
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	890	LF	24.00	21,360	27.00	24,030	51.00	45,390
HAUL SPOIL	23,074	CY	1.25	28,843			1.25	28,843
TOTAL ITEM	23,074	CY		1,212,202		2,199,584	147.86	3,411,786
CONCRETE								
FORM	70,800	SF	2.98	211,040	2.21	156,468	5.19	367,508
CONCRETE	6,889	CY	110.00	757,790	23.75	163,614	133.75	921,404
RESTEEL 85 LBS/CY	585,565	#	0.35	204,948	0.30	175,670	0.65	380,618
TOTAL ITEM	6889	CY		1,173,778		495,752	242.35	1,669,530
OTHERS	10%			238,598		269,534		508,132
TOTAL ITEM	OF ABOVE			238,598		269,534		508,132
TOTAL TAILRACE TUNNEL				2,624,578		2,964,870		5,589,448

FILE : 1194BA PROJECT : KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 6 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
4. POWERHOUSE								
EXCAVATION - ARCH								
UTILITIES & SUPPLY	11,487	CY	5.50	63,179			5.50	63,179
EXCAVATION	11,487	CY	7.00	80,409	52.74	605,824	59.74	686,233
GROUT	93,000	CF	4.50	418,500	3.20	297,600	7.70	716,100
RING BEAM SUPPORT	24,000	SF	7.25	174,000	19.14	459,360	26.39	633,360
HAUL SPOIL	11,487	CY	1.25	14,359			1.25	14,359
TOTAL ITEM	11,487	CY		750,447		1,362,784	183.97	2,113,231
EXCAVATION - MAIN PART								
UTILITIES & SUPPLY	37,037	CY	5.50	203,704			5.50	203,704
EXCAVATION	37,037	CY	7.00	259,259	43.00	1,592,591	50.00	1,851,850
GROUT	121,000	CF	4.50	544,500	7.05	853,050	11.55	1,397,550
GUNITE & ROCK BOLTS ALLOW PER LF OF STRUCT	2,000	LF	24.00	48,000	27.00	54,000	51.00	102,000
HAUL SPOIL	37,037	CY	1.25	46,296			1.25	46,296
TOTAL ITEM	37,037	CY		1,101,759		2,499,641	97.24	3,601,400
CONCRETE - WALL								
FORM 6 SF/CY	28,500	SF	2.00	57,000	3.80	108,300	5.80	165,300
CONCRETE	4,741	CY	120.00	568,920	48.00	227,568	168.00	796,488
RESTEEL 50 #/CY	237,050	#	0.35	82,968	0.30	71,115	0.65	154,083
TOTAL ITEM	4741	CY		708,888		406,983	235.37	1,115,871
CONCRETE - OTHER								
FORM 8 SF/CY	72,000	SF	3.00	216,000	5.00	360,000	8.00	576,000
CONCRETE	9,296	CY	120.00	1,115,520	48.00	446,208	168.00	1,561,728
RESTEEL 50 #/CY	464,800	#	0.35	162,680	0.30	139,440	0.65	302,120
TOTAL ITEM	9296	CY		1,494,200		945,648	262.46	2,439,848
MEASURING INSTRUMENT	LS			150,000				150,000
TOTAL ITEM				150,000				150,000
OTHERS	35% OF ABOVE			1,471,853		1,825,270		3,297,123
TOTAL ITEM				1,471,853		1,825,270		3,297,123
4. TOTAL POWERHOUSE				5,677,147		7,040,326		12,717,473

FILE : 1194BA PROJECT : KOKO CRATER - PUMPED STORAGE REV. NO. 0 29–Mar–94

ITEM : DIRECT COST SHEET 7 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
5. DRAFT GATE HALL								
EXCAVATION								
UTILITIES & SUPPLY	4,926	CY	6.50	32,019			6.50	32,019
EXCAVATION	4,926	CY	7.00	34,482	66.48	327,480	73.48	361,962
GROUT	36,000	CF	4.50	162,000	4.03	145,080	8.53	307,080
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	100	LF	24.00	2,400	27.00	2,700	51.00	5,100
HAUL SPOIL	4,926	CY	1.25	6,158			1.25	6,158
TOTAL ITEM	4,926	CY		237,059		475,260	144.60	712,319
CONCRETE								
FORM 6.28 SF/CY	14,250	SF	10.00	142,500	3.50	49,875	13.50	192,375
CONCRETE	2,259	CY	120.00	271,080	48.00	108,432	168.00	379,512
RESTEEL 50 #/CY	112,950	#	0.30	33,885	0.35	39,533	0.65	73,418
TOTAL ITEM	2,269	CY		447,465		197,840	284.40	645,305
OTHERS	10% OF ABOVE			68,452		67,310		135,762
TOTAL ITEM				68,452		67,310		135,762
DRAFT GATE	LUM SUM			1,500,000				1,500,000
TOTAL ITEM				1,500,000				1,500,000
5.TOTAL DRAFT GATE HALL				2,252,976		740,410		2,993,386

FILE : 1194BA **PROJECT :** KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 8 OF 10 PAGES

		QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
6. OUTLET STRUCTURE									
EXCAVATION									
COFFERD. MAT'L		144,500	SF	10.00	1,445,000			10.00	1,445,000
INSTALL & REMOVE		144,500	SF	0.15	21,675	3.25	469,625	3.40	491,300
STRUCTURE EXCAVATION		62,693	CY			15.00	940,395	15.00	940,395
TOTAL ITEM		62,693	CY		1,466,675		1,410,020	45.89	2,876,695
DREDGIMG									
EXCAVATION		25,926	CY			5.75	149,075	5.75	149,075
DISPOSAL		25,926	CY			2.35	60,926	2.35	60,926
TOTAL ITEM		25,926	CY		0		210,001	8.10	210,001
BACKFILL									
PLACE & COMPACT		5,926	CY			16.00	94,816	16.00	94,816
TOTAL ITEM		5,926	CY		0		94,816	16.00	94,816
CONCRETE STRUCTURE									
FORMS	24.04 SF/CY	160,280	SF	2.00	320,560	6.00	961,680	8.00	1,282,240
RESTEEL	60 #/CY	400,020	#	0.30	120,006	0.35	140,007	0.65	260,013
CONCRETE		6,667	CY	120.00	800,040	37.00	246,679	157.00	1,046,719
GATE		LUMP SUM			650,000				650,000
TOTAL ITEM		6,667	CY		1,890,606		1,348,366	485.82	3,238,972
40 TN CONC. DOLO UNITS									
MAKE UNITS		1,850	EA	2805.00	5,189,250	785.00	1,452,250	3590.00	6,641,500
PLACE UNITS		1,850	EA	170.00	314,500	390.00	721,500	560.00	1,036,000
TOTAL		1,850	EA		5,503,750		2,173,750	4150.00	7,677,500
STONE CORE FOR BREAKWATER									
BUY MAT'l CORE	65,074 CY	100,865	TNS	25.00	2,521,621			25.00	2,521,621
ARMOR	27,889 CY	40,439	TNS	30.00	1,213,167			30.00	1,213,167
WATER TRANSPORT		141,304	TNS			3.50	494,563	3.50	494,563
DUMP CORE	60,074 CY	60,074	CY			2.30	138,170	2.30	138,170
PLACE CORE	5,000 CY	5,000	CY			3.60	18,000	3.60	18,000
PLACE 4 TN	27,889 CY	40,439	TN			12.30	343,033	12.30	343,033
TOTAL		92,963	CY		3,734,788		993,766	50.86	4,728,554
TOTAL OUTLET STRUCTURE					12,595,819		6,230,719		18,826,538

FILE : 1194BA **PROJECT :** KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 9 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
7. POWERHOUSE ACCESS TUNNEL & ACCESS ROAD								
ACCESS TUNNEL								
EXCAVATION - TUNNEL								
UTILITIES & SUPPLY	40,000	CY	5.50	220,000			5.50	220,000
EXCAVATION	40,000	CY	7.00	280,000	74.91	2,996,400	81.91	3,276,400
GROUT	192,000	CF	4.50	864,000	5.49	1,054,080	9.99	1,918,080
TUNNEL SUPPORT 400 #/LF	2,200	LF	337.50	742,500	120.00	264,000	457.50	1,006,500
HAUL SPOIL	40,000	CY	1.25	50,000			1.25	50,000
TOTAL ITEM	40,000	CY		2,156,500		4,314,480	161.77	6,470,980
CONCRETE								
FORM	119,724	SF	2.18	261,200	3.27	391,497	5.45	652,697
CONCRETE	18,889	CY	110.00	2,077,790	23.75	448,614	133.75	2,526,404
RESTEEL 85 #/CY	1,605,565	#	0.35	561,948	0.30	481,670	0.65	1,043,618
TOTAL ITEM	18,889	CY		2,900,938		1,321,781	223.55	4,222,719
ACCESS ROAD								
ROAD CONST. 500' X 30'	1,667	SY	15.00	25,000	5.00	8,333	20.00	33,333
TOTAL ITEM				25,000		8,333		33,333
OTHERS	10% OF ABOVE			508,244		564,459		1,072,703
TOTAL ITEM				508,244		564,459		1,072,703
7. TOTAL TUNNEL & ROAD				5,590,682		6,209,053		11,799,735

FILE : 1194BA **PROJECT :** KOKO CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 10 OF 10 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
8. OUTLET ACCESS TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	5,778	CY	6.50	37,557			6.50	37,557
EXCAVATION	5,778	CY	7.00	40,446	232.38	1,342,692	239.38	1,383,138
GROUT	40,200	CF	4.50	180,900	14.45	580,890	18.95	761,790
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	980	LF	24.00	23,520	27.00	26,460	51.00	49,980
HAUL SPOIL	5,778	CY	1.25	7,223			1.25	7,223
TOTAL ITEM	5,778	CY		289,646		1,950,042	387.62	2,239,688
CONCRETE								
FORM	25,186	SF	8.16	205,600	2.42	60,950	10.58	266,550
CONCRETE	2,926	CY	110.00	321,860	23.75	69,493	133.75	391,353
RESTEEL 85 #/CY	248,710	#	0.35	87,049	0.30	74,613	0.65	161,662
TOTAL ITEM	2926	CY		614,509		205,056	280.10	819,565
OTHERS	5% OF ABOVE			45,208		107,755		152,963
TOTAL ITEM				45,208		107,755		152,963
8. TOTAL OUTLET ACCESS TUNNEL				949,363		2,262,853		3,212,216
9. POWERPLANT EQUIPMENT	LUMP SUM			40,289,855				40,289,855
10. SWITCHYARD	LUMP SUM			14,347,826				14,347,826
11. TRANSMISSION LINE	LUMP SUM			5,860,565				5,860,565

FPS ENGINEERING ASSOCIATES, INC.

FILE : 1194BB **PROJECT :** KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : PROJECT SUMMARY SHEET 1 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
SUMMARY DIRECT COST								
A. MOBILIZATION				1,230,000		375,000		1,605,000
B. SPECIAL PLANT				380,000		10,000		390,000
1. UPPER RESERVOIR				12,427,000		5,573,000		18,000,000
2. UPPER RESERVOIR ACCESS ROAD				924,000		308,000		1,232,000
3. INTAKE STRUCTURE				476,000		223,000		699,000
4. WATER CONDUCTORS								
i) PENSTOCK TUNNEL				6,648,000		7,579,000		14,227,000
ii) DRAFT TUBE TUNNEL				434,000		453,000		887,000
iii) TAILRACE TUNNEL				2,767,000		2,875,000		5,642,000
5. POWERHOUSE				5,545,000		7,124,000		12,669,000
6. SURGE TANK				1,725,000		2,050,000		3,775,000
7. DRAFT GATE HALL				1,207,000		713,000		1,920,000
8. TAILRACE GATE SHAFT				1,781,000		1,555,000		3,336,000
9. LOWER RESERVOIR				8,865,000		9,430,000		18,295,000
10. OUTLET STRUCTURE				375,000		297,000		672,000
11. CONNECTED POND				7,439,000		5,901,000		13,340,000
12. POWERHOUSE ACCESS TUNNEL				9,110,000		10,068,000		19,178,000
13. POWERHOUSE CABLE TUNNEL				2,144,000		2,310,000		4,454,000
14. ACCESS TUNNEL FOR SURGE TANK				1,950,000		1,377,000		3,327,000
15. POWERHOUSE EQUIPMENT				35,000,000				35,000,000
16. SWITCHYARD				7,246,000				7,246,000
17. TRANSMISSION LINE				507,000				507,000
TOTAL DIRECT COST				108,180,000		58,221,000		166,401,000
CONTRACTORS OH	15.00%							24,960,000
SUBTOTAL								191,361,000
CONTRACTORS CONTINGENCY & FEE	15.00%							28,704,000
SUBTOTAL								220,065,000
BOND & HAWAII G.I. TAX	4.50%							9,903,000
DESIGN / CM	6%							13,798,000
TOTAL PROJECT 1994 DOLLARS								243,766,000
OWNERS CONTINGENCY	5%							12,188,000
MITIGATING MEASURES	1%							2,438,000
TOTAL CONSTRUCTION 1994 DOLLARS								258,392,000
LAND AQUISITION								TO BE DETERMINED

APPENDIX J

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 2 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
A. MOBILIZATION								
OCEAN FRT	1,000	TNS	500	500,000				500,000
TOW	LS			500,000				500,000
LOCAL FRT	1,500	TNS	20	30,000				30,000
RIG UP	LS			100,000		275,000		375,000
RIG DOWN	LS			100,000		100,000		200,000
TOTAL				1,230,000		375,000		1,605,000
B. SPECIAL PLANT								
ELECTRIAL (SUBSTAION & MCC)	LS			100,000				100,000
VENT. FANS	LS			150,000				150,000
SPECIAL VENT FACILITY	1,000	LF	100	100,000				100,000
RAIL SWITCHES ETC	6	EA	20,000	120,000				120,000
DUMP PIT	LS			10,000		10,000		20,000
TOTAL				380,000		10,000		390,000

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 3 OF 12 PAGES

		QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
	1. UPPER RESERVOIR								
1A.	EXCAVATION CLEAR & GRUB	70	ACRES	800.00	56,000	3200.00	224,000	4000.00	280,000
	EXCAVATION	611,111	CY			2.50	1,527,778	2.50	1,527,778
	RIP MATERIAL	25,000	CY			1.00	25,000	1.00	25,000
	ROCK EXC. ALLOW	1,000	CY	5.00	5,000	10.00	10,000	15.00	15,000
	TOTAL	611,111	CY		61,000		1,786,778	3.02	1,847,778
1B.	EMBANKMENT SPREAD & ROLL	681,481	CY			1.65	1,124,444	1.65	1,124,444
	FINE GRADE	20,617	SY			0.40	8,247	0.40	8,247
	INSPECTION ROAD	16,000	SY	19.00	304,000			19.00	304,000
	TOTAL	681,481	CY		304,000		1,132,691	2.11	1,436,691
1C.	RUBBER MAT	185,556	SY	16.00	2,968,889	0.20	37,111	16.20	3,006,000
1D.	PROTECTIVE MAT								
	IMPERVOIS MAT'L	5,658	CY	5.00	28,292			5.00	28,292
	SPREAD & SPREAD & ROLL	11,317	CY			12.00	135,802	12.00	135,802
	TOTAL	305,556	SY		28,292		135,802	0.54	164,094
1E.	TRANSITION ROCK	228,852	TNS	20.00	4,577,037			20.00	4,577,037
	PLACE	123,704	CY			13.50	1,670,000	13.50	1,670,000
	TOTAL	123,704	CY		4,577,037		1,670,000	50.50	6,247,037
1F.	CONCRETE INSPECTION GALLERY	3,300	LF						
	EXC.	21,000	CY			6.60	138,600	6.60	138,600
	BACKFILL							N I C EXCAVATE NE	
	CONCRETE	17,148	CY	105.00	1,800,556	15.00	257,222	120.00	2,057,778
	FORM	69,090	SF	0.65	44,909	6.00	414,540	6.65	459,449
	RESTEEL	145,100	#	0.65	94,315			0.65	94,315
	TOTAL	17,148	CY		1,939,780		810,362	160.38	2,750,142
1G.	MEASURING INST.	LS			200,000				200,000
1H.	OTHERS 15.00% OF ABOVE	LS			2,347,761				2,347,761
	TOTAL ITEM 1				12,426,759		5,572,744		17,999,503
	2. UPPER RESERVOIR ACCESS ROAD	3.5 MILES							
	ROAD CONST. 18,480' X 30'	61,600	SY	15.00	924,000	5.00	308,000	20.00	1,232,000
	TOTAL ITEM 2				924,000		308,000		1,232,000
	3. INTAKE STRUCTURE								
	EXCAVATION MASS	741	CY			8.25	6,111	8.25	6,111
	EXCAVATION SHAFT	593	CY	28.00	16,593	87.00	51,556	115.00	68,149
	CONCRETE	2,074	CY	105.00	217,778	25.00	51,852	130.00	269,630
	FORMS	11,200	SF	4.00	44,800	7.50	84,000	11.50	128,800
	RESTEEL 100 #/CY	207,407	#	0.65	134,815			0.65	134,815
	OTHERS 15.00%	1	LS		62,098		29,028		91,126
	TOTAL ITEM 3	2,074	CY		476,084		222,547	336.84	698,631

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 4 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
4. i) PENSTOCK TUNNEL								
EXCAVATION - INCLINED PART								
UTILITIES & SUPPLY	14,333	CY	8.80	126,133			8.80	126,133
EXCAVATION	14,333	CY	7.00	100,333	115.00	1,648,333	122.00	1,748,666
GROUT 116097.3	116,000	CF	4.50	522,000	7.50	870,000	12.00	1,392,000
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	1,255	LF	24.00	30,120	27.00	33,885	51.00	64,005
HAUL SPOIL	14,333	CY	1.25	17,917			1.25	17,917
TOTAL ITEM	14,333	CY		796,503		2,552,218	233.63	3,348,721
EXCAVATION - OTHER	2,440	LF						
UTILITIES & SUPPLY	22,519	CY	8.80	198,163			8.80	198,163
EXCAVATION	22,519	CY	7.00	157,630	72.00	1,621,333	79.00	1,778,963
GROUT 182403.9	182,000	CF	4.50	819,000	3.60	655,200	8.10	1,474,200
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	2,440	LF	24.00	58,560	27.00	65,880	51.00	124,440
HAUL SPOIL	22,519	CY	1.25	28,148			1.25	28,148
TOTAL ITEM	22,519	CY		1,261,501		2,342,413	160.04	3,603,914
CONCRETE -INCLINED PART								
CONCRETE	5,963	CY	110.00	655,926	23.75	141,620	133.75	797,546
RESTEEL 85 #/CY	506,852	#	0.35	177,398	0.30	152,056	0.65	329,454
TOTAL ITEM	5,963	CY		833,324		293,676	189.00	1,127,000
CONCRETE - OTHER								
CONCRETE	9,370	CY	110.00	1,030,741	23.75	222,546	133.75	1,253,287
RESTEEL	796,481	#	0.35	278,769	0.30	238,944	0.65	517,713
TOTAL ITEM	9,370	CY		1,309,510		461,490	189.00	1,771,000
MEASURING INSTRUMENT	LS			50,000				50,000
TOTAL ITEM				50,000				50,000
OTHERS	10%			425,084		564,980		990,064
TOTAL ITEM	OF ABOVE			425,084		564,980		990,064
STL. LINING(14 D,L= 3,695)	1,240	TNS	1,590	1,971,600	1,100	1,364,000	2,690	3,335,600
671.2 #/FT 15.3 #/SF								
TOTAL ITEM	1240	TNS		1,971,600		1,364,000	2,690	3,335,600
TOTAL PENSTOCK TUNNEL				6,647,522		7,578,777		14,226,299

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29–Mar–94

ITEM : DIRECT COST SHEET 5 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
ii) DRAFT TUBE TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	2,037	CY	8.80	17,926			8.80	17,926
EXCAVATION	2,037	CY	7.00	14,259	115.00	234,259	122.00	248,518
GROUT 16499.7	16,500	CF	4.50	74,250	6.50	107,250	11.00	181,500
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	400	LF	24.00	9,600	27.00	10,800	51.00	20,400
HAUL SPOIL	2,037	CY	1.25	2,546			1.25	2,546
TOTAL ITEM	2,037	CY		118,581		352,309	231.16	470,890
CONCRETE								
FORM	12,568	SF	12.50	157,055	1.40	17,595	13.90	174,650
CONCRETE	852	CY	110.00	93,720	23.75	20,235	133.75	113,955
RESTEEL 85 LBS/CY	72,420	#	0.35	25,347	0.30	21,726	0.65	47,073
TOTAL ITEM	1,556	CY		276,122		59,556	215.73	335,678
OTHERS	10%			39,470		41,187		80,657
TOTAL ITEM	OF ABOVE			39,470		41,187		80,657
TOTAL DRAFT TUBE TUNNEL				434,173		453,052		887,225
4. iii) TAILRACE TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	18,630	CY	8.80	163,944			8.80	163,944
EXCAVATION	18,630	CY	7.00	130,410	70.00	1,304,100	77.00	1,434,510
GROUT	176,054	CF	4.50	792,241	3.80	669,003	8.30	1,461,244
GUNITE & ROCK BOLTS ALLOW PER LF OF TUNNEL	2,090	LF	24.00	50,160	27.00	56,430	51.00	106,590
HAUL SPOIL	18,630	CY	1.25	23,288			1.25	23,288
TOTAL ITEM	18,630	CY		1,160,043		2,029,533	171.21	3,189,576
CONCRETE								
FORM	91,960	SF	2.98	274,114	2.21	203,232	5.19	477,346
CONCRETE	7,740	CY	110.00	851,400	23.75	183,825	133.75	1,035,225
RESTEEL 85 LBS/CY	657,900	#	0.35	230,265	0.30	197,370	0.65	427,635
TOTAL ITEM	7,740	CY		1,355,779		584,427	250.67	1,940,206
OTHERS	10%			251,582		261,396		512,978
TOTAL ITEM	OF ABOVE			251,582		261,396		512,978
TOTAL TAILRACE TUNNEL				2,767,404		2,875,356		5,642,760

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 6 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
5. POWERHOUSE								
EXCAVATION - ARCH								
UTILITIES & SUPPLY	11,487	CY	8.80	101,086			8.80	101,086
EXCAVATION	11,487	CY	7.00	80,409	62.00	712,194	69.00	792,603
GROUT	108,552	CF	4.50	488,485	3.20	347,367	7.70	835,852
RING BEAM SUPPORT	24,000	SF	7.25	174,000	19.14	459,360	26.39	633,360
HAUL SPOIL	11,487	CY	1.25	14,359			1.25	14,359
TOTAL ITEM	11,487	CY		858,339		1,518,921	206.95	2,377,260
EXCAVATION - MAIN PART								
UTILITIES & SUPPLY	33,000	CY	8.80	290,400			8.80	290,400
EXCAVATION	33,000	CY	7.00	231,000	52.00	1,716,000	59.00	1,947,000
GROUT	108,000	CF	4.50	486,000	7.05	761,400	11.55	1,247,400
GUNITE & ROCK BOLTS ALLOW PER LF OF STRUCT	2,000	LF	24.00	48,000	27.00	54,000	51.00	102,000
HAUL SPOIL	33,000	CY	1.25	41,250			1.25	41,250
TOTAL ITEM	33,000	CY		1,096,650		2,531,400	109.94	3,628,050
CONCRETE - WALL								
FORM 6 SF/CY	27,833	SF	2.00	55,665	3.80	105,764	5.80	161,429
CONCRETE	4,630	CY	120.00	555,600	48.00	222,240	168.00	777,840
RESTEEL 50 #/CY	231,500	#	0.35	81,025	0.30	69,450	0.65	150,475
TOTAL ITEM	4,630	CY		692,290		397,454	235.37	1,089,744
CONCRETE - OTHER								
FORM 8 SF/CY	63,124	SF	3.00	189,372	5.00	315,620	8.00	504,992
CONCRETE	8,150	CY	120.00	978,000	48.00	391,200	168.00	1,369,200
RESTEEL 50 #/CY	407,500	#	0.35	142,625	0.30	122,250	0.65	264,875
TOTAL ITEM	8,150	CY		1,309,997		829,070	262.46	2,139,067
MEASURING INSTRUMENT	LS			150,000				150,000
TOTAL ITEM				150,000				150,000
OTHERS	35% OF ABOVE			1,437,547		1,846,896		3,284,442
TOTAL ITEM				1,437,547		1,846,896		3,284,442
5. TOTAL POWERHOUSE				5,544,823		7,123,741		12,668,563

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
6. SURGE TANK								
EXCAVATION								
UTILITIES & SUPPLY	13,700	CY	8.80	120,560			8.80	120,560
EXCAVATION	13,700	CY	7.00	95,900	75.00	1,027,500	82.00	1,123,400
GROUT	129,465	CF	4.50	582,592	4.03	521,744	8.53	1,104,336
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	350	LF	24.00	8,400	27.00	9,450	51.00	17,850
HAUL SPOIL	13,700	CY	1.25	17,125			1.25	17,125
TOTAL ITEM	13,700	CY		824,577		1,558,694	173.96	2,383,271
CONCRETE								
FORM 6.84 SF/CY	26,000	SF	10.00	260,000	3.50	91,000	13.50	351,000
CONCRETE	3,800	CY	120.00	456,000	48.00	182,400	168.00	638,400
RESTEEL 50 #/CY	190,000	#	0.30	57,000	0.35	66,500	0.65	123,500
TOTAL ITEM	3,800	CY		773,000		339,900	292.87	1,112,900
OTHERS	8% OF ABOVE			127,806		151,888		279,694
TOTAL ITEM				127,806		151,888		279,694
6.TOTAL SURGE TANK				1,725,383		2,050,482		3,775,865
7. DRAFT GATE HALL								
EXCAVATION								
UTILITIES & SUPPLY	4,400	CY	8.80	38,720			8.80	38,720
EXCAVATION	4,400	CY	7.00	30,800	68.00	299,200	75.00	330,000
GROUT	41,580	CF	4.50	187,110	4.03	167,567	8.53	354,677
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	100	LF	24.00	2,400	27.00	2,700	51.00	5,100
HAUL SPOIL	4,400	CY	1.25	5,500			1.25	5,500
TOTAL ITEM	4,400	CY		264,530		469,467	166.82	733,997
CONCRETE								
FORM 6.28 SF/CY	12,812	SF	10.00	128,118	3.50	44,841	13.50	172,959
CONCRETE	2,040	CY	120.00	244,800	48.00	97,920	168.00	342,720
RESTEEL 50 #/CY	102,000	#	0.30	30,600	0.35	35,700	0.65	66,300
TOTAL ITEM	2,040	CY		403,518		178,461	285.28	581,979
OTHERS	10% OF ABOVE			66,805		64,793		131,598
TOTAL ITEM				66,805		64,793		131,598
DRAFT GATE	LUMP SUM			472,000				472,000
TOTAL ITEM				472,000				472,000
7.TOTAL DRAFT GATE HALL				1,206,853		712,721		1,919,574

FILE : 1194BB **PROJECT :** KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 8 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
8. TAILRACE GATE SHAFT								
EXCAVATION								
UTILITIES & SUPPLY	9,260	CY	8.80	81,488			8.80	81,488
EXCAVATION	9,260	CY	35.00	324,100	87.00	805,620	122.00	1,129,720
GROUT	87,507	CF	4.50	393,782	4.03	352,653	8.53	746,435
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	200	LF	24.00	4,800	27.00	5,400	51.00	10,200
HAUL SPOIL	9,260	CY	1.25	11,575			1.25	11,575
TOTAL ITEM	9,260	CY		815,745		1,163,673	213.76	1,979,418
CONCRETE								
FORM 6.25 SF/CY	16,250	SF	10.00	162,500	3.50	56,875	13.50	219,375
CONCRETE	2,600	CY	120.00	312,000	48.00	124,800	168.00	436,800
RESTEEL 75 #/CY	195,000	#	0.30	58,500	0.35	68,250	0.65	126,750
TOTAL ITEM	2,600	CY		533,000		249,925	301.13	782,925
OTHERS	10% OF ABOVE			134,875		141,360		276,234
TOTAL ITEM				134,875		141,360		276,234
TAILRACE GATE	LUMP SUM			297,101				297,101
TOTAL ITEM				297,101				297,101
8.TOTAL TAILRACE GATE SHAFT				1,780,721		1,554,958		3,335,679

FILE : 1194BB **PROJECT :** KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 9 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
9. LOWER RESERVOIR								
EXCAVATION CLEAR & GRUB	70	ACRES	1000.00	70,000	4000.00	280,000	5000.00	350,000
EXCAVATION	213,000	CY			2.50	532,500	2.50	532,500
RIP MATERIAL	25,000	CY			1.00	25,000	1.00	25,000
ROCK EXC. ALLOW	23,700	CY	5.00	118,500	10.00	237,000	15.00	355,500
TOTAL	236,700	CY		188,500		1,074,500	5.34	1,263,000
EMBANKMENT SPREAD & ROLL	1,111,000	CY			4.50	4,999,500	4.50	4,999,500
FINE GRADE	1,134,000	SY			0.40	453,600	0.40	453,600
INSPECTION ROAD	16,667	SY	19.00	316,667			19.00	316,667
TOTAL	1,111,000	CY		316,667		5,453,100	5.19	5,769,767
RUBBER MAT	126,000	SY	16.00	2,016,000	0.20	25,200	16.20	2,041,200
TOTAL				2,016,000		25,200		2,041,200
PROTECTIVE MAT								
SPREAD, ROLL & COMPACT	85,000	CY			12.00	1,020,000	12.00	1,020,000
TOTAL	126,000	SY				1,020,000	8.10	1,020,000
TRANSITION ROCK	116,550	TNS	20.00	2,331,000		0	20.00	2,331,000
CLAY	21,000	CY	6.00	126,000		0	6.00	126,000
PLACE	84,000	CY			13.50	1,134,000	13.50	1,134,000
TOTAL	84,000	CY		2,457,000		1,134,000	42.75	3,591,000
CONCRETE INSPECTION GALLERY								
EXC.	13,000	CY			16.60	215,800	16.60	215,800
BACKFILL							N I C EXCAVATE NE	
CONCRETE	13,000	CY	105.00	1,365,000	15.00	195,000	120.00	1,560,000
FORM 4	52,000	SF	0.65	33,800	6.00	312,000	6.65	345,800
RESTEEL 8.5	110,500	#	0.65	71,825			0.65	71,825
TOTAL	13,000	CY		1,470,625		722,800	168.73	2,193,425
MEASURING INST.	LS			30,000				30,000
OTHERS 15.00% OF ABOVE	LS			2,386,259				2,386,259
TOTAL ITEM 9 LOWER RESERVOIR				8,865,051		9,429,600		18,294,651

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 10 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
10. OUTLET STRUCTURE								
EXCAVATION								
EXCAVATION	8,520	CY			12.00	102,240	12.00	102,240
BACKFILL	2,200	CY			10.00	22,000	10.00	22,000
HAUL SPOIL	8,520	CY	1.25	10,650			1.25	10,650
TOTAL ITEM	8,520	CY		10,650		124,240	15.83	134,890
CONCRETE								
FORM 6.28 SF/CY	10,488	SF	10.00	104,881	3.50	36,708	13.50	141,589
CONCRETE	1,670	CY	120.00	200,400	48.00	80,160	168.00	280,560
RESTEEL 50 #/CY	83,500	#	0.30	25,050	0.35	29,225	0.65	54,275
TOTAL ITEM	1,670	CY		330,331		146,093	285.28	476,424
OTHERS	10% OF ABOVE			34,098		27,033		61,131
TOTAL ITEM				34,098		27,033		61,131
10. TOTAL OUTLET STRUCTURE				375,079		297,366		672,445
11. CONNECTED POND								
DAM CONSTRUCTION								
ACCESS & HAUL ROADS 3,500 LF	12,000	SY	15.00	180,000	8.50	102,000	23.50	282,000
CLEAR & GRUB	4	ACRES	5,000	20,000			5,000	20,000
EXCAVATION	10,000	CY	5.00	50,000	3.00	30,000	8.00	80,000
FOUNDATION PREP	20,000	SF	4.55	91,000	2.00	40,000	6.55	131,000
FORMS 7.5 SF/CY	288,889	SF	1.00	288,889	6.00	1,733,333	7.00	2,022,222
CONCRETE	38,519	CY	110.00	4,237,037	25.00	962,963	135.00	5,200,000
TOTAL ITEM	38,519	CY		4,866,926		2,868,296	201	7,735,222
WATER SUPPLY & DRAINAGE TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	15,700	CY	8.80	138,160			8.80	138,160
EXCAVATION	15,700	CY	7.00	109,900	77.00	1,208,900	84.00	1,318,800
GROUT	148,365	CF	4.50	667,643	4.03	597,911	8.53	1,265,554
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	500	LF	24.00	12,000	27.00	13,500	51.00	25,500
HAUL SPOIL	15,700	CY	1.25	19,625			1.25	19,625
TOTAL ITEM	15,700	CY		947,328		1,820,311	176.28	2,767,639
CONCRETE								
FORM	83,560	SF	2.50	208,900	3.50	292,460	6.00	501,360
CONCRETE	8,000	CY	120.00	960,000	48.00	384,000	168.00	1,344,000
RESTEEL 50 #/CY	400,000	#	0.30	120,000	0.35	140,000	0.65	260,000
TOTAL ITEM	8,000	CY		1,288,900		816,460	263.17	2,105,360
OTHERS	15% OF ABOVE			335,434		395,516		730,950
TOTAL ITEM				335,434		395,516		730,950
11. TOTAL CONNECTED POND				7,438,588		5,900,583		13,339,171

FILE : 1194BB PROJECT : KAAU CRATER - PUMPED STORAGE REV. NO. 0 29-Mar-94

ITEM : DIRECT COST SHEET 11 OF 12 PAGES

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
12. POWERHOUSE ACCESS TUNNEL								
ACCESS TUNNEL								
EXCAVATION - TUNNEL								
UTILITIES & SUPPLY	55,000	CY	8.80	484,000			8.80	484,000
EXCAVATION	55,000	CY	7.00	385,000	74.91	4,120,050	81.91	4,505,050
GROUT	519,750	CF	4.50	2,338,875	5.49	2,853,428	9.99	5,192,303
TUNNEL SUPPORT 400 #/LF	3,000	LF	337.50	1,012,500	120.00	360,000	457.50	1,372,500
HAUL SPOIL	55,000	CY	1.25	68,750			1.25	68,750
TOTAL ITEM	55,000	CY		4,289,125		7,333,478	211.32	11,622,603
CONCRETE								
FORM 6.34 SF/CY	164,840	SF	2.18	359,629	3.27	539,027	5.45	898,656
CONCRETE	26,000	CY	110.00	2,860,000	23.75	617,500	133.75	3,477,500
RESTEEL 85 #/CY	2,210,000	#	0.35	773,500	0.30	663,000	0.65	1,436,500
TOTAL ITEM	26,000	CY		3,993,129		1,819,527	223.56	5,812,656
OTHERS	10% OF ABOVE			828,225		915,301		1,743,526
TOTAL ITEM				828,225		915,301		1,743,526
12. TOTAL POWER POWERHOUSE TUNNEL				9,110,479		10,068,306		19,178,785
13. TOTAL POWER CABLE TUNNEL								
EXCAVATION								
UTILITIES & SUPPLY	15,000	CY	8.80	132,000			8.80	132,000
EXCAVATION	15,000	CY	7.00	105,000	80.00	1,200,000	87.00	1,305,000
GROUT	36,000	CF	4.50	162,000	4.03	145,080	8.53	307,080
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	500	LF	24.00	12,000	27.00	13,500	51.00	25,500
HAUL SPOIL	15,000	CY	1.25	18,750			1.25	18,750
TOTAL ITEM	15,000	CY		429,750		1,358,580	119.22	1,788,330
CONCRETE								
FORM 13.33 SF/CY	100,000	SF	6.00	600,000	3.50	350,000	9.50	950,000
CONCRETE	7,500	CY	120.00	900,000	48.00	360,000	168.00	1,260,000
RESTEEL 50 #/CY	375,000	#	0.30	112,500	0.35	131,250	0.65	243,750
TOTAL ITEM	7,500	CY		1,612,500		841,250	327.17	2,453,750
OTHERS	5% OF ABOVE			102,113		109,992		212,104
TOTAL ITEM				102,113		109,992		212,104
13. TOTAL POWER CABLE TUNNEL				2,144,363		2,309,822		4,454,184

	QUANTITY	Unit	Unit Price	MAT'L & SUB	Unit Price	LABOR & EQUIPT	Unit Price	TOTAL
14. ACCESS TUNNEL FOR SURGE TANK								
EXCAVATION								
UTILITIES & SUPPLY	4,150	CY	8.80	36,520			8.80	36,520
EXCAVATION	4,150	CY	7.00	29,050	75.00	311,250	82.00	340,300
GROUT	36,000	CF	4.50	162,000	4.03	145,080	8.53	307,080
GUNITE& ROCK BOLTS ALLOW PER LF OF STRUCT	500	LF	24.00	12,000	27.00	13,500	51.00	25,500
HAUL SPOIL	4,150	CY	1.25	5,188			1.25	5,188
TOTAL ITEM	4,150	CY		244,758		469,830	172.19	714,588
CONCRETE								
FORM 13.33 SF/CY	100,000	SF	6.00	600,000	3.50	350,000	9.50	950,000
CONCRETE	7,500	CY	120.00	900,000	48.00	360,000	168.00	1,260,000
RESTEEL 50 #/CY	375,000	#	0.30	112,500	0.35	131,250	0.65	243,750
TOTAL ITEM	7,500	CY		1,612,500		841,250	327.17	2,453,750
OTHERS	5% OF ABOVE			92,863		65,554		158,417
TOTAL ITEM				92,863		65,554		158,417
14. TOTAL ACCESS TUNNEL FOR SURGE TANK				1,950,121		1,376,634		3,326,755
15. POWERHOUSE EQUIPMENT	LUMP SUM			35,000,000				35,000,000
16. SWITCHYARD	LUMP SUM			7,246,377				7,246,377
17. TRANSMISSION LINE	LUMP SUM			507,246				507,246

GENPP 19-8
TA/R

INTEROFFICE CORRESPONDENCE

Hawaiian Electric Co., Inc. **An HEI Company**

May 25, 1994

To: R. B. Munger
From: T. C. Simmons for T. C. Simmons
Subject: Oahu Pumped Storage Hydroelectric Project
Updated Cost Estimates

In response to your 4/15/94 IOC, we have reviewed the Kaau and Koko Crater pumped storage hydroelectric resources. Based on our preliminary economic analysis, these resources could continue to be considered as supply-side resource options for Oahu.

Objective

The objective of this analysis is to perform a preliminary economic analysis to determine if the Kaau and Koko Crater pumped storage hydroelectric (hydro) resources could continue to be considered as supply-side resource options for Oahu.

Assumptions for Kaau and Koko Crater Pumped Storage Hydroelectric Resources

O & M Cost: Kaau 1,976,000 \$/year (38,000 \$/week),
Koko Crater 2,236,000 \$/year (43,000 \$/week) (1993 \$)
Generation Capacity: 160 MW
Pumping Capacity: Kaau 162 MW, Koko Crater 160 MW
Efficiency: 75%
7 cycles per week
Cost including land: Kaau 1554 \$/KW, Koko 1543 \$/KW (1993 \$)
Life: 75 years

Analysis

The PROSCREEN II (PROSCREEN) system was used in this analysis. Two PROSCREEN runs were made:

Run 1 - The hydro resources were available to be added from 2002 to 2011.
Run 2 - The hydro resources were available to be added only in 2002.

Given the constraints of the runs, PROSCREEN optimized the addition of resources. Attachments 1 and 2 show partial outputs from both runs. From each of these runs, two plans were selected for evaluation: 1) the least cost plan with the Kaau resource, and 2) the least cost plan with the Koko Crater resource. Additionally, two more plans were selected from Run 1: 1) the least cost plan with the Kaau resource and with an atmospheric flludized bed combustion (AFBC) resource as the first supply-side resource, and 2) the least cost plan with the Koko Crater resource and with an AFBC resource as the first supply-side resource. Note that all of these plans do not have a simple cycle combustion turbine to replace Waiau 9 and 10, which are planned to be retired in 2008. It is assumed that the hydro resources will serve as peaking resources.

All of these plans were compared to two plans from the most recent IRP evaluation: the least cost plan (INTR-1) and the preferred plan (INTRCL-1) (see Attachment 3). Therefore, the following plans were compared:

Plan	Description
INTR-1	Least cost plan from IRP
INTRCL-1	Preferred plan from IRP
Kaau1R	Least cost plan w/ Kaau resource from Run 1 (Waiau repowering as 1st supply-side resource)
Kaau1F	Least cost plan w/ Kaau resource & AFBC as 1st supply-side resource, from Run 1
Kaau2	Least cost plan w/ Kaau resource from Run 2
Koko1R	Least cost plan w/ Koko resource from Run 1 (Waiau repowering as 1st supply-side resource)
Koko1F	Least cost plan w/ Koko resource & AFBC as 1st supply-side resource, from Run 1
Koko2	Least cost plan w/ Koko resource from Run 2

Attachment 4 shows the Total Resource Cost with and without end effects for all of the plans. Note that the difference between INTR-1, and Kaau1R and Koko1R is about $18 million in 1993 dollars (or 0.3%) in the 20-year period (without end effects). We feel that this is not a large enough difference to eliminate the hydro resources from further consideration. (Note that plans INTR-1, Kaau1R, and Koko1R are similar, with Waiau repowering as the first supply-side resources.)

The difference between INTRCL-1, and Kaau1R and Koko1R is only about $2 million in the 20-year period. However, this is not a fair comparison since plan INTRCL-1 has a coal unit as the first supply-side resource (with the accompanying cost premium and fuel diversity benefits), whereas plans Kaau1R and Koko1R have Waiau repowering as the first supply-side resources.

A fairer comparison is between INTRCL-1 and Kaau1F and Koko1F. As can be seen in Attachments 1 and 3, these plans are very similar, with an AFBC as the first supply-side resource in each plan. In this comparison, the difference is about $34 million in 1993 dollars (or 0.5%) in the 20-year period (see Attachment 4). Again, we feel that this is not a large enough difference to eliminate the hydro resources from further consideration.

Attachment 5 compares the annual revenue required for the plans (in current dollars).

The PROSCREEN runs indicate that the hydro units are operating. They are running at annual capacity factors ranging from 1 to 13%. In comparison, simple cycle combustion turbines in plans INTR-1 and INTRCL-1 are operating at capacity factors ranging from 0 to 3%.

Conclusion

The analysis indicates differences in total resource cost of about $18 to $34 million (or 0.3 to 0.5%) between plans with and without the pumped storage hydroelectric resources (20-year period, 1993 $). Based on the assumptions of this preliminary analysis, the Kaau and Koko Crater pumped storage hydroelectric resources could continue to be considered as supply-side resource options for Oahu.

Attachments

TCS:dy

cc: J. Dizon
A. Seki
L. Lopez (Okahara & Associates, Inc.)
IRP GENPP 22, Studies/Statistics
GPD-cf

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05/03/94  13:24:40  V12.0 R02.3            Run 1                    ENERGY MANAGEMENT ASSOCIATES, INC.
                                                                    PROVIEW                   PAGE    1
                                            PSH2

                              PROVIEW LEAST COST OPTIMIZATION SYSTEM
                                   STUDY PERIOD PLAN COMPARISON
                                           KaaulR              KokolR
      PLAN RANK              1          2          ③          4          ⑤          6          7          8
-----------------------------------------------------------------------------------------------------------
          1993
          1994
          1995         C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)
                       NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)
                       RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)
                       CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)
          1996
          1997
          1998
          1999
          2000         INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)
                       INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)
                       STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)
          2001
          2002
          2003
          2004
          2005         REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)
          2006         REP2(  1)  REP2(  1)  REP2(  1)  REP2(  1)  REP2(  1)  REP2(  1)  REP2(  1)  REP2(  1)
          2007
          2008                                                                         SC  (  1)
          2009         FBC1(  1)  FBC1(  1)  KA4 (  1)  KA4 (  1)  KO4 (  1)  KO4 (  1)  SC  (  1)  FBC1(  1)
          2010
          2011                    SC  (  1)  FBC1(  1)  SC  (  1)  FBC1(  1)  SC  (  1)  FBC1(  1)  FBC1(  1)
          2012         REU( 128)  REU(  50)             REU(   6)             REU(   6)
          2013         REU( 158)  REU(  81)             REU(  39)             REU(  39)  REU(   4)  REU(  15)
-----------------------------------------------------------------------------------------------------------
P.V. TOTAL COST:
 LANNING PERIOD        6369816.5  6384309.5  6416810.5  6376099.5  6416625.5  6375907.0  6388786.0  6435685.0
   % DIFFERENCE            0.00%      0.23%      0.74%      0.10%      0.73%      0.10%      0.30%      1.03%
END EFFECTS PERIOD     5932593.5  5954026.5  5978704.5  6020038.5  5979774.5  6021101.0  6009120.0  5992960.0
   % DIFFERENCE            0.00%      0.36%      0.78%      1.47%      0.80%      1.49%      1.29%      1.02%
 TUDY PERIOD          12302410.0 12338336.0 12395515.0 12396138.0 12396400.0 12397008.0 12397906.0 12428645.0
   % DIFFERENCE            0.00%      0.29%      0.76%      0.76%      0.76%      0.77%      0.78%      1.03%
 LANNING PERIOD RANK           1          4         11          3         10          2          5         14



 TUDY PERIOD = PLANNING PERIOD + END EFFECTS PERIOD
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DSM Bundles

C&I = Commercial & Industrial (Prescriptive/Existing Market)
CUST = Custom Rebate (Industrial & Commercial Sectors)
INEX = Interruptible Rate Program (Expanded Option-Medium Participation)
INLM = Interruptible Rate Program (Limited Option-Medium Participation)
NEWC = Commercial & Industrial (New Market)
RWH = Residential Water Heating (New & Existing Market)
STBY = Stand-By Generator Program

Supply-Side Resources

REP1, REP2 = Waiau Repowering
FBC1 = Fluidized Bed Combustion
KA4 = Kaau Crater Pumped Storage Hydroelectric
KO4 = Koko Crater Pumped Storage Hydroelectric
SC = Simple Cycle Combustion Turbine
REU = Reliability Equalization Unit

Run 1

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                                   PSH2

                  PROVIEW LEAST COST OPTIMIZATION SYSTEM
                      STUDY PERIOD PLAN COMPARISON

                        KaaulF  KokolF
PLAN RANK                       9            10            11            12            13            14            15            16
-----------------------------------------------------------------------------------------------------------------------------------
            1993
            1994
            1995        C&I (  1)     C&I (  1)     C&I (  1)     C&I (  1)     C&I (  1)     C&I (  1)     C&I (  1)     C&I (  1)
                        NEWC(  1)     NEWC(  1)     NEWC(  1)     NEWC(  1)     NEWC(  1)     NEWC(  1)     NEWC(  1)     NEWC(  1)
                        RWH (  1)     RWH (  1)     RWH (  1)     RWH (  1)     RWH (  1)     RWH (  1)     RWH (  1)     RWH (  1)
                        CUST(  1)     CUST(  1)     CUST(  1)     CUST(  1)     CUST(  1)     CUST(  1)     CUST(  1)     CUST(  1)
            1996
            1997
            1998
            1999
            2000        INLM(  1)     INLM(  1)     INLM(  1)     INLM(  1)     INLM(  1)     INLM(  1)     INLM(  1)     INLM(  1)
                        INEX(  1)     INEX(  1)     INEX(  1)     INEX(  1)     INEX(  1)     INEX(  1)     INEX(  1)     INEX(  1)
                        STBY(  1)     STBY(  1)     STBY(  1)     STBY(  1)     STBY(  1)     STBY(  1)     STBY(  1)     STBY(  1)
            2001
            2002
            2003
            2004
            2005        FBC1(  1)     FBC1(  1)     REP1(  1)     REP1(  1)     FBC1(  1)     FBC1(  1)     FBC1(  1)     REP1(  1)
            2006                                    SC  (  1)     REP2(  1)                                               SC  (  1)
            2007
            2008
            2009        KA4 (  1)     KO4 (  1)     FBC1(  1)     KA4 (  1)     KA4 (  1)     FBC1(  1)     KO4 (  1)     FBC1(  1)
            2010        REP1(  1)     REP1(  1)                                               REP1(  1)
            2011                                    SC  (  1)     KO4 (  1)     FBC1(  1)                   FBC1(  1)     FBC1(  1)
            2012        REU(  77)     REU(  77)     REU( 105)                   REU(  67)     REU( 116)     REU(  67)     REU(  38)
            2013        REU( 108)     REU( 108)     REU( 139)                   REU(  98)     REU( 146)     REU(  98)     REU(  69)
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P.V. TOTAL COST:
PLANNING PERIOD         6452751.0     6452572.5     6397755.0     6412396.5     6471870.5     6474535.5     6471711.5     6442237.5
   % DIFFERENCE             1.30%         1.30%         0.44%         0.67%         1.60%         1.64%         1.60%         1.14%
END EFFECTS PERIOD      5983523.0     5984557.5     6047118.0     6039531.5     5993073.5     5990489.5     5994221.5     6038320.5
   % DIFFERENCE             0.86%         0.88%         1.93%         1.80%         1.02%         0.98%         1.04%         1.78%
STUDY PERIOD           12436274.0    12437130.0    12444873.0    12451928.0    12464944.0    12465025.0    12465933.0    12480558.0
   % DIFFERENCE             1.09%         1.10%         1.16%         1.22%         1.32%         1.32%         1.33%         1.45%
PLANNING PERIOD RANK           21            20             8             9            28            29            27            16




STUDY PERIOD = PLANNING PERIOD + END EFFECTS PERIOD
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05/03/94  13:34:39  V12.0 R02.3              Run 2                  ENERGY MANAGEMENT ASSOCIATES, INC.
                                                                    PROVIEW                     PAGE    1
                                              PSH3

                                 PROVIEW LEAST COST OPTIMIZATION SYSTEM
                                     STUDY PERIOD PLAN COMPARISON

                                                                                     Kaau2

      PLAN RANK             1          2          3          4          5          6          7          8
-------------------------------------------------------------------------------------------------------------
         1993
         1994
         1995        C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)  C&I (  1)
                     NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)  NEWC(  1)
                     RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)  RWH (  1)
                     CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)  CUST(  1)
         1996
         1997
         1998
         1999
         2000        INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)  INLM(  1)
                     INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)  INEX(  1)
                     STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)  STBY(  1)
         2001
         2002                                                                      KA4 (  1)  KA4 (  1)
         2003
         2004
         2005        REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)  REP1(  1)  FBC1(  1)
         2006        REP2(  1)  REP2(  1)  REP2(  1)  REP2(  1)  SC  (  1)
         2007
         2008                              SC  (  1)                                  REP1(  1)  REP1(  1)
         2009        FBC1(  1)  FBC1(  1)  SC  (  1)  FBC1(  1)  FBC1(  1)  FBC1(  1)  REP2(  1)  REP2(  1)
         2010                                                               REP1(  1)
         2011                   SC  (  1)  FBC1(  1)  FBC1(  1)  SC  (  1)             FBC1(  1)  SC  (  1)
         2012        REU( 128)  REU(  50)                        REU( 105)  REU( 116)             REU(   6)
         2013        REU( 158)  REU(  81)  REU(   4)  REU(  15)  REU( 139)  REU( 146)             REU(  39)
-------------------------------------------------------------------------------------------------------------
P.V. TOTAL COST:
PLANNING PERIOD       6369816.5  6384309.5  6388786.0  6435685.0  6397755.0  6474535.5  6532957.5  6492246.0
  % DIFFERENCE            0.00%      0.23%      0.30%      1.03%      0.44%      1.64%      2.56%      1.92%
END EFFECTS PERIOD    5932593.5  5954026.5  6009120.0  5992960.0  6047118.0  5990489.5  5941392.5  5982727.0
  % DIFFERENCE            0.00%      0.36%      1.29%      1.02%      1.93%      0.98%      0.15%      0.85%
STUDY PERIOD         12302410.0 12338336.0 12397906.0 12428645.0 12444873.0 12465025.0 12474350.0 12474973.0
  % DIFFERENCE            0.00%      0.29%      0.78%      1.03%      1.16%      1.32%      1.40%      1.40%
PLANNING PERIOD RANK          1          2          3          5          4          9         15         11




STUDY PERIOD = PLANNING PERIOD - END EFFECTS PERIOD
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Attachment 2 (page 1 of 2)

Run 2

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                                   PSH3

                  PROVIEW LEAST COST OPTIMIZATION SYSTEM
                      STUDY PERIOD PLAN COMPARISON
```

Koko2

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      PLAN RANK              9           10           11           12           13           14           15           16
-----------------------------------------------------------------------------------------------------------------------------
         1993
         1994
         1995         C&I (  1)    C&I (  1)    C&I (  1)    C&I (  1)    C&I (  1)    C&I (  1)    C&I (  1)    C&I (  1)
                      NEWC(  1)    NEWC(  1)    NEWC(  1)    NEWC(  1)    NEWC(  1)    NEWC(  1)    NEWC(  1)    NEWC(  1)
                      RWH (  1)    RWH (  1)    RWH (  1)    RWH (  1)    RWH (  1)    RWH (  1)    RWH (  1)    RWH (  1)
                      CUST(  1)    CUST(  1)    CUST(  1)    CUST(  1)    CUST(  1)    CUST(  1)    CUST(  1)    CUST(  1)
         1996
         1997
         1998
         1999
         2000         INLM(  1)    INLM(  1)    INLM(  1)    INLM(  1)    INLM(  1)    INLM(  1)    INLM(  1)    INLM(  1)
                      INEX(  1)    INEX(  1)    INEX(  1)    INEX(  1)    INEX(  1)    INEX(  1)    INEX(  1)    INEX(  1)
                      STBY(  1)    STBY(  1)    STBY(  1)    STBY(  1)    STBY(  1)    STBY(  1)    STBY(  1)    STBY(  1)
         2001
         2002         KO4 (  1)    KO4 (  1)                              KA4 (  1)    KO4 (  1)    KA4 (  1)    KO4 (  1)
         2003
         2004
         2005                                   REP1(  1)    FBC1(  1)
         2006                                   SC  (  1)
         2007
         2008         REP1(  1)    REP1(  1)                 SC  (  1)    FBC1(  1)    FBC1(  1)    FBC1(  1)    FBC1(  1)
         2009         REP2(  1)    REP2(  1)    FBC1(  1)    SC  (  1)
         2010                                                             REP1(  1)    REP1(  1)
         2011         FBC1(  1)    SC  (  1)    FBC1(  1)    FBC1(  1)                              FBC1(  1)    FBC1(  1)
         2012                      REU(   6)    REU(  38)    REU(  96)    REU(  77)    REU(  77)    REU(  67)    REU(  67)
         2013                      REU(  39)    REU(  69)    REU( 124)    REU( 108)    REU( 108)    REU(  98)    REU(  98)
-----------------------------------------------------------------------------------------------------------------------------
P.V. TOTAL COST:
 LANNING PERIOD       6532677.0    6491958.5    6442237.5    6449470.0    6551745.0    6551489.0    6570865.0    6570628.0
   % DIFFERENCE           2.56%        1.92%        1.14%        1.25%        2.86%        2.85%        3.16%        3.15%
END EFFECTS PERIOD    5942827.0    5984153.5    6038320.5    6052019.0    5954093.0    5955491.0    5963644.0    5965156.0
   % DIFFERENCE           0.17%        0.87%        1.78%        2.01%        0.36%        0.39%        0.52%        0.55%
TUDY PERIOD          12475504.0   12476112.0   12480558.0   12501489.0   12505838.0   12506980.0   12534509.0   12535784.0
   % DIFFERENCE           1.41%        1.41%        1.45%        1.62%        1.65%        1.66%        1.89%        1.90%
 LANNING PERIOD RANK         14           10            6            7           17           16           23           22




 TUDY PERIOD = PLANNING PERIOD + END EFFECTS PERIOD
```

FINAL CAN DATE PLANS
RESOL E MIX
December 1993

Year	Plans										Year
	COAL-1	INTR-1	INTR-3	INTRCL-1	INTRCC-1	NDSM-1	CCREPR-1	CEC-1	CEC-6	CEC-165	
1994											1994
1995	C&I NEWC RWH CUST	C&I NEWC RWH CUST	C&I NEWC RWH CUST	C&I NEWC RWH CUST	C&I NEWC RWH CUST		C&I NEWC RWH CUST	C&I NEWC RWH CUST WIND	C&I NEWC RWH CUST WIND	C&I NEWC RWH CUST WIND	1995
1996											1996
1997											1997
1998											1998
1999											1999
2000		INLM INEX STBY	INLM INEX STBY	INLM INEX STBY	INLM INEX STBY						2000
2001											2001
2002						REP1 101					2002
2003											2003
2004					P1DT 82	REP2 101	P1DT 82				2004
2005	AFBC 190	REP1 101	REP1 101	AFBC 190	P2DT 82	AFBC 190	P2DT 82	GCC 273	GCC 273	GCC 273	2005
2006		REP2 101	REP2 101				P3DT 76				2006
2007	REP1 101				P3DT 76						2007
2008						AFBC 190					2008
2009	SCCT 82	AFBC 190 SCCT 82	SCCT 82 P1DT 82	SCCT 82 REP1 101	SCCT 82	SCCT 82	SCCT 82 REP1 101	SCCT 82 BIOM 50	SCCT 82 BIOM 50	SCCT 82 BIOM 50	2009
2010	REP2 101			REP2 101	REP1 101 REP2 101		REP2 101				2010
2011			P2DT 82 P3DT 76					GCC 273	KOKO 160	GCC 273 STPT 80	2011
2012	REU (110)	REU (50)	REU (1)	REU (50)	REU (1)	REU (145)	REU (61)	REU (84)	REU (92)		2012
2013	REU (142)	REU (81)	REU (34)	REU (81)	REU (34)	REU (183)	REU (94)	REU (116)	REU (124)	REU (27)	2013

lotes:
- o Information from PROVIEW Least Cost Optimization System Report
- o File = IRPredoA.xls
- o 12/21/93

Attachment 3

Plan	Total Resource Cost with End Effects $1,000	Total Resource Cost without End Effects $1,000
INTR-1	12,348,792	6,398,608
INTRCL-1	12,357,292	6,418,542
Kaau1R	12,395,515	6,416,811
Kaau1F	12,436,274	6,452,751
Kaau2	12,474,350	6,532,958
Koko1R	12,396,400	6,416,626
Koko1F	12,437,130	6,452,573
Koko2	12,475,504	6,532,677

Difference from INTR-1 (least cost plan)

	Total Resource Cost with End Effects		Total Resource Cost without End Effects	
Plan	$1,000	% Diff	$1,000	% Diff
INTR-1	0	0.0	0	0.0
INTRCL-1	8,500	0.1	19,934	0.3
Kaau1R	46,723	0.4	18,203	0.3
Kaau1F	87,482	0.7	54,143	0.8
Kaau2	125,558	1.0	134,350	2.1
Koko1R	47,608	0.4	18,018	0.3
Koko1F	88,338	0.7	53,965	0.8
Koko2	126,712	1.0	134,069	2.1

Difference from INTRCL-1 (preferred plan)

	Total Resource Cost with End Effects		Total Resource Cost without End Effects	
Plan	$1,000	% Diff	$1,000	% Diff
INTR-1	-8,500	-0.1	-19,934	-0.3
INTRCL-1	0	0.0	0	0.0
Kaau1R	38,223	0.3	-1,731	0.0
Kaau1F	78,982	0.6	34,209	0.5
Kaau2	117,058	0.9	114,416	1.8
Koko1R	39,108	0.3	-1,916	0.0
Koko1F	79,838	0.6	34,031	0.5
Koko2	118,212	1.0	114,135	1.8

Notes:
INTR-1 is the least cost plan from HECO Rebuttal Testimony, Docket No. 7257.
INTRCL-1 is the preferred plan from HECO Rebuttal Testimony, Docket No. 7257.
Kaau1R is the least cost plan with the Kaau pumped storage unit, and with Waiau repowering as 1st supply-side resource, from PROSCREEN Run 1 (PSH2.SAV, plan #3).
Kaau1F is the least cost plan with the Kaau pumped storage unit, and with fluidized bed as 1st supply-side resource, from PROSCREEN Run 1 (PSH2.SAV, plan #9).
Kaau2 is the least cost plan with the Kaau pumped storage unit from PROSCREEN Run 2 (PSH3.SAV, plan #7).
Koko1R is the least cost plan with the Koko pumped storage unit, and with Waiau repowering as 1st supply-side resource from PROSCREEN Run 1 (PSH2.SAV, plan #5).
Koko1F is the least cost plan with the Koko pumped storage unit, and with fluidized bed as 1st supply-side resource from PROSCREEN Run 1 (PSH2.SAV, plan #10).
Koko2 is the least cost plan with the Koko pumped storage unit from PROSCREEN Run 2 (PSH3.SAV, plan #9).
1993 $.

Attachment 4

Revenue Required ($1,000)

	INTR-1	INTRCL-1	Kaau1R	Kaau1F	Kaau2	Koko1R	Koko1F	Koko2
1993	305,839	305,839	305,839	305,839	305,839	305,839	305,839	305,839
1994	328,053	328,053	328,053	328,053	328,053	328,053	328,053	328,053
1995	365,913	365,913	365,913	365,913	365,913	365,913	365,913	365,913
1996	394,657	394,657	394,657	394,657	394,657	394,657	394,657	394,657
1997	430,988	430,988	430,988	430,988	430,988	430,988	430,988	430,988
1998	466,257	466,257	466,257	466,257	466,257	466,257	466,257	466,257
1999	504,969	504,969	504,969	504,969	504,969	504,969	504,969	504,969
2000	535,697	535,697	535,697	535,697	535,697	535,697	535,697	535,697
2001	581,755	581,755	581,755	581,755	581,755	581,755	581,755	581,755
2002	623,061	623,061	623,061	623,061	697,983	623,061	623,061	697,824
2003	667,590	667,590	667,590	667,590	747,315	667,590	667,590	747,145
2004	712,654	712,654	712,654	712,654	790,646	712,654	712,654	790,496
2005	811,760	860,200	811,760	860,200	849,805	811,760	860,200	849,679
2006	890,973	925,388	890,973	925,388	897,717	890,973	925,388	897,617
2007	954,779	980,290	954,779	980,290	961,200	954,779	980,290	961,124
2008	1,017,007	1,038,649	1,017,007	1,038,649	1,068,252	1,017,007	1,038,649	1,068,171
2009	1,209,417	1,173,198	1,172,453	1,188,673	1,159,176	1,172,254	1,188,505	1,159,159
2010	1,346,083	1,324,823	1,290,748	1,356,513	1,276,630	1,290,526	1,356,318	1,276,635
2011	1,403,571	1,389,090	1,465,505	1,422,300	1,450,693	1,465,341	1,422,133	1,450,757
2012	1,501,891	1,487,846	1,578,725	1,527,472	1,564,513	1,578,582	1,527,309	1,564,590
2013	1,617,844	1,604,210	1,683,927	1,646,580	1,668,718	1,683,828	1,646,472	1,668,842

Difference from INTR-1 (least cost plan)

Revenue Required ($1,000)

	INTR-1	INTRCL-1	Kaau1R	Kaau1F	Kaau2	Koko1R	Koko1F	Koko2
1993	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	74,922	0	0	74,763
2003	0	0	0	0	79,725	0	0	79,555
2004	0	0	0	0	77,992	0	0	77,842
2005	0	48,440	0	48,440	38,045	0	48,440	37,919
2006	0	34,415	0	34,415	6,744	0	34,415	6,644
2007	0	25,511	0	25,511	6,421	0	25,511	6,345
2008	0	21,642	0	21,642	51,245	0	21,642	51,164
2009	0	-36,219	-36,964	20,744	-50,241	-37,163	-20,912	-50,258
2010	0	21,260	-55,335	10,430	-69,453	-55,557	10,235	-69,448
2011	0	-14,481	61,934	18,729	47,122	61,770	18,562	47,186
2012	0	-14,045	76,834	25,581	62,622	76,691	25,418	62,699
2013	0	-13,634	66,083	28,736	50,874	65,984	28,628	50,998

Difference from INTRCL-1 (preferred plan)

Revenue Required ($1,000)

	INTR-1	INTRCL-1	Kaau1R	Kaau1F	Kaau2	Koko1R	Koko1F	Koko2
1993	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	74,922	0	0	74,763
2003	0	0	0	0	79,725	0	0	79,555
2004	0	0	0	0	77,992	0	0	77,842
2005	-48,440	0	-48,440	0	-10,395	-48,440	0	-10,521
2006	-34,415	0	-34,415	0	-27,671	-34,415	0	-27,771
2007	-25,511	0	-25,511	0	-19,090	-25,511	0	-19,166
2008	-21,642	0	-21,642	0	29,603	-21,642	0	29,522
2009	36,219	0	-745	15,475	-14,022	-944	15,307	-14,039
2010	21,260	0	-34,075	31,690	-48,193	-34,297	31,495	-48,188
2011	14,481	0	76,415	33,210	61,603	76,251	33,043	61,667
2012	14,045	0	90,879	39,626	76,667	90,736	39,463	76,744
2013	13,634	0	79,717	42,370	64,508	79,618	42,262	64,632

Note:
From Utility Cost from PROVIEW System Cost Report
Current $.

IPSH.XLW|revreq 5/20/94

Attachment 5